UPOV

International Union for the Protection of New Varieties of Plants

SEMINAR ON THE ROLE OF PLANT BREEDING AND PLANT VARIETY PROTECTION IN ENABLING AGRICULTURE TO MITIGATE AND ADAPT TO CLIMATE CHANGE

October 11, 12 and 26, 2022

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Mr. Manuel Toro Ugalde, Vice-Chair of the Administrative and Legal Committee, UPOV

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Ms. Kitisri Sukhapinda, Patent Attorney, Office of Policy and Affairs (OPIA), United States Patent and Trademark Office (USPTO), United States of America

17.00 **Panel Discussion**
Moderator: Mr. Marien Valstar, President of the Council, UPOV

- Mr. John Derera, Keynote speaker
- Ms. Arianna Giuliodori, WFO
- Mr. Michael Keller, ISF
- Mr. Edgar Krieger, CIOPORA
- Mr. Yehan Cui, Moderator Session 2
- Mr. Patrick Ngwediagi, Moderator Session 3
- Mr. Manuel Toro Ugalde, Moderator Session 4
- Ms. Kitisri Sukhapinda, Moderator Session 5

17.50 **Concluding remarks**
Mr. Marien Valstar, President of the Council, UPOV

WELCOME AND OPENING REMARKS

Mr. Daren Tang
Secretary-General, UPOV

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Mr. Marien Valstar, President of the UPOV Council,

Dear Participants, Dear Colleagues, Dear Friends,

Warm greetings from Geneva. It is a great pleasure to speak to you today.

The challenges presented by climate change are clear and considerable.

As the most recent IPCC report states with high confidence, rising temperatures are a serious threat to human life, biodiversity and infrastructure.

Extreme weather is exposing millions of people to food and water scarcity, especially in the global south.

Plants and animal species are experiencing changes in their ranges, seasonal patterns and habitats.

Economies are being hit by the increasing frequency of heatwaves, floods, droughts, wildfires and other climate hazards.

And shifts in temperature and rainfall patterns threaten key crop yields.

In response, we must sow the seeds of climate action across all sectors of the economy.

The role agriculture can play in mitigating and adapting to the climate threat was a theme that emerged strongly from last year’s UPOV seminar on the policy impact of plant breeding and plant variety protection.

We heard how PVP is enhancing food security and improving farmers’ livelihoods in China, Kenya and Mexico.

We heard how PVP is supporting the development of the European Union’s flagship Green Deal and Farm to Fork strategy.

And we heard how agritech is progressing innovative solutions, including through the authorization of a new agricultural R&D authority in the United States.

This led the UPOV council to agree to bring the global community together for a session dedicated to the role of plant breeding and PVP in combatting climate change.

In so doing, we are building momentum behind one of the key recommendations from the IPCC’s special report on climate change and land.

The report surveyed various policy options and concluded that, in this context, boosting soil carbon and increasing food productivity are amongst the most effective climate responses at our disposal.

New and improved plant varieties have an important role to play on both fronts.

On soil carbon, improved rotation and the development of deeper rooting varieties are two concrete ways in which plants can regenerate soil fertility and protect natural ecosystems.

While on food productivity, we know that plant breeding and PVP help increase yields in a sustainable way.

A study of Viet Nam's experience after a decade of UPOV membership, found that the use of inputs per hectare in arable farming had decreased, at the same time as crop yields grew.

Meanwhile, a recent EU paper revealed that the CVPR (Community Plant Variety Rights) system is helping to lower annual greenhouse gas emissions by over 60 million tons each year.

These are just two examples of how plant breeding and plant variety protection are increasing food productivity in a sustainable way.

Our work now must be to build on this momentum and to use innovation, technology and improved practices to further accelerate climate action for the benefit of all.

Ladies and Gentlemen,

Over the next few days, we will hear from expert speakers from every region of the world.

I urge you to use this opportunity to continue to share best practices and to learn from one another.

It is your engagement, in the work of UPOV and beyond, that will help to shape effective policy responses and put the planet on a more sustainable footing.

Thank you very much and best wishes for a productive seminar.

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THEMATIC SESSION 1:

CLIMATE CHANGE AND ITS IMPACT ON AGRICULTURAL PRODUCTION

Moderator: Mr. Marien Valstar, President of the Council, UPOV

Impacts and risks for agriculture from climate change: adaptation solutions and the role of new plant varieties

Mr. John Derera, Head of Breeding, International Institute of Tropical Agriculture (IITA)

World Farmers' Organization perspective

Ms. Arianna Giuliodori, Secretary-General, WFO

International Seed Federation perspective

Mr. Michael Keller, Secretary-General, ISF

International Community of Breeders of Asexually Reproduced Horticultural Plants perspective

Mr. Edgar Krieger, Secretary General, CIOPORA

Conclusion of the session

Moderator: Mr. Marien Valstar, President of the Council, UPOV

IMPACTS AND RISKS TO AGRICULTURE FROM CLIMATE CHANGE: ADAPTATION SOLUTIONS AND THE ROLE OF NEW PLANT VARIETIES

Mr. John Derera
Head of Breeding, International Institute of Tropical Agriculture (IITA)
Mr. John DERERA,[1] Ms. Delphine AMAH,[1] Mr. Casper KAMUTANDO[2] and Mr. Nyasha CHIURAISE[3]

INTRODUCTION

Climate change remains one of the most daunting challenges to agriculture and food security worldwide. Climate change relates to extreme temperature increases with significant global impacts such as the melting of glaciers and more frequent hurricanes, floods and droughts. These extreme weather events are also associated with forest fires and have devastating impacts on biodiversity as they affect survival of selected species (Levine and Steele 2021). Furthermore, climactic variability can modify genotype by environment interactions which cause complications in deployment of crop varieties, and significantly affect agricultural crop productivity with serious consequences for food and nutrition security. The aim of this paper is to give a global overview of impacts and risks to agriculture from climate change, call a few illustrative regional or local experiences and highlight the types of adaptation solutions and the role that new plant varieties play in adapting communities to the climate change crisis.

CAUSES OF CLIMATE CHANGE

The Greenhouse Gas (GHG) emissions caused by both natural and human activities contribute to climate change. Since the industrial revolution, human activities have drastically enhanced the greenhouse effect causing the earth's average temperature to rise by almost 1°C (Manabe 2019). According to the Sixth Assessment Report of the Intergovernmental Panel on Climate Change (Allan *et al.* 2021) human influence has warmed the atmosphere, ocean and land since around 1750 due to the increases in GHG concentrations. The land and ocean have taken up ±56% of carbon dioxide (CO2) emissions per year over the past six decades. The annual average increases of the main GHGs (2011–2019) ranged from 410 parts per million (ppm) for CO_2, 1,866 parts per billion (ppb) for methane (CH4) and 332 ppb for nitrous oxide (N_2O). The IPCC report for policy makers (Allan *et al.* 2021) also listed other GHGs that are contributing to global warming and changes in precipitation. These are perfluorocarbons with 109 parts per trillion (ppt) CF4 equivalent, sulphur hexafluoride (10 ppt), nitrogen trifluoride (2 ppt), hydrofluorocarbons (237 ppt), chlorofluorocarbons and hydrochlorofluorocarbons (1,032 ppt).

As a result of the GHG emissions, global surface temperatures have increased by at least 1°C relative to levels of 1850–1900. According to the IPCC report (Allan *et al.* 2021), the trend shows that each of the last four decades has been successively warmer than any decade that preceded it, since 1850. For example, during the 2001 to 2010 decade, the average temperature increase was 0.99°C with ranging from 0.84 to 1.10°C. The following decade, 2011 to 2020, showed an increased warming with the average above 1oC (1.09°C) and a higher range of 0.95 to 1.20°C. There was greater impact on land, with larger increases of 1.59°C and a range of 1.34 to 1.83°C compared to the increase over oceans with an average of 0.88°C and ranging from 0.68 to 1.01°C. The effects of these gas emissions include variations in annual rainfall, average temperature, heatwaves, modifications in incidence and emergence of weeds, pests or microbes, changes in atmospheric CO_2 or ozone level, fluctuations in sea level and even loss of biodiversity. Disturbances in the agro-ecological environment consequently affect growth and yield of agricultural crops.

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IMPACT AND RISK OF CLIMATE CHANGE TO AGRICULTURAL GROWTH

Although the effect of increased warming is global, the immediate effect to developing countries with limited technologies or crop varietal options to cope with climate change is daunting. Climate trends observed over the last few decades already impact agriculture with the likelihood to change the distribution and productivity of major crops (Thornton *et al.* 2018). Climate change could have catastrophic effects on cereal production, with an expected 20% reduction in wheat and maize production in Africa alone. This significant challenge therefore calls for transformative action to combat climate change and the associated disruptions in agriculture and food systems (Campbell *et al.* 2018). Climate change impacts on food security through complex interactions of abiotic and biotic factors affecting agriculture are widely documented.

Increases in temperature and water-related stresses hurt global agricultural productivity, especially in tropical countries. Rising temperatures impact on the hydrological cycle and crop productivity through increased evaporation, accelerating the global hydrological cycle, increased dryness in subtropical areas and increased precipitation at higher latitudes. The increase in temperature (1–3°C) as well as the changes in CO2 concentration and rainfall patterns in the temperate zones could result in positive effects such as increased productivity through utilization of an extended growing season. However, climate changes cause overall decline in productivity of crops in tropical and subtropical environments. Extreme weather events pose a serious threat to the least developed agriculture in the low latitude or tropical environments. Climate change causes lower production by limiting the length of the crop growing season and has direct negative effects on resource capture and processes underpinning growth and yield, such as hastened crop maturity or reducing the leaf area duration that compromises accumulation of assimilates through photosynthesis. Ortiz-Bobea *et al.* (2021) cited 21–34% loss in global agricultural productivity growth since 1961, about 26–30% in Africa, Latin America and the Caribbean. The impact of reduced productivity is naturally high on small land holdings in developing countries, because the farmers have limited technology options, reduced availability of agricultural land due to urbanization and, in general, lack of capital to implement mitigation strategies.

Maximum temperature increases in Zimbabwe can be illustrated using the El Niño events of 2015–2016 and 1990–1991 seasons versus the 35-year mean associated with a severe drought that caused severe hunger and reduced economic growth. A local example of increased temperature due to this extreme weather event was recorded at the Rattray Arnold Research Station, near Harare, in Zimbabwe. The extreme temperatures showed increased daytime temperatures ranging from 0.2°C to 1.4°C during 2015–2016 (Table 1) in a non-industrialized environment. Whereas during the 1991–1992 season, the station recorded higher temperature increases ranging from 0.3°C to 3.3°C (Table 2).

Year	July.	Aug.	Sept.	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.
2015/16	22.8	24.7	28.0	30.4	30.6	29.1	27.6	28.6	26.1
35-year mean	22.2	24.5	27.7	29.2	29.2	27.8	27.4	27.2	27.1
Change	0.6	0.2	0.3	1.2	1.4	1.3	0.2	1.4	- 1.0

Table 1. *Rattray Arnold Station, maximum temperature in 2015–2016 versus 35-year mean season ending 2015/16.*

Year	July	Aug.	Sep.	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May	Jun.
1990/91	25.3	24.8	28.2	31.7	31.2	31.0	29.2	29.9	29.7	27.2	25.5	25.3
34-year mean	22.1	24.5	27.7	29.1	29.1	27.7	27.4	27.1	27.1	25.8	24.5	22.7
Change	3.2	0.3	0.5	2.6	2.1	3.3	1.8	2.8	2.6	1.4	1.0	2.6

Table 2. *Rattray Arnold Station, maximum temperature in 1990–1991 versus 34-year mean season ending 2014/15.*

The temperature increases during the El Niño event compared to the long-term mean for the crop growing seasons in 1991–1992 and 2015–2016 is also shown graphically in Figures 1 and 2.

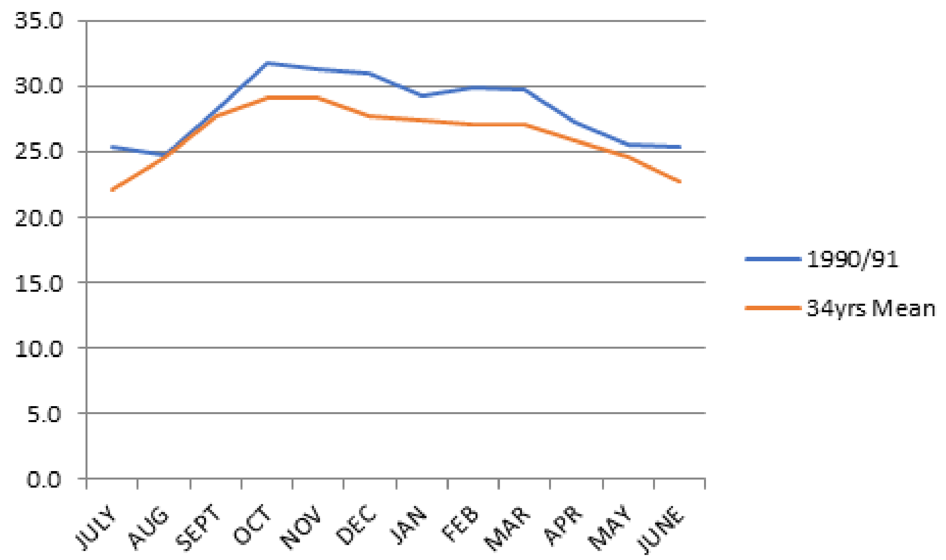

Figure 1. *Rattray Arnold Station's seasonal temperature of 1990–1991 versus long-term mean.*

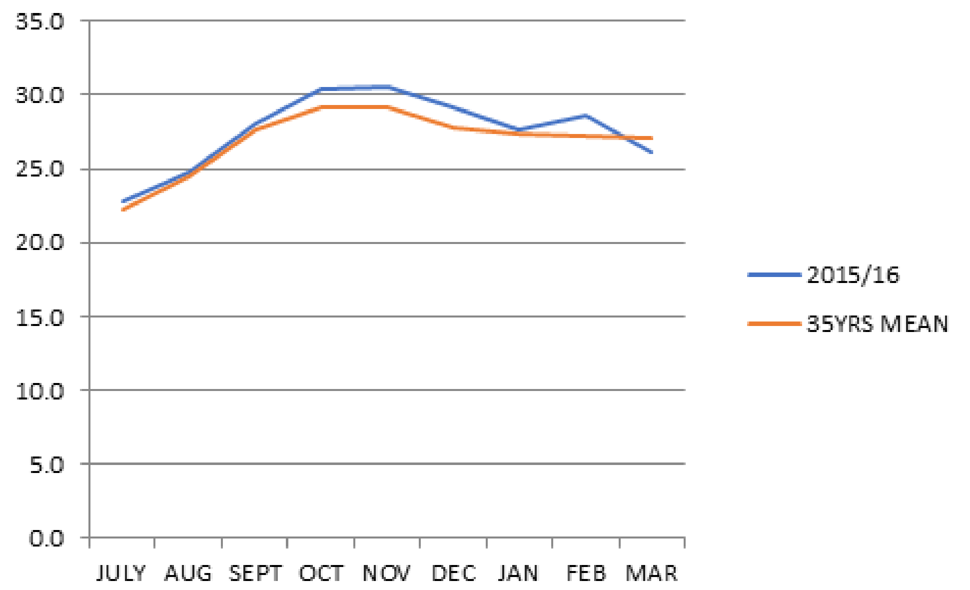

Figure 2. *Rattray Arnold Station's seasonal temperature of 2015–2016 versus long-term mean.*

As a result of these temperature increases, the station and the region are experiencing the emergence of new diseases and insect pests, for example fall armyworm (FAW) which has high incidence levels in Eastern and Southern Africa (Figure 3). The insect pest causes severe damage on maize foliage and grain leading to devastating losses amounting to 12–53% yield loss as recorded in sub-Saharan Africa (Matova *et al.* 2020).

Figure 3. *Foliage damage caused by FAW that can lead to heavy yield losses in the smallholder farmer plots if maize is grown without pesticide application.*

Analysis of the magnitude and frequency of climate and yield variability of crops, such as maize, rice, soybean and wheat using historical data from 1981 to 2016 considering multiscale droughts revealed higher global yield susceptibility under complex drought patterns than previously assessed (Santini *et al.* 2022). Bradshaw *et al.* (2022) analyzed the impact of unprecedented climate extremes in South Africa and their implications for maize production. The dynamics of temperature and precipitation due to the occurrence of *El Niño* and *La Niña* events cause serious challenges and reduce agricultural productivity in Southern Africa, for example. The *La Niña* years bring growing conditions which are closer to or towards the optimum, while the *El Niño* years result in stress growing conditions of combined heat and drought in the region. The rising January to March temperature poses a threat to agricultural productivity growth in the region, spanning from South Africa, Zimbabwe, Zambia, Malawi, Mozambique and Southern Tanzania. This is usually accompanied by increasing dry spell duration during the reproductive growth stages which drastically reduces maize grain yields. The increasing wet spell duration during *La Niña* leads to waterlogging, and the excessive wetness reduces maize grain yield and is often accompanied by the occurrence of many foliar and grain diseases. According to Bradshaw *et al.* (2022), the maize grain yield decreases associated with *El Niño* events tend to be larger than corresponding yield increases during *La Niña* events. This partly explains the common occurrence of food deficit for most countries in the region. Farmers in the region require crop varieties that have tolerance to both abiotic and biotic stresses to cope with these extreme weather events.

ADAPTATION SOLUTIONS TO CLIMATE CHANGE – AGRONOMY AND CULTURAL PRACT ICES

Agriculture also contributes to climate change through anthropogenic emissions of about 25% greenhouse gases and conversion of non-agricultural land such as forests to agricultural land which affect the carbon balance. For this reason, cultural changes in agricultural practices will minimize the continuous threat of climate change to food security in developing countries. Adopting agricultural practices that contribute to capturing the excess carbon generated by agriculture itself and other industries should be part of the climate change adaptation solutions package. This includes soil conservation culture, reducing tillage, expanding crop rotations, planting cover crops, integrating livestock into crop production systems and growing climate change resilient crop varieties. The practices such as altering planting and harvesting time, crop rotation and irrigation offer great potential for crop adaptability in the face of climate change (Raza *et al.* 2019). The effectiveness of irrigation in minimizing the impact of climate change effects is clear. For example, managing banana through irrigation would double both production and area of suitability for banana cultivation compared to current levels under rainfed conditions. However, smallholder farmers in sub-Saharan Africa lack access to both water and enabling infrastructure for irrigation. The crops are predominantly grown in the humid tropics and are rainfed. This calls for agricultural solutions that combine crop improvement and faster breeding of new climate change resilient crop varieties using modern breeding techniques, with concomitant improvements and changes in cultural and agronomic practices.

ADAPTATION SOLUTIONS TO CLIMATE CHANGE – THE ROLE OF NEW PLANT VARIETIES

The key role of plant breeding in agriculture is to develop genetically superior varieties which have value for cultivation and use in the target production environment. The contribution of plant breeding to improving crop productivity has been shown by incredible yield increases for most major crops, such as maize, soybean, sorghum, wheat, rice and soybean since the second world war. At least 50–60% of yield increases of maize and other crops is attributable to genetic improvements. This indicates that investments in plant breeding will significantly improve crop productivity through genetics improvements in a changing climate. The Consultative Group on International Agriculture Research's (CGIAR) breeding programs target variety improvements for disease and pest resistance, and tolerance to abiotic stresses, such as high and low temperature, excessive water/flooding, drought, high salinity and alkaline soil challenges that are encountered in a climate crisis. New CGIAR initiatives on gene bank, accelerated breeding for meeting farmers' needs with nutritious, climate-resilient crops and investments in breeding resources, seed equal, market intelligence and plant health initiatives will fast-track delivery of climate smart products to smallholder farmers in tropical countries. These initiatives are designed to enable breeding programs to achieve a capability for continual increase of genetic gain under challenges of climate change and effectively deliver new varieties through the partnerships network comprising the private sector and national agricultural research and extension systems (NARES) collaboration. Modernization of public programs to deliver appropriate market and climate change resilient varieties will require a sustainable germplasm plan, and optimization of resource plan. For example, Thiele *et al.* (2017) proposed a framework for climate smart breeding of vegetative propagated crops which are important staples for SSA. The framework highlights six steps addressing scaling of climate change models, identification and prioritization of climate change responsive traits, breeding and varietal selection, phenotyping and genomic research, and development and deployment of seeds and management options for climate smart varieties.

Recent developments in new breeding tools, such as genomics in combination with high-throughput and precision phenotyping facilitate the identification of genes controlling critical biotic and abiotic traits. The discovery of these genes can now be combined with genome editing techniques to rapidly develop climate resilient crop varieties with better biotic and abiotic stress tolerance and enhanced nutritional value. The CGIAR's research centers, such as the International Maize and Wheat Improvement Center (CIMMYT) and International Institute of Tropical Agriculture (IITA) breeding programs have made tremendous progress to deliver climate smart maize varieties in sub-Saharan Africa and have demonstrated the efficacy of plant breeding in delivering solutions to declining crop productivity amidst a global climate change crisis. Accelerating Genetic Gain (AGG) in maize and wheat project of CIMMYT, IITA, NARES and small to medium seed enterprises (SMEs) breeding network has shown significant gains towards delivery of stress-tolerant and input-responsive maize varieties. At least 69 new climate smart varieties were deployed across sub-Saharan Africa by the AGG during 2020–2021. The yield levels of these varieties reached record highs of 9–15 t/ha at some sites, indicating the feasibility of breeding climate resilient maize hybrids and varieties which are adapted to multiple biotic and abiotic stresses under a climate crisis.

CONCLUSION AND PERSPECTIVES

Climate change could cause catastrophic effects on agricultural productivity through increases of greenhouse gas emissions. The climate change causes challenges of increasing incidence and severity of biotic and abiotic stresses which have compromised crop production, causing a mismatch of food production and population growth rates, especially in developing countries, and in the tropical environments. This calls for the agricultural research and development community to collaborate on combating climate change and its impact. Agriculture contributes to climate change, therefore there is need to adopt agricultural practices that contribute to capturing the excess carbon generated by agriculture, and other industries. Investments in research and implementation of improved agronomic practices, and the development of new and climate resilient crop varieties would contribute to incredible yield improvements under a climate change crisis. This can be spurred by strengthening collaboration and partnerships of the private and public sector, CGIAR and NARES/SMEs breeding networks, and protection of innovations/varieties, using the effective UPOV's sui generis plant variety protection systems.

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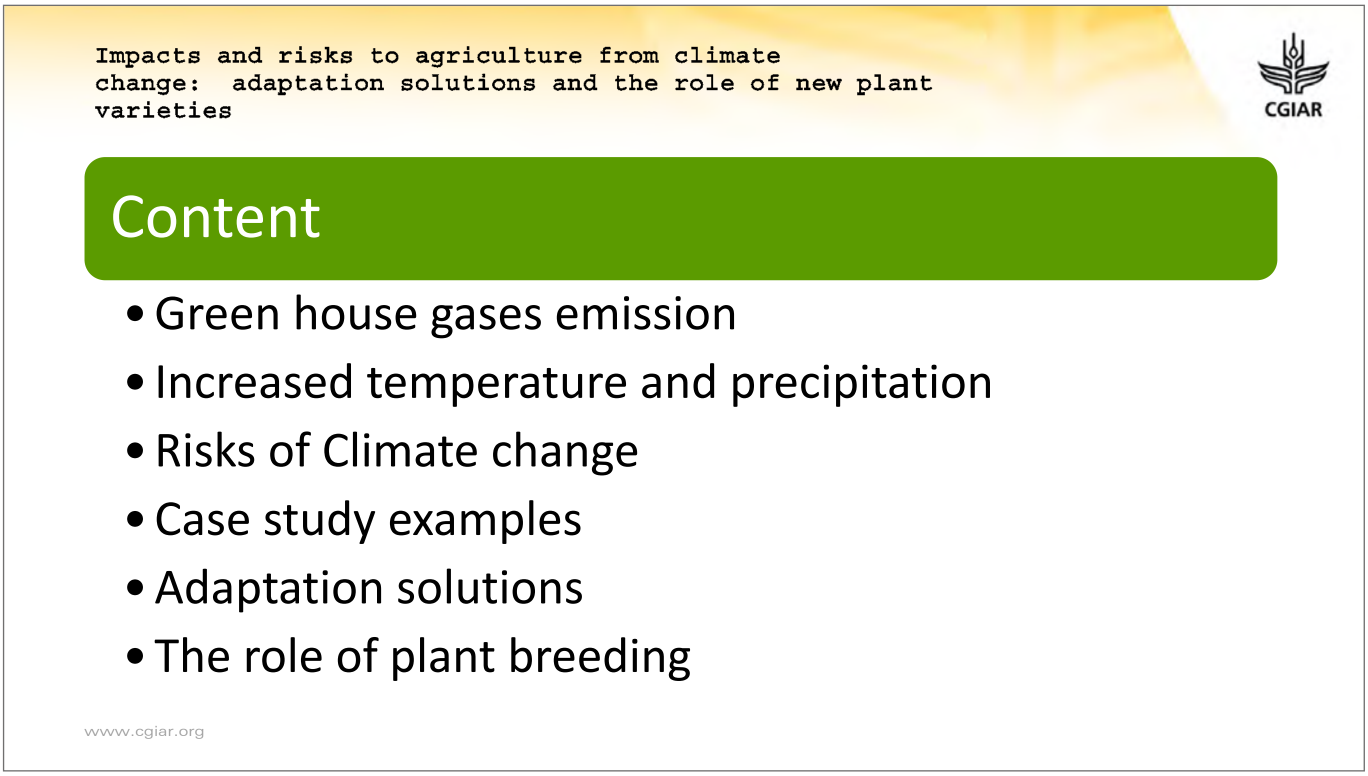
Presentation made at the Seminar



Human influence has warmed the atmosphere, ocean and land since around 1750 (IPCC, 2021 Summary for Policymakers)

CGIAR

Increases in Greenhouse Gas (GHG) concentrations caused by human activities

Land and ocean have taken up ±56% of CO_2 emissions per year over the past 6 decades

Annual average increases of GHGs (2011-2019)

- 410 parts per million (ppm) for carbon dioxide (CO_2)
- 1866 parts per billion (ppb) for methane (CH_4)
- 332 ppb for nitrous oxide (N_2O)

Other GHGs (2019)

- Perfluorocarbons (PFCs) – 109 parts per trillion (ppt) CF4 equivalent;
- Sulphur hexafluoride (SF6) – 10 ppt
- Nitrogen trifluoride (NF3) – 2 ppt
- Hydrofluorocarbons (HFCs) – 237 ppt
- Chlorofluorocarbons (CFCs) and hydrochlorofluorocarbons (HCFCs) – 1032 ppt

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IPCC, 2021: Summary for Policymakers. In: Climate Change 2021: The Physical Science Basis. Contribution of Working Group I to the **Sixth Assessment Report of the Intergovernmental Panel on Climate Change** [Masson-Delmotte, V., P. Zhai, A. Pirani, S.L. et al (eds.)]. Cambridge University Press, Cambridge, United Kingdom and New York, NY, USA, pp. 3–32, doi:10.1017/9781009157896.001

As a result of GHG emissions the Global surface temperatures have increased relative to levels of 1850-1900

CGIAR

Each of the last four decades has been successively warmer than any decade that preceded it since 1850.

- 2001–2020 was **0.99** °C [0.84 to 1.10] higher than 1850–1900
- 2011–2020 was **1.09** °C [0.95 to 1.20] higher than 1850–1900
- Larger increases over land of **1.59** °C [1.34 to 1.83] higher than 1850–1900
- Increase over ocean of **0.88** °C [0.68 to 1.01] higher than 1850–1900

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IPCC, 2021: Summary for Policymakers. In: Climate Change 2021: The Physical Science Basis. Contribution of Working Group I to the **Sixth Assessment Report of the Intergovernmental Panel on Climate Change** [Masson-Delmotte, V., P. Zhai, A. Pirani, S.L. et al (eds.)]. Cambridge University Press, Cambridge, United Kingdom and New York, NY, USA, pp. 3–32, doi:10.1017/9781009157896.001

Increases in temp & water-related stresses affect global agricultural productivity

CGIAR

Increased productivity in temperate environments

- Increased temperature (1–3⁰C), CO_2 & rainfall changes
- Extended growing season

A decline in productivity in tropical and subtropical environments

- More frequent extreme weather (drought, heat, flood)
- Lower production by limiting the length of the growing season
- Implications: compromised resource capture and processes underpinning growth and yield

Extreme weather events posing a serious threat to agriculture in the tropics*

- An estimated **21-34% loss in global** agricultural productivity growth since 1961
- About **26-30% in Africa**, Latin America and Caribbean
- Impact of reduce productivity high on small land holding
- Limited technology options
- Reduced availability of agricultural land due to urbanization
- Lack of capital to mitigate

**(Ariel Ortiz-Bobea et al. 2021 Nature Climate Change (VOL 11: 306–312) | www.nature.com/natureclimatechange)*

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Excesses of temperature and precipitation - *El Niño* & *La Niña* events affects agricultural productivity e.g., in Southern Africa

CGIAR

- La Niña years bring the growing conditions closer towards the optimum
- El Niño years result in stress growing conditions of heat & drought
- Rising Jan - Mar temperatures posing a threat to agricultural productivity growth
- Increasing dry spell duration during the reproductive growth stages reduce maize yields
- Increasing wet spell duration leads to waterlogging
  - Excessive wetness reduce maize yield
- Maize yield decreases associated with *El Niño* events tend to be larger than corresponding yield increases during La Niña events.

Unprecedented climate extremes in South Africa and implications for maize production. Catherine D Bradshaw et al 2022 Environ. Res. Lett. 17 084028

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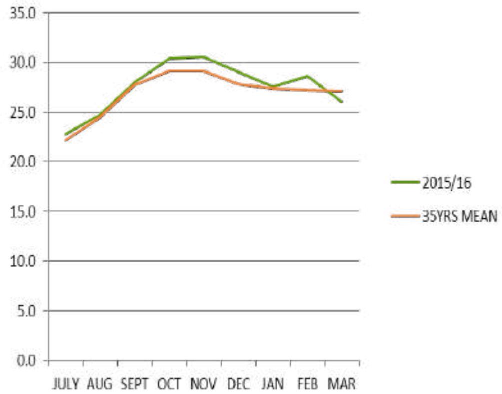
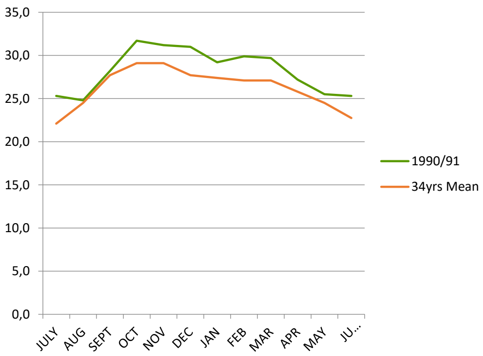
Maximum temperature increases at Rattray Arnold Research Station, Zimbabwe, during El Niño in 2015-16, 1990-1991 vs 35-yr mean

CGIAR

Season	JUL	AUG	SEPT	OCT	NOV	DEC	JAN	FEB	MAR
2015/16	22.8	24.7	28.0	30.4	30.6	29.1	27.6	28.6	26.1
35-yr mean	22.2	24.5	27.7	29.2	29.2	27.8	27.4	27.2	27.1
Change	0.6	0.2	0.3	1.2	1.4	1.3	0.2	1.4	- 1.0

Season	JUL	AUG	SEPT	OCT	NOV	DEC	JAN	FEB	MAR
1990/91	25.3	24.8	28.2	31.7	31.2	31.0	29.2	29.9	29.7
34-yr mean	22.1	24.5	27.7	29.1	29.1	27.7	27.4	27.1	27.1
Change	3.2	0.3	0.5	2.6	2.1	3.3	1.8	2.8	2.6





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Rising temperatures support Emergence of new pests in new places – the case of devastating fall armyworm in sub-Saharan Africa

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Adaptation solutions & the role of new plant varieties

CGIAR

Agriculture contributes to climate change

- Agricultural emissions contribute about 25% GHGs which must be reduced
- Conversion of forests to agricultural land

Therefore, there is need to adopt agricultural practices that contribute to capturing the excess carbon generated by agriculture, and other industries

- Intensification of agriculture will reduce deforestation
- Reducing tillage, expanding crop rotations, planting cover crops
- Integrating livestock into crop production systems
- Irrigation
- Breeding climate change resilient crop varieties

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CGIAR Research program on climate change and food security

CGIAR

Nutrition, Health & Food Security

Poverty Reduction, Livelihoods & Jobs

Gender Equality, Youth & Social Inclusion

Climate Adaptation & Mitigation

Environmental Health & Biodiversity

- Research on climate-smart technologies and practices to transition to climate-smart agriculture at a large scale
- Reduction of GHG emissions and increase carbon sequestration in the agriculture sector
- Effective climate information & advisory services for farmers and climate-informed safety net interventions
- Increased production and distribution of burdens and benefits in agriculture among women and men
- Fast-track solutions to millions of farmers and food system actors

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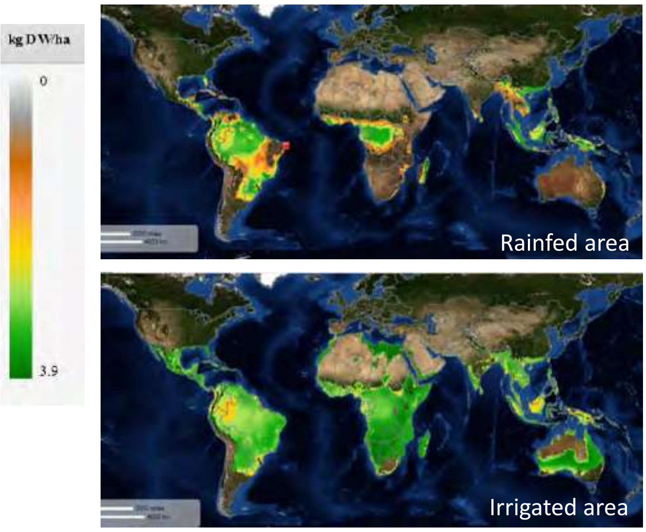
Agronomic interventions such as irrigation can increase banana production area and productivity

CGIAR



Courtesy, Bioscience Engineering, Biosystems, TPL

Left: Leaf folding due to moisture stress.

Below: Areal imaging of banana canopy show leaf area index changes due to moisture stress

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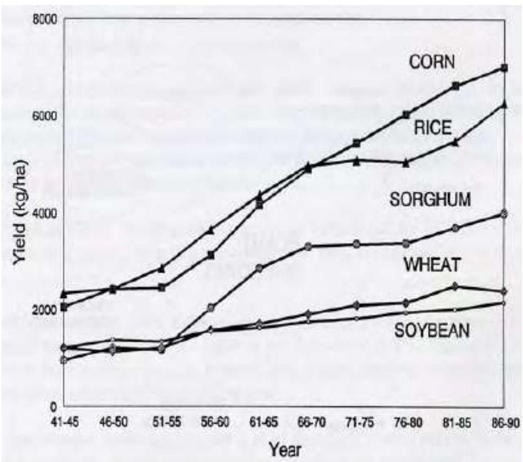
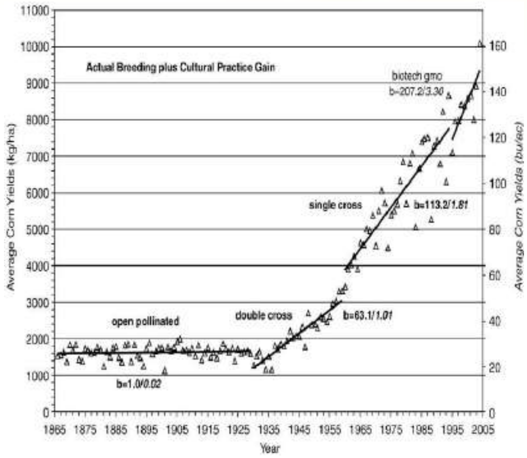
The role of new plant varieties- incredible yield improvements in a changing climate – a result of genetics improvements

CGIAR

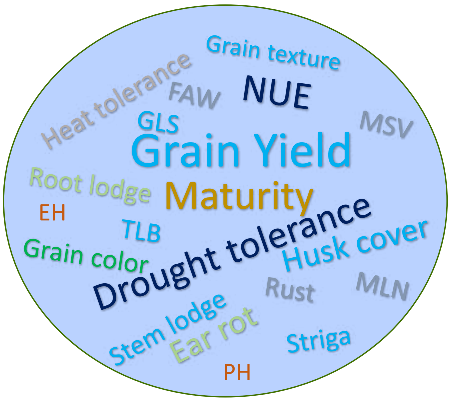




- At least 50-60% of yield increases of USA maize (corn) is attributable to genetic improvement
- CGIAR breeding programs target variety improvements for disease and pest resistance, and abiotic stress resistance (high/low temperature, excessive water/flooding, drought, high salinity, alkaline soils).
- This results in continual increase of genetic gain under climate challenges

CIMMYT & IITA have made a tremendous progress to deliver climate smart maize varieties

Multiple traits improved to adapt maize to climate change challenges



No.	Country	# hybrids	Center
1	Ethiopia	2	CIMMYT
2	Ghana	5	IITA
3	Kenya	8	CIMMYT
4	Malawi	4	CIMMYT
5	Mozambique	1	CIMMYT
6	Nigeria	20	IITA/CIMMYT
7	Rwanda	4	CIMMYT
8	Tanzania	2	CIMMYT
9	Zambia	15	CIMMYT/IITA
10	Zimbabwe	8	CIMMYT

Accelerated Genetic Gain (AGG) project making significant gains in delivering stress tolerant & input responsive maize varieties. 69 new varieties deployed across SSA in 2020-2021. Yield levels of 9-15 t/ha recorded.

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Conclusion

Climate change could cause catastrophic effects on agricultural productivity through increases of GHG emission

Agriculture contributes to climate change therefore, there is need to adopt agricultural practices that contribute to capturing the excess carbon generated by agriculture, and other industries

Improved agronomic practices and development of new plant varieties could contribute to incredible yield improvements in a changing climate

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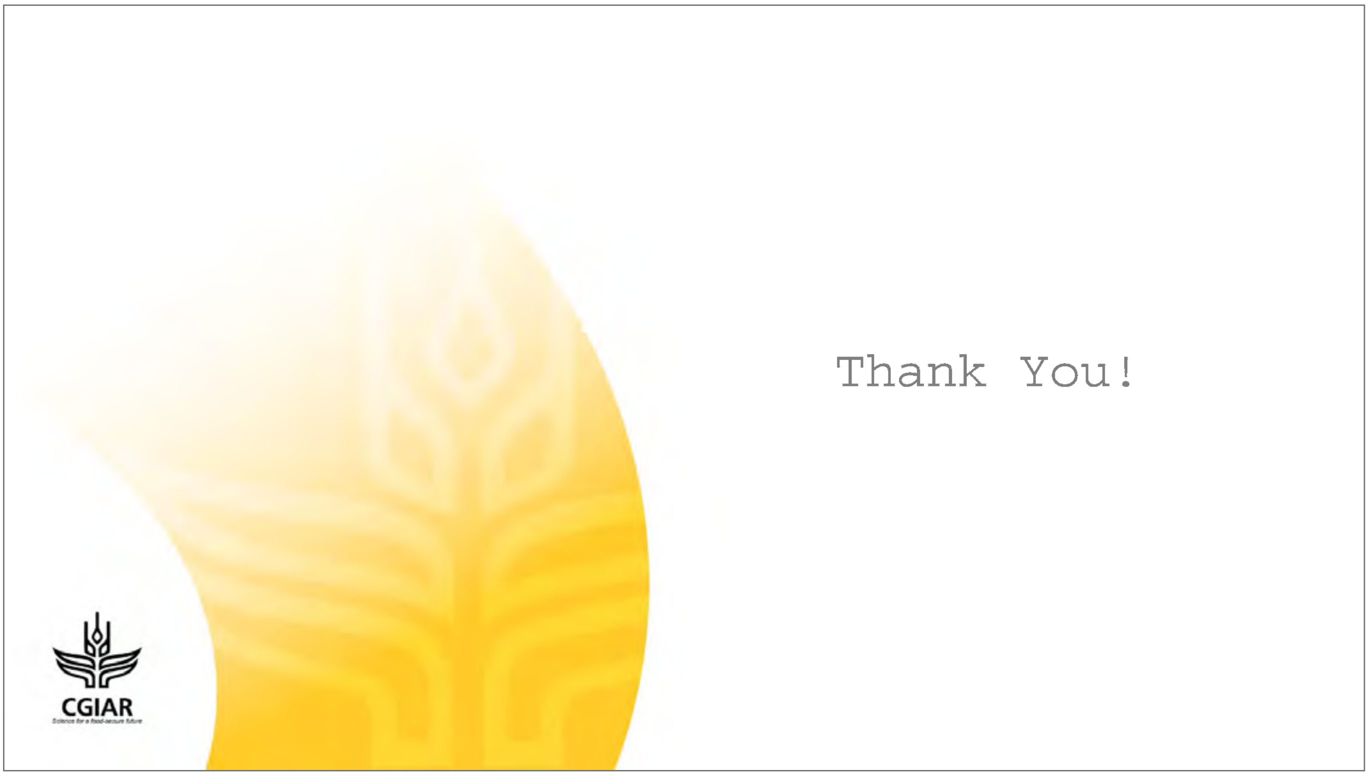

Thank You!
CGIAR

FARMERS' PERSPECTIVE ON ENABLING AGRICULTURE TO MITIGATE AND ADAPT TO CLIMATE CHANGE

Ms. Arianna GIULIODORI
Secretary General, World Farmers' Organisation (WFO)

The World Farmers' Organisation (WFO), for whom I have the honour to serve as Secretary General, was born only 11 years ago. However, it has quickly grown into the biggest independent global farmer's voice, representing the farmers' community, regardless of their gender, age or farm size – small, medium or large-scale – in all the relevant international processes.

WFO is organized in six regional constituencies (Africa, Asia, Europe, Latin America, North America and Oceania), each with its own specificity and story to tell, and it is our commitment to bring them on the global stage so that every continent's voice can be heard. As of today, WFO counts 78 members, with 54 countries represented, and more than 1.2 billion farmers across the globe.

What matters to us is enhancing farmers' positions in relevant international debates by supporting their values and solutions. Whatever we do is driven by the farmers through an authentic bottom-up approach that ensures we can advocate for the real needs and expectations of the farming community.

Food systems transformation, climate change, food security and nutrition, trade and value chain, livestock, One Health and antimicrobial resistance (AMR), cooperatives, innovation, youth and women empowerment, nature and biodiversity represent all the areas where farmers' leaders from WFO member organizations across the globe, on the occasion of the General Assembly, have expressed the wish to be active, to be engaged and to be committed to drive change and to have positions to advocate for on the global scene.

Climate change is one of the most crucial issues for farmers, and WFO members decided to move from a reactive to a proactive approach, adopting a different perspective with farmers sitting in the driver's seat and coming up with the clear message that they hold an essential part of the solution to address the challenges of combating climate change and its impacts.

In 2018, the WFO proposed a new agenda according to which all the relevant actors in the food value chain, research institutions, private sector associations, civil society, multilateral organizations and media partners, work together with the farmers to strengthen their capacity to influence the decision-making processes on agriculture and climate change.

This initiative, born under the name of "TheClimakers", is a multi-stakeholder alliance proposing solutions to climate change that are farmer-driven, science-based and result-oriented.

Our overarching goal is defining a win-win-win scenario: WIN for the governments to successfully implement the Paris Agreement in agriculture; WIN for the farmers and the wider food systems and value chains that can be sustainable in all dimensions to thrive in the future; and last but not least, WIN for all of us on this planet who deserve to live in a healthier place.

Under The Climakers initiative, we held and are still holding dialogue and consultations with farmers across the globe to learn more about the most significant impacts of climate change on their daily activities and what they need to mitigate and adapt to them.

What has clearly emerged is that farmers feel climate change on their farms and need help in terms of extension services and support in terms of programs to innovate and drive change. Most of all, they need knowledge exchange about new techniques or solutions to implement on their farms.

Too often, there is a lack of conducive environment and policy frameworks coherent with the challenges they face; it is not that farmers are either missing the point of enhancing resilience or not contributing enough to mitigation.

However, I am not here to share what the farmers are missing or what the farmers are complaining about. I am here to highlight examples from farmers around the globe implementing new techniques and solutions.

For instance, in **Germany**, our members are working on improving soil quality, adopting practices such as minimal tillage or improving the water retention capacity in the soil and generating excellent adaptation to potential drought events. Moving to the other side of the planet, in **Vietnam**, Hop Tien Agricultural Cooperative is promoting the adoption of the best available technologies to combine science with the needs of small-scale farmers so that they have improved plant resistance to extreme weather events. In **Kenya**, our member in the country is investing in education, one fundamental pillar to be able to improve the livelihoods of the farmers, and in particular they are investing in explaining to family farmers, women and young farmers the importance of planting trees to work on the mitigation side of climate change, combining this effort of mitigation with increasing livelihoods because the products and by-products coming from this investment can be sold, contributing to the livelihoods of the family farm. And finally, in **Uganda**, an investment in switching to irrigation systems has ensured higher water availability for production and home consumption.

These solutions reflect not only farmers' needs as economic actors but also the needs of their communities.

Moving on, one year ago, we partnered with UPOV and the International Seed Federation (ISF) to explore and collect farmers' needs, constraints and expectations around the role of new improved plant varieties in facing a changing climate. The work was carried from February to June 2021, including an in-depth consultation between our members and the wider farmers' community and a virtual dialogue between farmers, breeders and relevant stakeholders of the value chain.

A total of 82% of the farmers we had the chance to interview said that new improved plant varieties are essential to respond to climate change – and I also would like to draw your attention to why farmers gave this answer. First, the new improved plant varieties would better cope with diseases and adapt to climate change. Also, they could be crucial for mitigation and adaptation at the same time. Finally, in the face of the increasing relevance of extreme weather events, new improved plant varieties could provide the right answer in helping farmers to protect their livelihoods and to be more resilient.

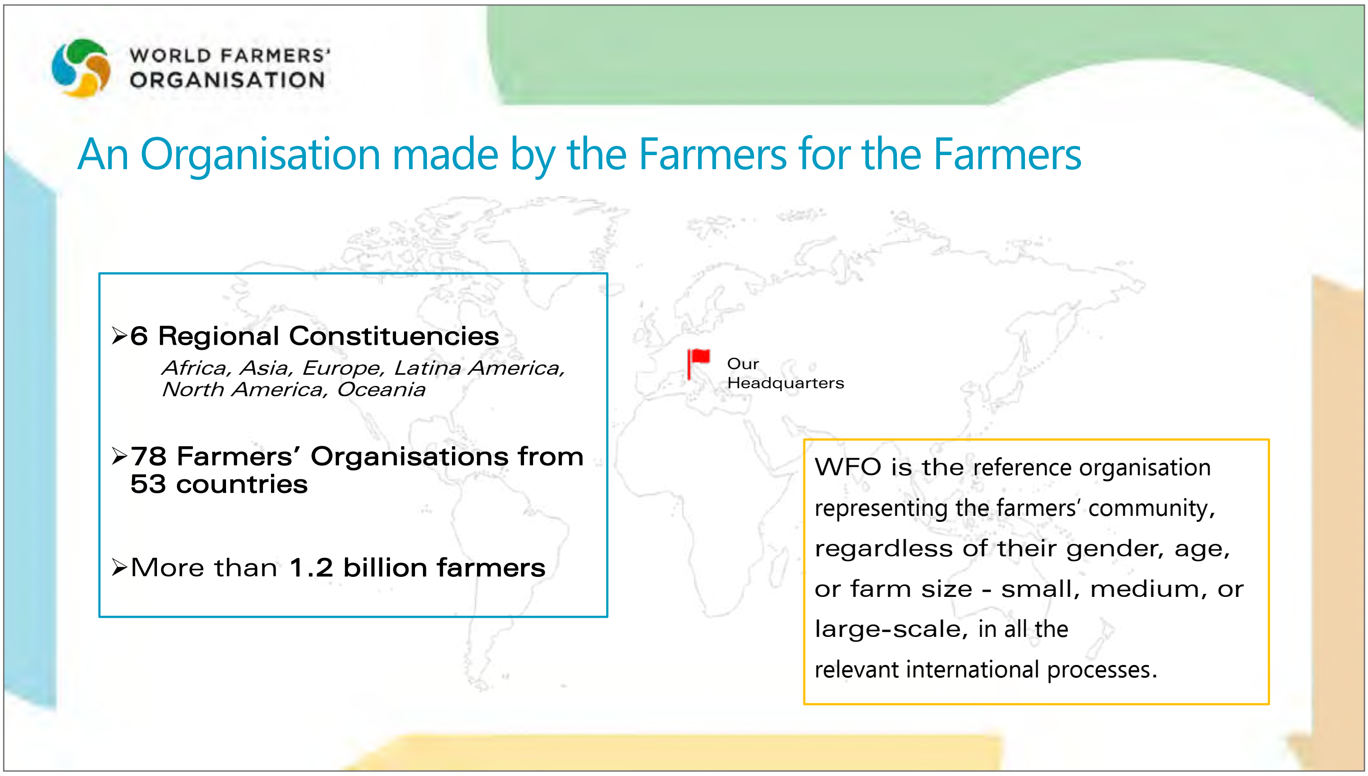
But what are the needs and the expectations of the farmers' communities when it comes to approaching climate change from the specific angle of new improved plant varieties? Farmers are asking for better access to seeds in terms of availability and affordability, and one year on, with the issue of affordability of inputs frightening many producers, both from the global North and the global South due to the ongoing conflict in Ukraine, this need is more crucial than ever.

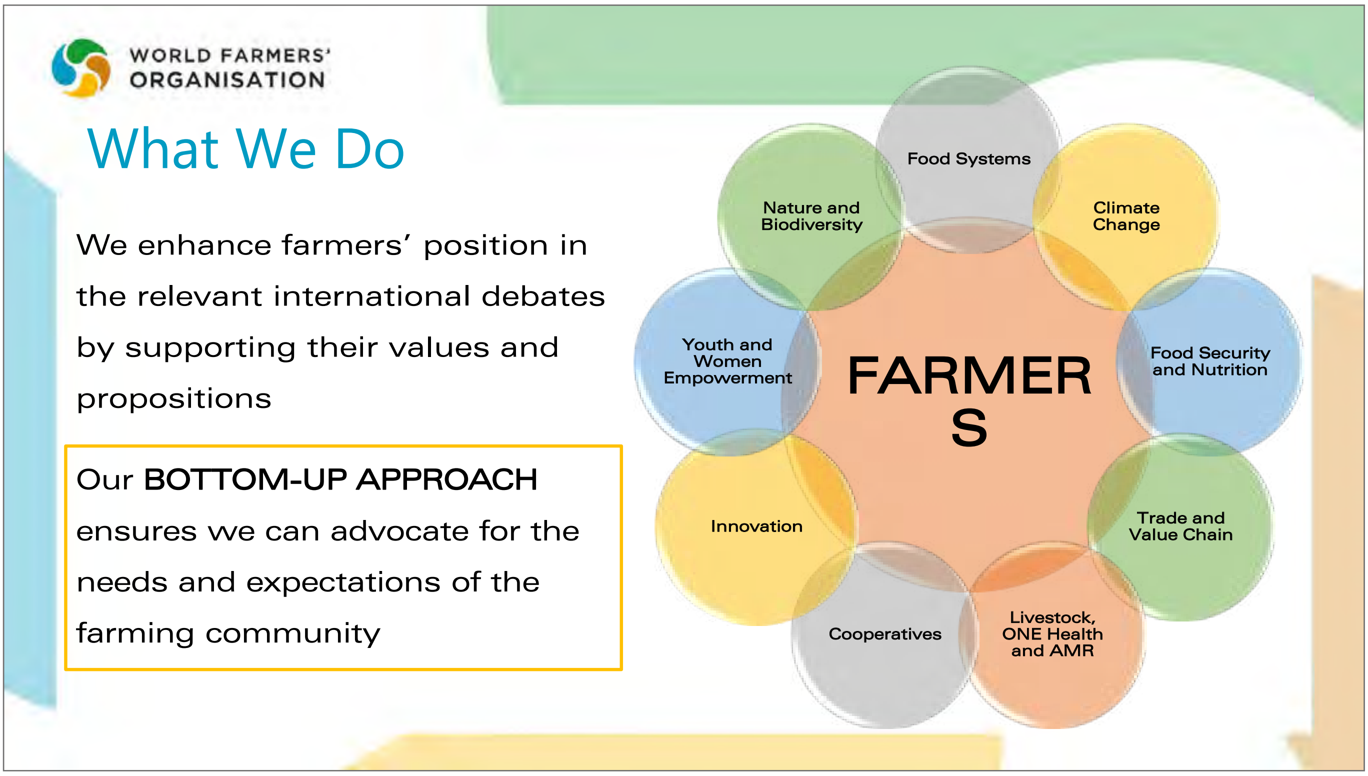
Farmers also pointed out that training information exchange and access to knowledge on new improved plant varieties are still huge gaps that needs to be tackled, as well as the lack of a clear enabling regulatory scientific framework that can facilitate access to these.

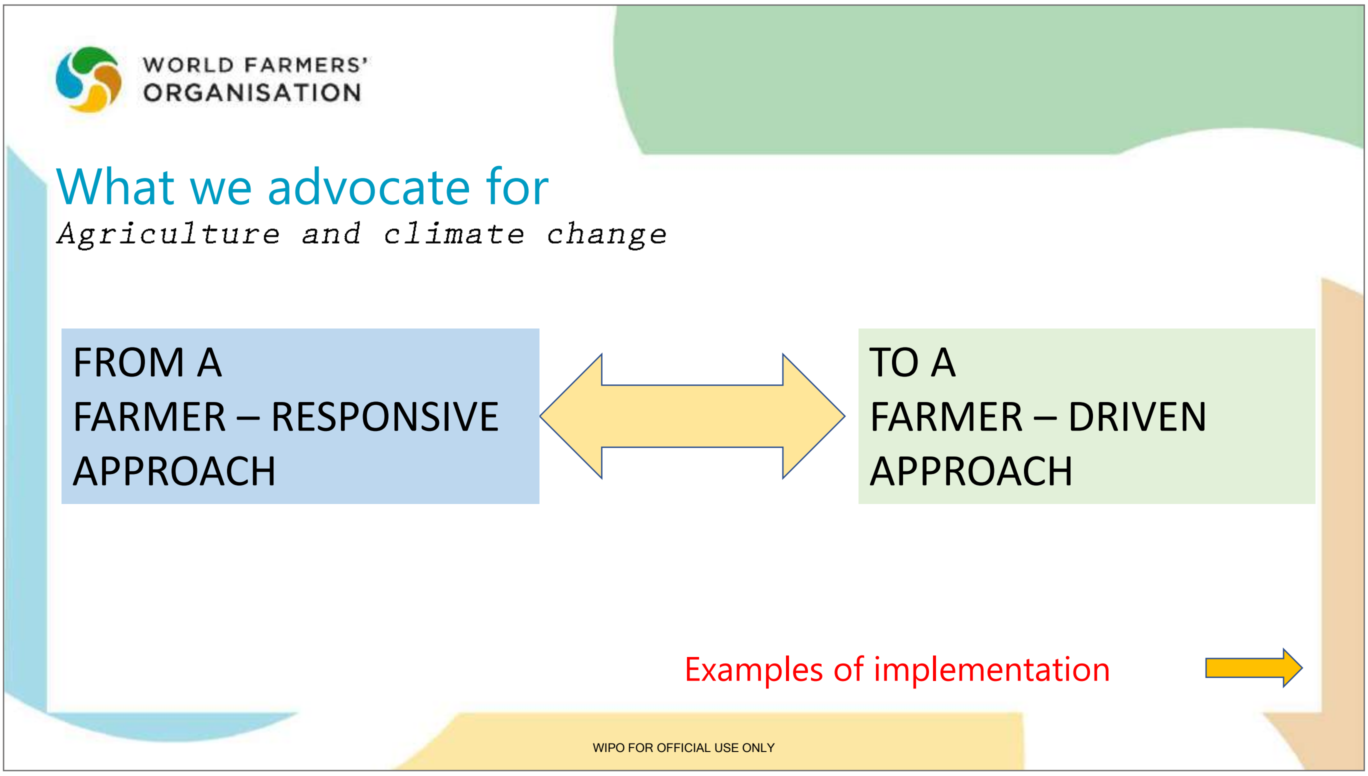
Then there is a call to us, as farmers' organizations, to improve the way we create capacity across the globe so that better-organized farmers can improve the way they have access to the best available innovation. At the opposite side of the food systems of the value chain, consumers' education has also been highlighted as one fundamental element we should invest in to ensure that we can build trust. And finally, these aims cannot be achieved by farmers on their own. It has never been a solitary effort. It is meant to be realized in partnership with other stakeholders in the value chain so that, on the one hand, we can better interpret farmers' needs and expectations, and on the other hand, we can better cooperate to the benefit of all the actors involved.

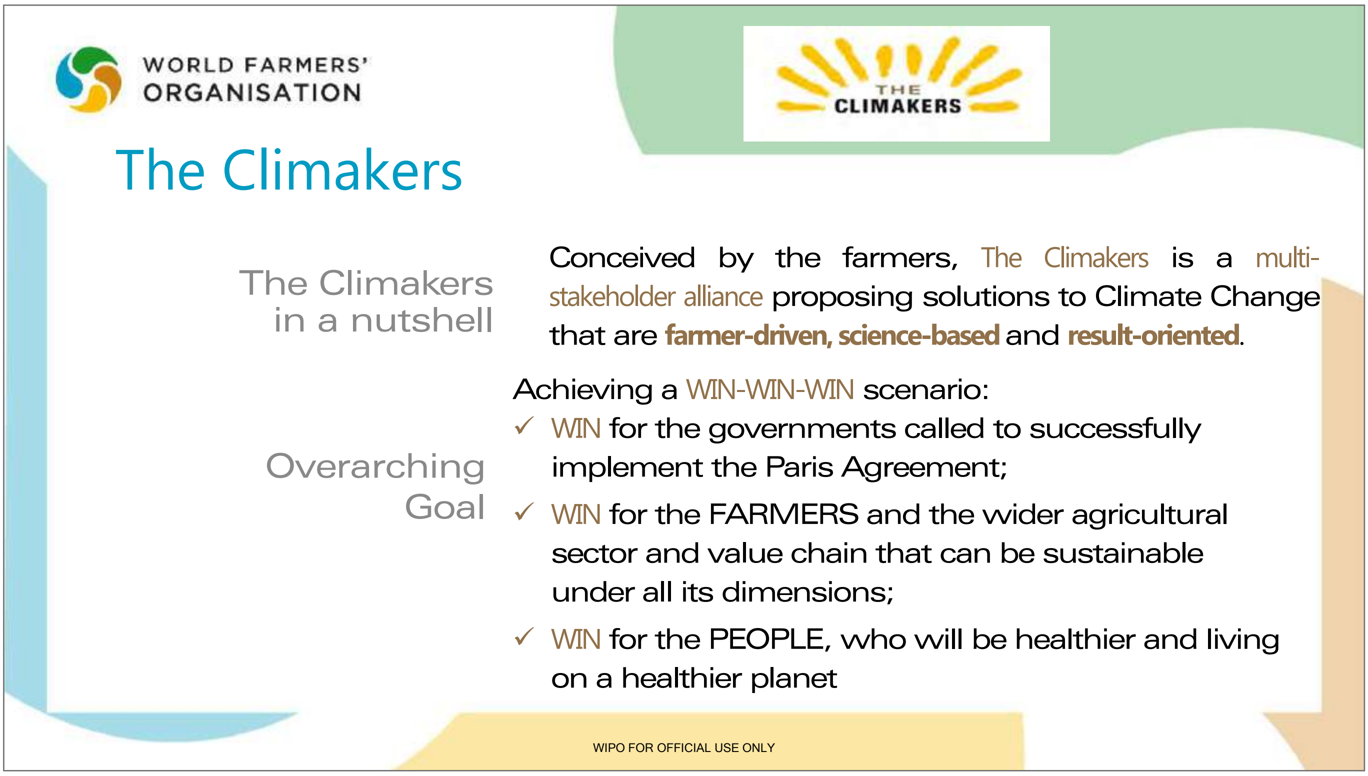
Less than a month separates us from the United Nations Climate Change Conference COP 27. The level of attention around food systems, food production and agriculture is rising in the framework of COP. Expectations are rising not only about what is needed but also around the fact that agriculture is the solution to the challenges we face. Agriculture is in a position to provide the answers that are needed, both for mitigation and adaptation, but also to generate a positive impact on nature around us. Farmers are ready to do their part. Will other stakeholders and actors also be ready to collaborate and succeed?

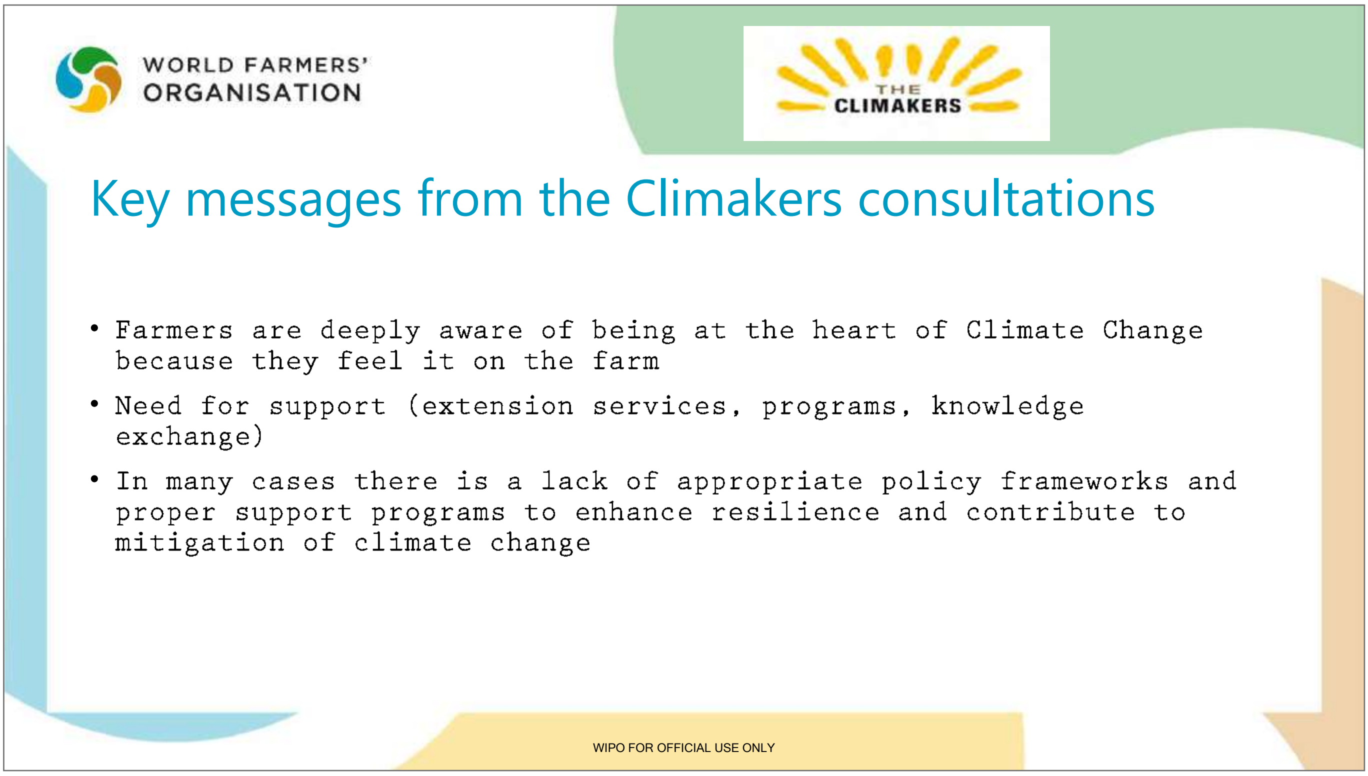
Presentation made at the Seminar




WORLD FARMERS' ORGANISATION
What We Do
We enhance farmers' position in the relevant international debates by supporting their values and propositions
Our BOTTOM-UP APPROACH ensures we can advocate for the needs and expectations of the farming community
Food Systems
Climate Change
Food Security and Nutrition
Trade and Value Chain
Livestock, ONE Health and AMR
Cooperatives
Innovation
Youth and Women Empowerment
Nature and Biodiversity
FARMER S


WORLD FARMERS' ORGANISATION
What we advocate for
Agriculture and climate change
FROM A FARMER – RESPONSIVE APPROACH
TO A FARMER – DRIVEN APPROACH
Examples of implementation
WIPO FOR OFFICIAL USE ONLY


WORLD FARMERS' ORGANISATION
THE CLIMAKERS
The Climakers
The Climakers in a nutshell
Conceived by the farmers, The Climakers is a multi-stakeholder alliance proposing solutions to Climate Change that are farmer-driven, science-based and result-oriented.
Overarching Goal
Achieving a WIN-WIN-WIN scenario:
✓ WIN for the governments called to successfully implement the Paris Agreement;
✓ WIN for the FARMERS and the wider agricultural sector and value chain that can be sustainable under all its dimensions;
✓ WIN for the PEOPLE, who will be healthier and living on a healthier planet
WIPO FOR OFFICIAL USE ONLY


WORLD FARMERS' ORGANISATION
THE CLIMAKERS
Key messages from the Climakers consultations
• Farmers are deeply aware of being at the heart of Climate Change because they feel it on the farm
• Need for support (extension services, programs, knowledge exchange)
• In many cases there is a lack of appropriate policy frameworks and proper support programs to enhance resilience and contribute to mitigation of climate change
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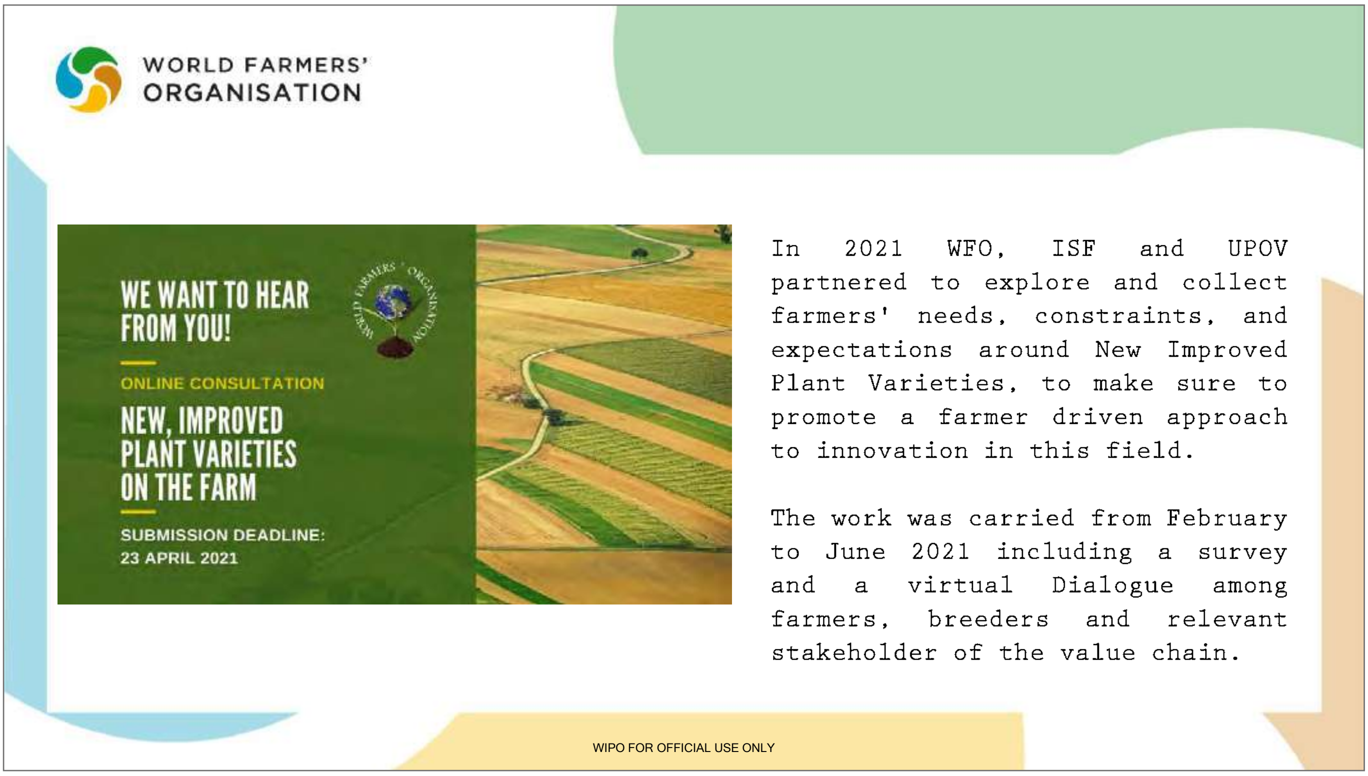
WORLD FARMERS' ORGANISATION
THE CLIMAKERS
Examples of Farmers' solutions to Climate Change
Germany
For Brenkenhagener Gemues ehfarmers, the best possible way to mitigate the effects of climate change is by improving soil quality. Adopting practices such as minimal tilling enhance water retention in the soil, generating a greater adaptation to drought
Vietnam
Hop Tien Agricultural Cooperative promotes the application of science and technology to actively respond to extreme weather. These new innovative farming methods have improved plant resistance to extreme weather.
Kenya
KENAFF educates smallholder farmers, women, and youth on the importance of planting trees to mitigate climate change. Livelihoods of farmers are improved through the sale of tree seedlings, tree products like fruits from established tree nurseries
Uganda
Diversification of farming methods and the switch to irrigation systems have ensured higher water availability for production and home consumption and improved the health and livelihoods of rural communities
WIPO FOR OFFICIAL USE ONLY


WORLD FARMERS' ORGANISATION
WE WANT TO HEAR FROM YOU!
ONLINE CONSULTATION
NEW, IMPROVED PLANT VARIETIES ON THE FARM
SUBMISSION DEADLINE: 23 APRIL 2021
In 2021 WFO, ISF and UPOV partnered to explore and collect farmers' needs, constraints, and expectations around New Improved Plant Varieties, to make sure to promote a farmer driven approach to innovation in this field.
The work was carried from February to June 2021 including a survey and a virtual Dialogue among farmers, breeders and relevant stakeholder of the value chain.
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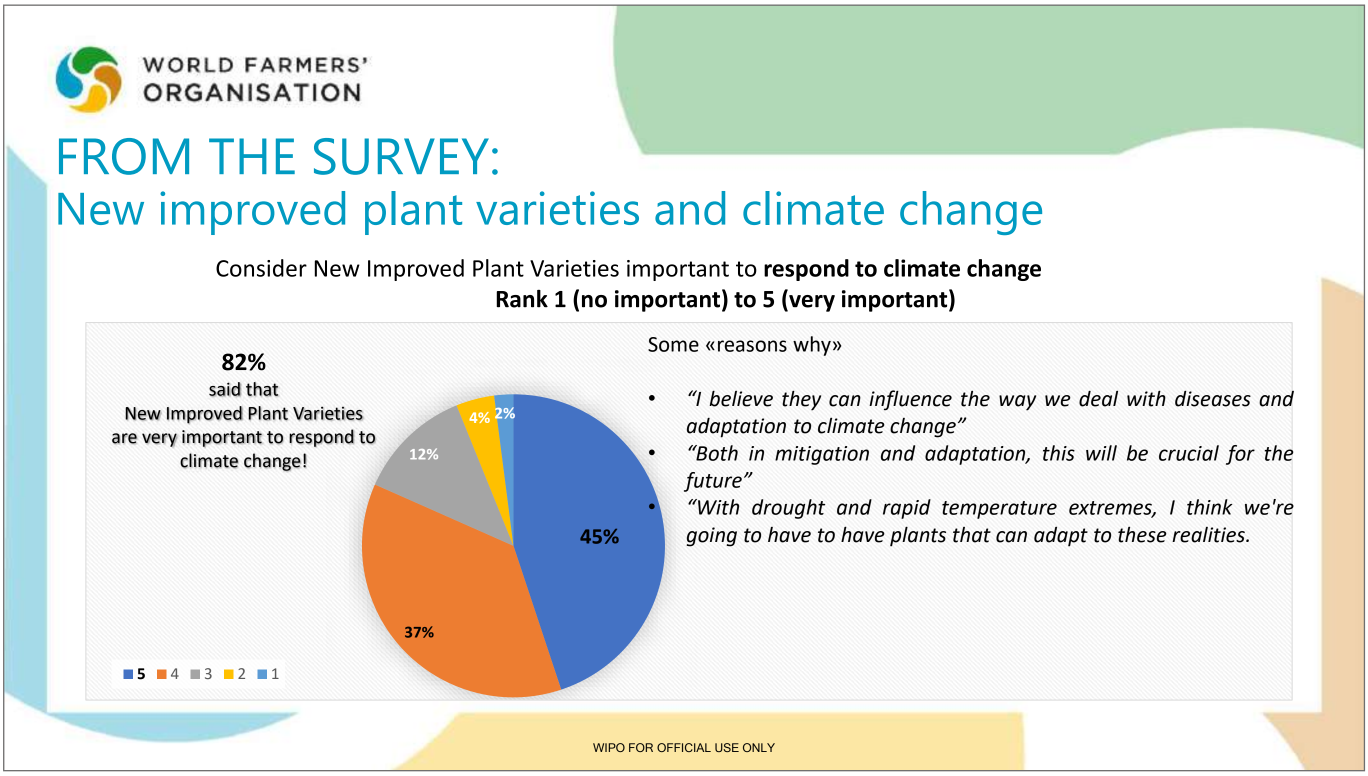
WORLD FARMERS' ORGANISATION
FROM THE SURVEY:
New improved plant varieties and climate change
Consider New Improved Plant Varieties important to respond to climate change
Rank 1 (no important) to 5 (very important)
82%
said that
New Improved Plant Varieties are very important to respond to climate change!
45%
37%
12%
4%
2%
5 4 3 2 1
Some «reasons why»
"I believe they can influence the way we deal with diseases and adaptation to climate change"
"Both in mitigation and adaptation, this will be crucial for the future"
"With drought and rapid temperature extremes, I think we're going to have to have plants that can adapt to these realities.
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WORLD FARMERS' ORGANISATION
Farmers' expectations on New Improved Plant Varieties
KEY EXPECTATIONS AND NEEDS AROUND THE USE OF NEW IMPROVED PLANT VARIETIES
Access to seeds (availability and affordability);
Access to training, information and knowledge on New Improved plant varieties;
Enabling regulatory; innovation and scientific framework to access new improved plant varieties;
Organized Agriculture: Farmers Organisations' as key actors to ensure that farmers of all sizes and everywhere have access to the best available innovation;
Consumers' education in order to build trust around new varieties thanks, among others, to traceability systems;
Partnership with stakeholders in the value chain to ensure farmers' expectations and needs are met building a cooperation framework that benefits all the actors involved.
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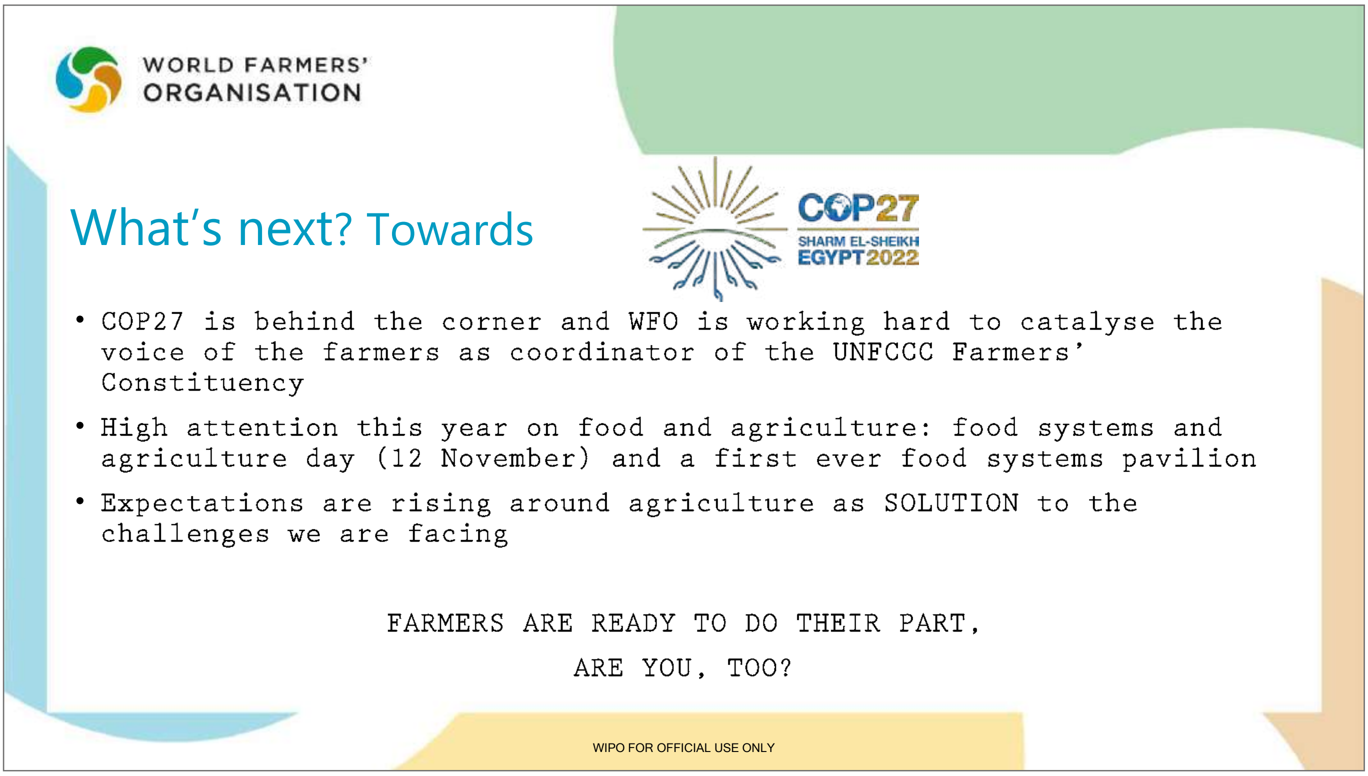

WORLD FARMERS' ORGANISATION
What's next? Towards
COP27
SHARM EL-SHEIKH EGYPT 2022
• COP27 is behind the corner and WFO is working hard to catalyse the voice of the farmers as coordinator of the UNFCCC Farmers' Constituency
• High attention this year on food and agriculture: food systems and agriculture day (12 November) and a first ever food systems pavilion
• Expectations are rising around agriculture as SOLUTION to the challenges we are facing
FARMERS ARE READY TO DO THEIR PART,
ARE YOU, TOO?
WIPO FOR OFFICIAL USE ONLY

INTERNATIONAL SEED FEDERATION PERSPECTIVE

Mr. Michael Keller
Secretary-General, International Seed Federation (ISF)

The role of plant breeding and plant variety protection in enabling agriculture to mitigate and adapt to climate change s a very important topic, which is also impacting our capacity to address the food security challenge worldwide in a changing world. For this reason, I would like to thank UPOV for having taken this initiative. Figure 1 shows an image I discovered some years back during an OECD meeting in Paris. It shows that it is important to speak about climate change, but there are many other factors impacting our capacity to provide the best improved quality seed to the farmer, to produce food, feed and fiber for the whole value chain and for the consumer.

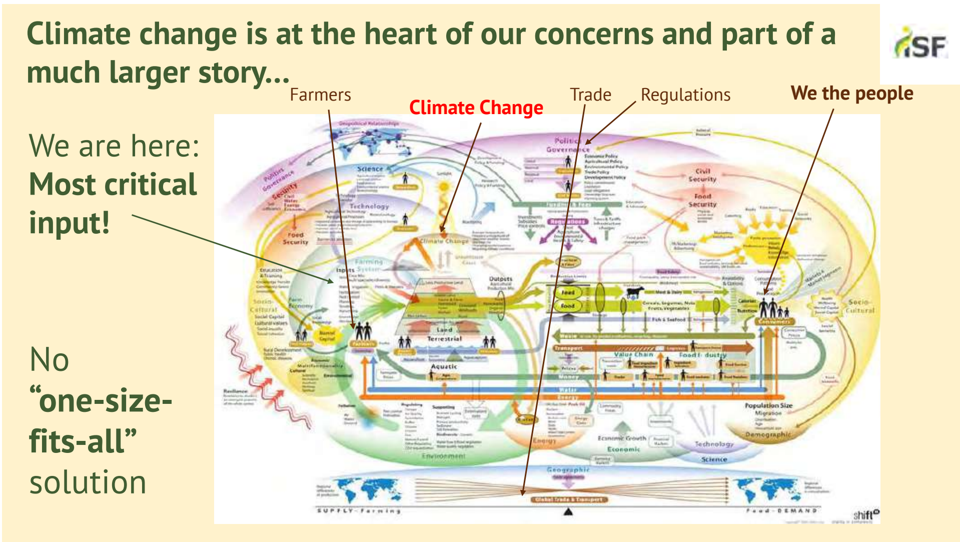


Figure 1 *(Source: OECD)*

First of all, I hope we all agree that seed is the most critical input in food production, and therefore there is a high responsibility on us, all of us, to respond to the diverse challenges and to increase our capacity in terms of continued breeding efforts. There is no one-size-fits-all solution; any improved variety needs to be locally adapted, and we should never forget this in our debate.

I would like to emphasize that there is an interdependency in terms of seed supply, and no country today is independent in terms of seed supply. We need to bear this in mind when we are addressing the farmer's needs in her or his fields, and the impact of climate change; therefore the whole discussion on trade and regulations is critical. This is the landscape in which we need to be able to act and to provide the best improved varieties to the farmers.

And here shown in a slightly different way, the same point: like a puzzle, we need to get this puzzle right. Today we are in a critical situation: from increased occurrence of pests and diseases, scarcity of water and land, decline in soil quality, complexity of trade and other factors that limit our ability to make food available and accessible and thereby decrease hunger. We have to produce more, to produce more on less, because we will have a 7 trillion calorie gap within a couple of years. And at the same time, we have had the COVID epidemic, and we are facing issues with wars and conflict.

Therefore, my first call is that we need to work together. And it is absolutely essential for us also as a private sector that we get the recognition that seed is an essential good, which needs to move and which contributes to global food security. Because, in the end, we must act together. Our strength is our complementarity. Private sector, public sector, the farmers, civil society – all actors are important. We are always saying, as the private seed sector, that we would like to contribute, but we are not saying we are the only solution. Let us embrace our diversity and our complementarity.

Figure 2 *International Seed Federation and UN SDGs*

We need all solutions; therefore, let us build resilience and adapt together and adjust to a changing world. Now is the time for action. Now is the time to recognize diversity. Now is the time to move together. And, just to clarify, and we mention this very often during UPOV meetings, this is what we as the private sector are looking for. We are looking for a world where the best quality seed is accessible to all farmers, all farmers everywhere, in every country, and this includes subsistence farmers, smallholder farmers, family farmers, as well as large-scale farmers. Every farmer should have the right of choice of the best locally adapted variety. The best quality seed should be accessible to support sustainable agriculture and food security. And you see also all the boxes where we are convinced that seed is contributing to achieve the Sustainable Development Goals, from No Poverty, Zero Hunger, Live on Land, and others.

Where does our contribution begin? In plant breeding. You will hear in the next two days several exciting examples of private breeding programs. Breeding and providing solutions, that is our day-to-day business. This is in our DNA. And all that we are doing is always in a collaborative effort with farmers. It is about increasing yield; we should never forget, we need to continue to increase yield. In the last decades, seed helped to increase more than 50% of agricultural productivity; however, we must admit, the yield gains have been slowing down in the last 20 years. That means the pace of change in the environment and pest pressures are accelerating. Therefore, we need also to continue the yield increase in the future. In addition, we have to address questions of taste, nutritional quality, climate and environmental adaptability to stresses like drought, salinity, disease, pests. That means our capacity to drive these topics depends also on our capacity to build the breeding programs to enhance heat, drought and salt tolerance, to improve water use efficiency, reduce water loss under water deficit conditions, to better stress tolerances and resistance to multiple pests and diseases. And on top of this, as perhaps you have heard recently, our breeding efforts have helped to increase carbon capture by using genome editing tools.

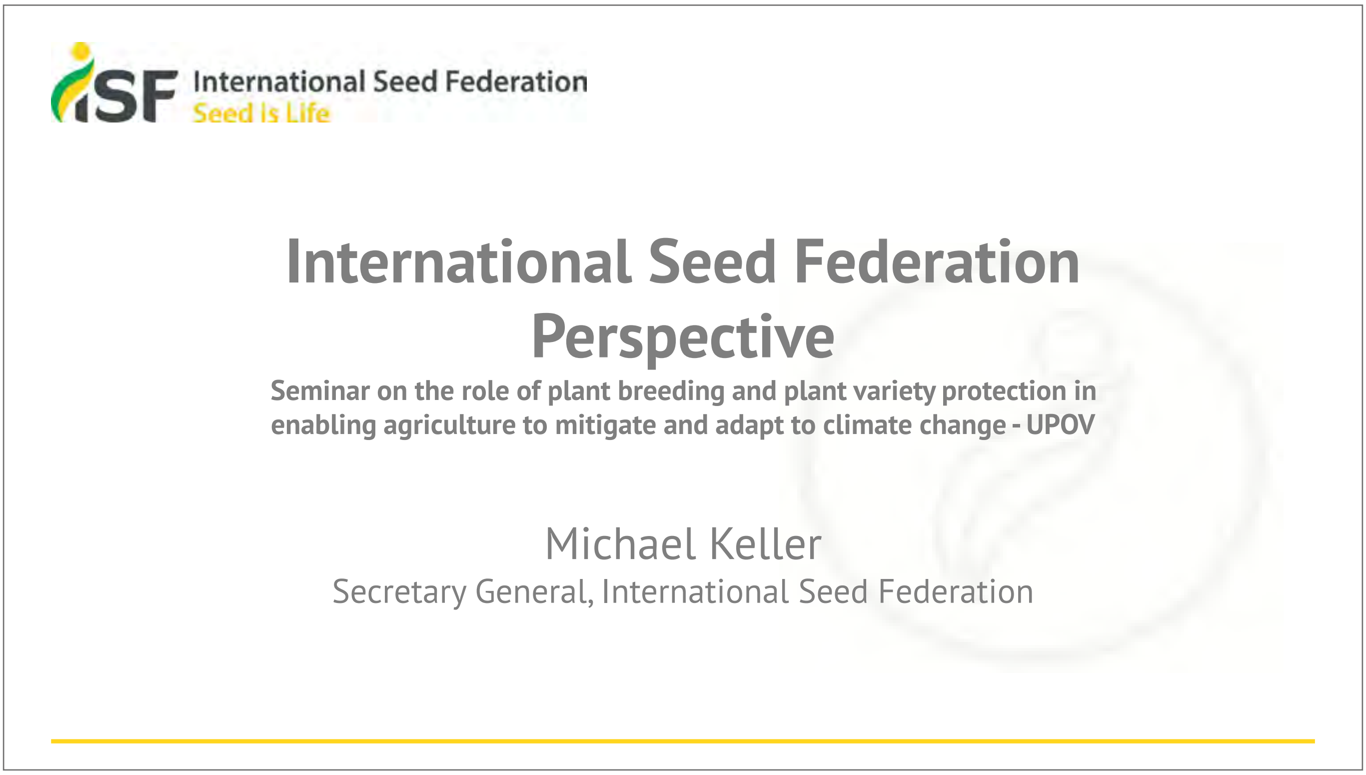
Speaking about genome editing, I think it is absolutely essential for us. It is a tremendous tool. And breeders are looking forward to being able to use all the existing breeding tools and all the breeding tools which will come in the future. Genome editing today is used in more than 40 crops in 30 countries, and there are a broad range of developers from the private sector and public sector. They are using this to improve performance. Let us work together to achieve regulatory consistency so that plant breeders, public or private, can use all the tools to support the needs of farmers for climate change adaptation and mitigation. On top of this, and I think this is important, increasingly so in our capacity to drive breeding programs, is access to supporting technologies. Tremendous opportunities lie in digitalization, bioinformatics or big data. You will hear more throughout the next days.

Again, plant breeding is in the heart of the private seed sector. We want to continue in the next years with our breeding efforts to address climate change, but we are only able to do this if it is economically sustainable. And we should never forget this. And here we are today, in the UPOV panel, therefore it is so important for us that UPOV's role is recognized. It cannot be that plant breeders continue to invest a lot of money without having plant breeders' rights. This is needed for us to be sustainable. But we are always saying, yes, it needs to be sustainable for us, business-wise, but it also needs to be sustainable for the farmers, business-wise. Farmers are also business people. And therefore, if we are able to bring them improved varieties to address all the challenges they are facing on the ground, it will also help the farmer to continue to live off their land, to continue to fight against poverty, all the Sustainable Development Goals (SDGs). I mentioned earlier here today. And let us not forget, in all the discussions in UPOV, what is the role of UPOV? It is to encourage the development of new plant varieties for the benefit of society. And I think when we discuss about climate change, is this not about also benefiting and supporting society in this changing environment?

What is important for us? I spoke about genome editing tools, but there are other regulations out there which can hinder our impact, our capacity to provide improved varieties to farmers. You know, we are moving seeds around the world, and this interdependency on seed, I think, is recognized today. Therefore, our capacity to move seeds around the world and to be able to respond, sometimes very quickly, to the requests of farmers of different varieties to face the challenges they have on the ground – this depends on rules and regulations globally and their implementation at national levels. That means from breeding, to variety registration, to plant protection, to seed production, seed marketing, the whole cycle of seed supply. It needs us to be consistent, it needs to be clear and it needs to be predictable. From plant breeding to seed marketing, for some varieties – you can take a lettuce variety, for instance, it can take 15 to 20 years. You can imagine, when we start a breeding program, we need also to be clear, are we able to bring this also to the market, perhaps even to markets we have not foreseen at the start of the breeding programs? It is absolutely essential in these times of a changing world with more impact of climate change, that we have the right regulations out there recognizing the interdependency and recognizing the need for the farmer to choose, because it is all about the joint capacity of private sector, public sector, authorities around the world to provide seed choice for farmers. On the ground, the farmers have to deal with climate change at the local level, and this capacity depends on what we as the private sector continue to do in breeding by using the latest breeding tools, by being able to move seeds around and being able in a given country to build a vibrant private seed sector. I think these are the discussions we need to have.

I am very happy that you took this up at the UPOV level, organizing this highly important discussion around climate change. And with this, I wish you all the best for the next two days. We will meet also in October in person. Seed is life.

Presentation made at the Seminar



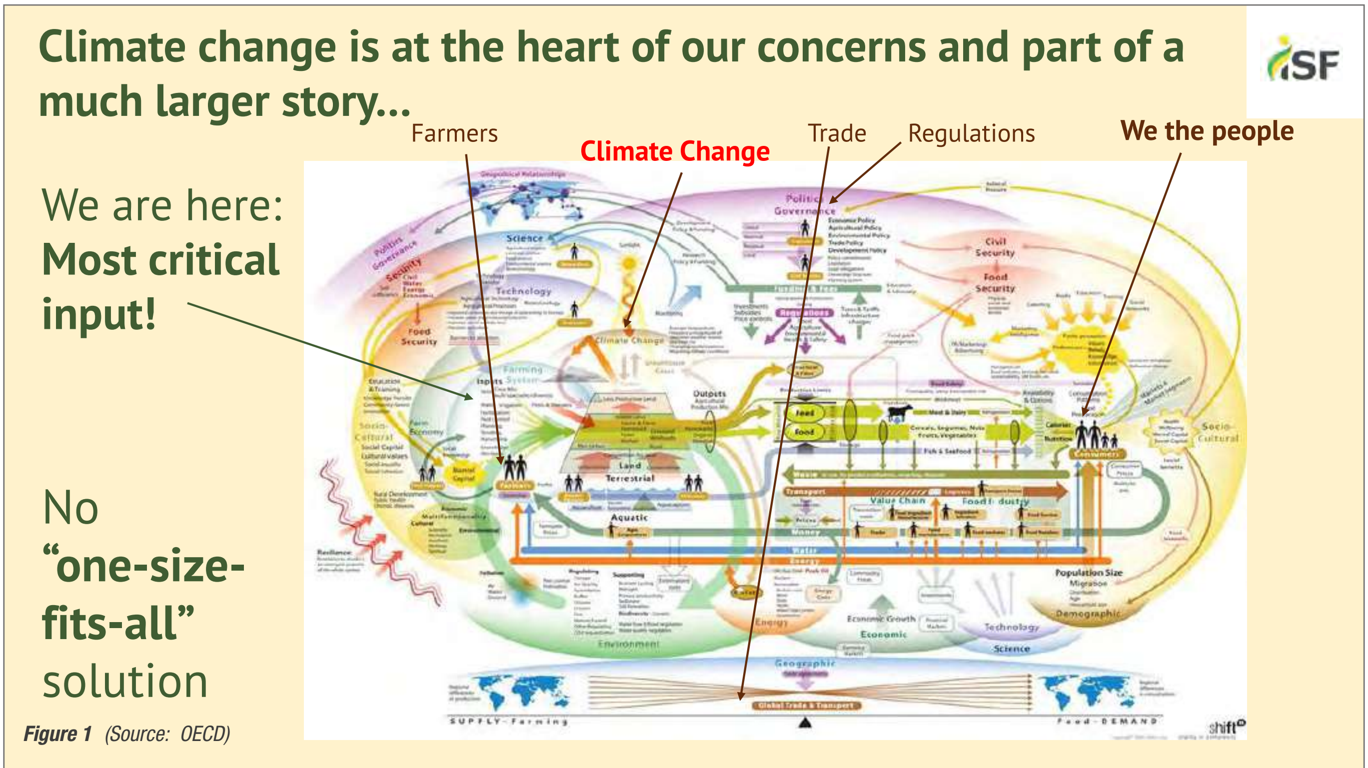


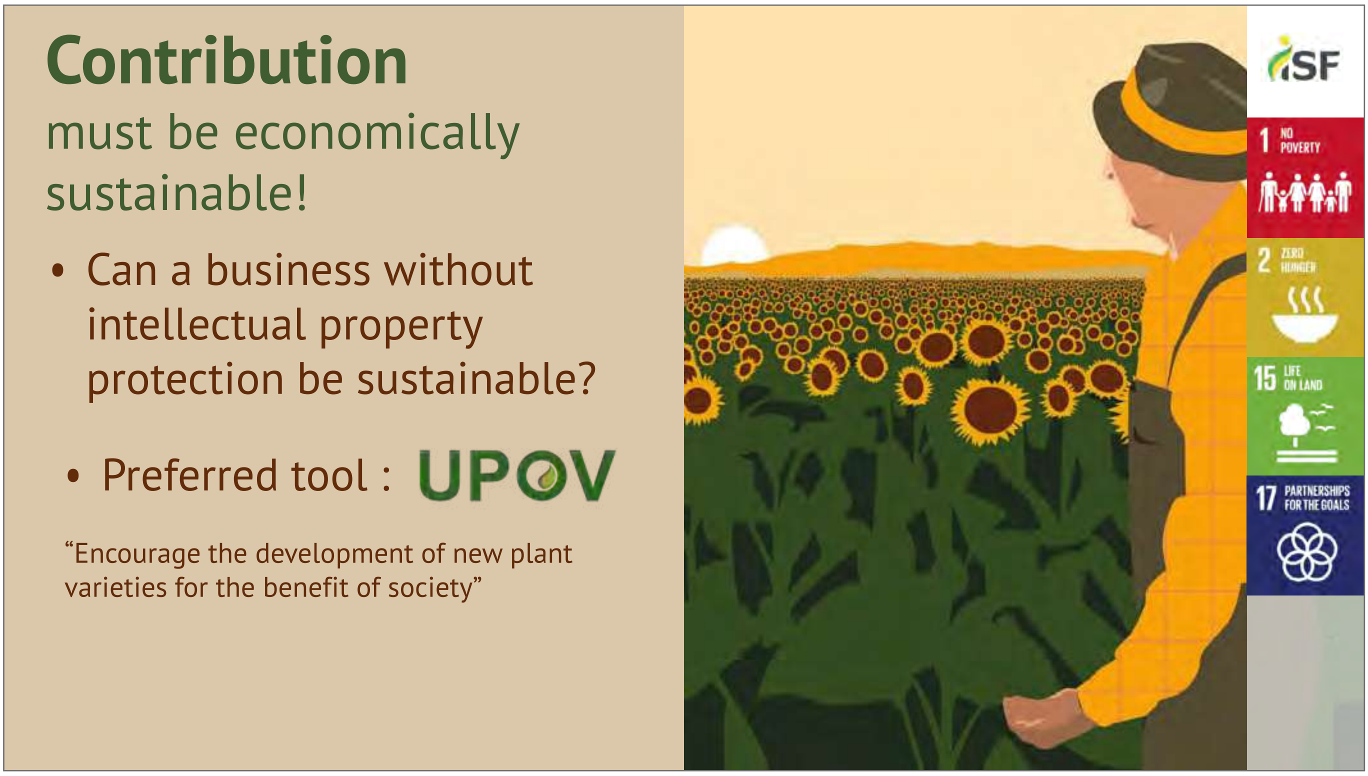
Figure 1 *(Source: OECD)*

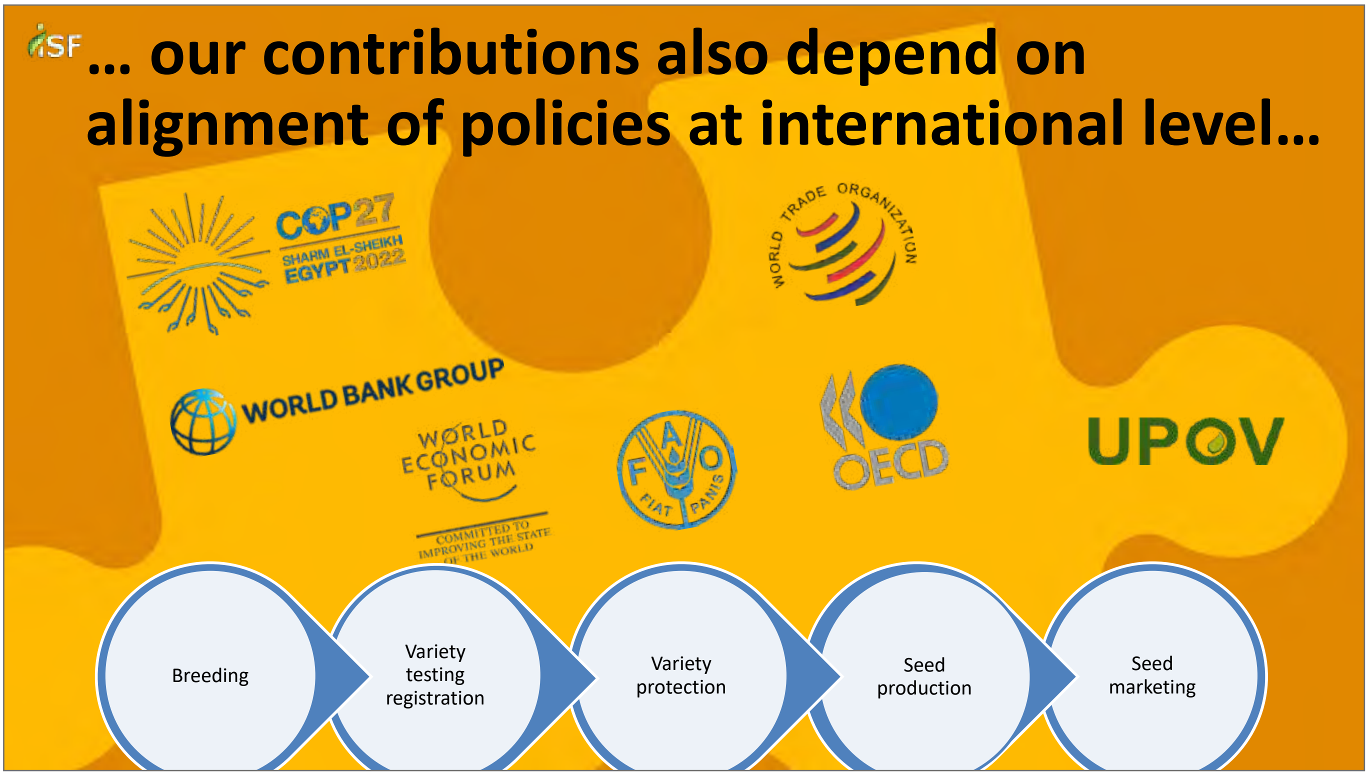
Inno-vation
Reg. Burden
Threats on IP
7 trillion calorie gap
Climate Change
Inter-dependency
Seed Resil.
Bio-diversity
Prices
Increasing population + income
End of Multilateralism
License to operate
Covid
Hunger
Trust?
+ 2°
Wars, conflict
Soil Health
Inflation
Scarcity of land
Genetic Resources
Transpa-rency
Incl. Sed Systems
Water demand
+ 25% Pests
0.15 ha per capita

"There is absolutely no doubt that today is the time to gather our strength, complementarity, and diversity to build resilience and to adapt and adjust to a changing world."
It is now!
ISF


"A world where the **best quality seed** is accessible to all, supporting **sustainable agriculture** and **food security**."
1 NO POVERTY
2 ZERO HUNGER
3 GOOD HEALTH AND WELL-BEING
8 DECENT WORK AND ECONOMIC GROWTH
12 RESPONSIBLE CONSUMPTION AND PRODUCTION
13 CLIMATE ACTION
15 LIFE ON LAND
17 PARTNERSHIPS FOR THE GOALS


Contribution
through Plant Breeding Innovation
• Innovation is in our DNA!
• Yield, taste, nutritional quality, drought, salinity, disease resistance, pests, etc…
• Capacity to use all existing breeding tools
• Genome editing: + 40 Crops 30 countries broad range of developers (private + public) – "improved performances"
• Access to supporting technologies
• Digitalization, Bioinformatics, Big Data,…
2 ZERO HUNGER
3 GOOD HEALTH AND WELL-BEING
13 CLIMATE ACTION
15 LIFE ON LAND
17 PARTNERSHIPS FOR THE GOALS


Contribution
must be economically sustainable!
• Can a business without intellectual property protection be sustainable?
• Preferred tool : UPOV
"Encourage the development of new plant varieties for the benefit of society"
ISF
1 NO POVERTY
2 ZERO HUNGER
15 LIFE ON LAND
17 PARTNERSHIPS FOR THE GOALS


ISF
… our contributions also depend on alignment of policies at international level…
COP27 SHARM EL-SHEIKH EGYPT 2022
WORLD TRADE ORGANIZATION
WORLD BANK GROUP
WORLD ECONOMIC FORUM
COMMITTED TO IMPROVING THE STATE OF THE WORLD
FIAT PANIS
OECD
UPOV
Breeding
Variety testing registration
Variety protection
Seed production
Seed marketing

ISF

It's about our joint capacity to provide **seed choice for farmers** to address **climate change** at the local level.

Seed is Life

ISF Chemin du Reposoir 7 | 1260 Nyon | Switzerland www.worldseed.org

INTERNATIONAL COMMUNITY OF BREEDERS OF ASEXUALLY REPRODUCED ASEXUALLY REPRODUCED HORTICULTURAL PLANTS PERSPECTIVE - IMPACTS AND RISKS FOR AGRICULTURE FROM CLIMATE CHANGE: ADAPTATION SOLUTIONS AND THE ROLE OF NEW PLANT VARIETIES

Mr. Edgar Krieger
Secretary General of the International Community of Breeders of asexually reproduced horticultural plants (CIOPORA)

Climate change is a clear phenomenon with noticeable impacts on horticultural activities and with an increasing trend of effects during the last few decades. Plant breeding offers the necessary tools to help mitigate climate change by the creation of more resilient, more tolerant or less susceptible plant varieties.

Some of the most recent consequences of climate change in agricultural activities are due to heatwaves in Europe and North America dramatically affecting fruit orchards such as avocado, olive and citrus. Floods have been also reported in several parts of the world, such as Pakistan in June last year; and frosts negatively influenced crops in Brazil and Florida during 2021.

Climate change is now unequivocal, particularly in terms of increasing temperature, boosting carbon dioxide concentration, widespread melting of snow and ice, and rising global average sea level, while the increase in the frequency of drought is very likely, but not as certain.

These fluctuations caused by climate change directly affect agricultural activities and represent a challenge for plant breeders. The main targets to be addressed in plant breeding programs associated with climate change adaptation are changes in seasonality, water supply (scarce or excess), heat stress, loss of genetic diversity and more common outbreaks of pests and diseases.

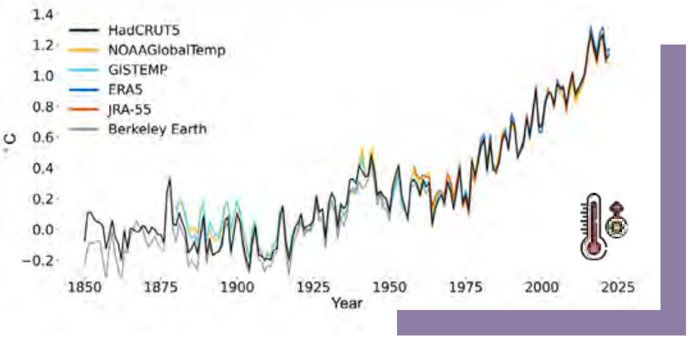
The adaptation solutions provided by plant breeding include new varieties with improved features for higher performance under different growing conditions. For instance, grapevine varieties that have traditionally been produced in temperate climates are now being developed in tropical and subtropical regions with warmer conditions. Moreover, breeders are making efforts to control flowering time and ripening. Quality of taste, color, aroma, acidity and sweetness are equally influenced by climatic conditions and therefore are part of the characteristics involved in plant breeding schemes.

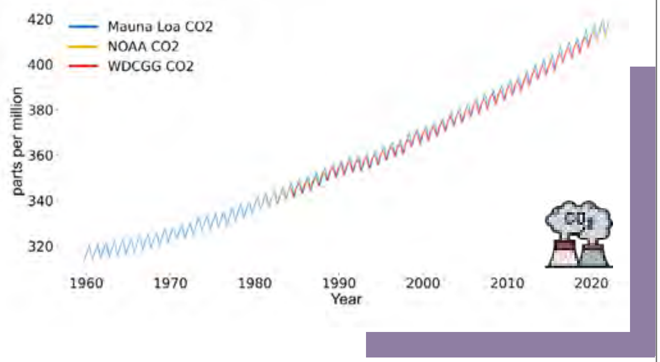
Ultimately, plant breeding offers alternatives to relieve the negative impacts of climate change. The advent of clustered regularly interspaced short palindromic repeats and CRISPR-associated (CRISPR-Cas) systems has presented a new option: creating new varieties more quickly. Speed breeding strategies have also accelerated the process, while predictive breeding has provided a method to save resources and to analyze the outcomes of intended crosses. Lastly, securing genetic diversity has been another way to incorporate lost traits, aiming to solve homogeneity and susceptibility among current plant varieties.

Presentation made at the Seminar

CIOPORA

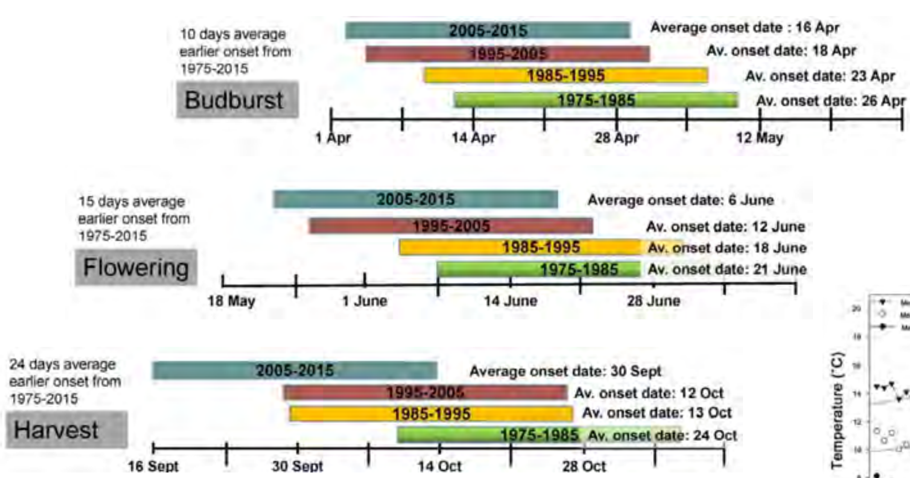
Climate change global indicators

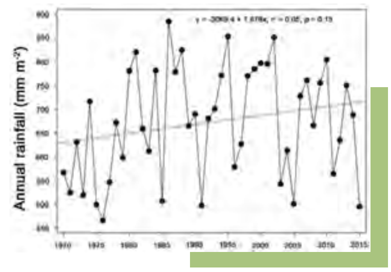


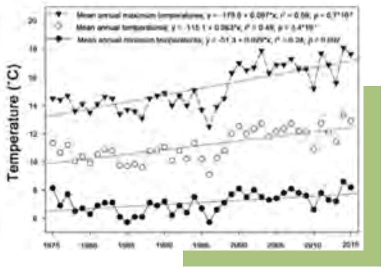


CIOPORA

Phenological changes of four grapevine varieties







4

Impact of climate change on plant breeding

Loss of genetic biodiversity
Changes in environmental conditions promote erosion of biodiversity

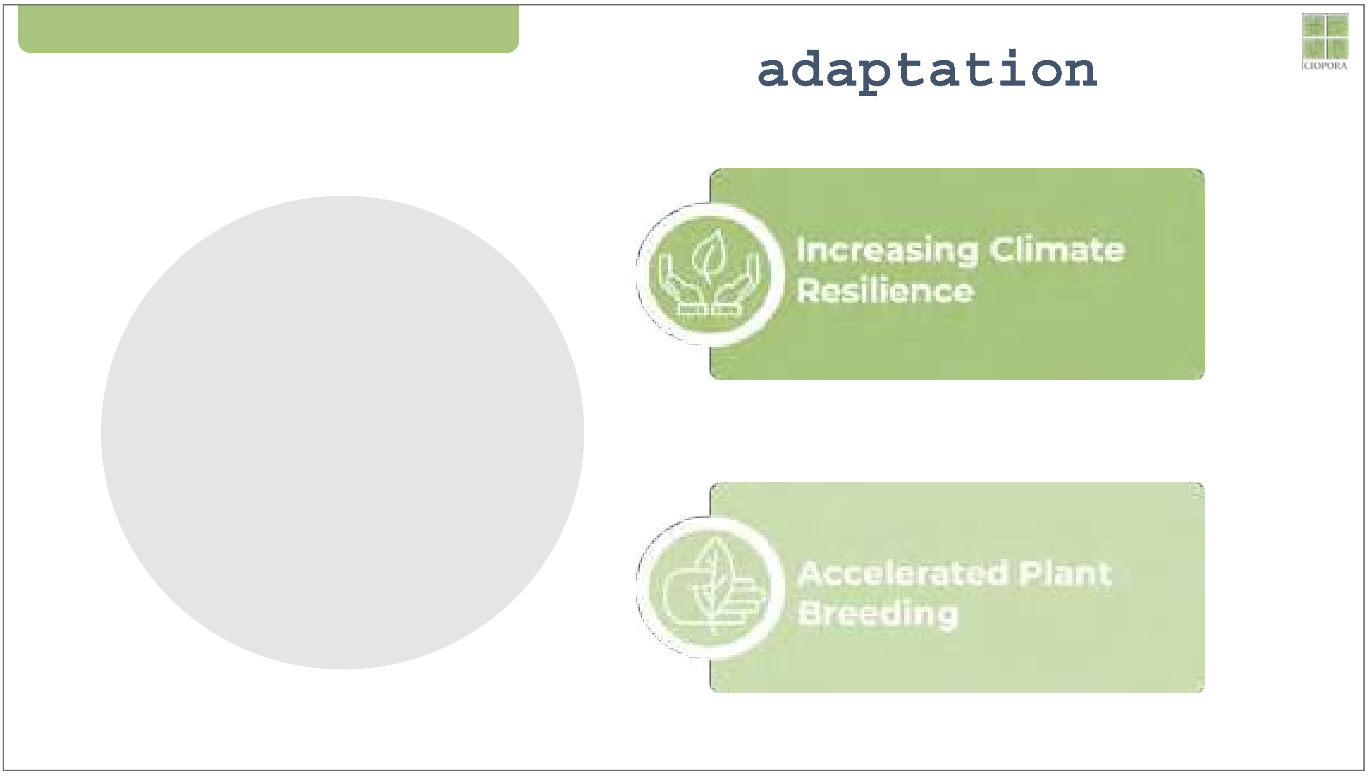
Outbreak of pest and diseases
Increase in temperature and relative humidity set the ideal environment for disease proliferation

Risk of water supply
In some areas, rainfall intensifies or on the contrary it can cause prolonged drought

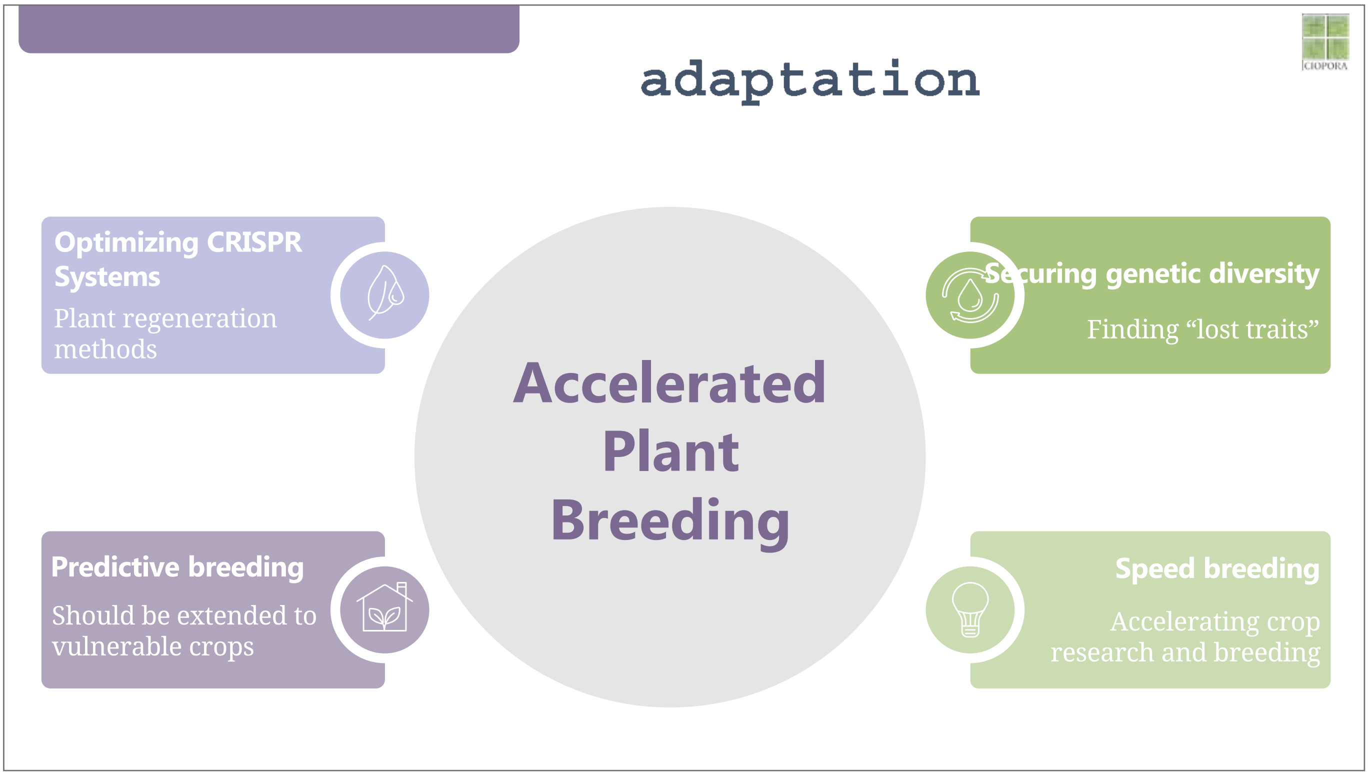
Change in seasonality
Increasing occurrence of climatic events out of season such as late-spring frosts

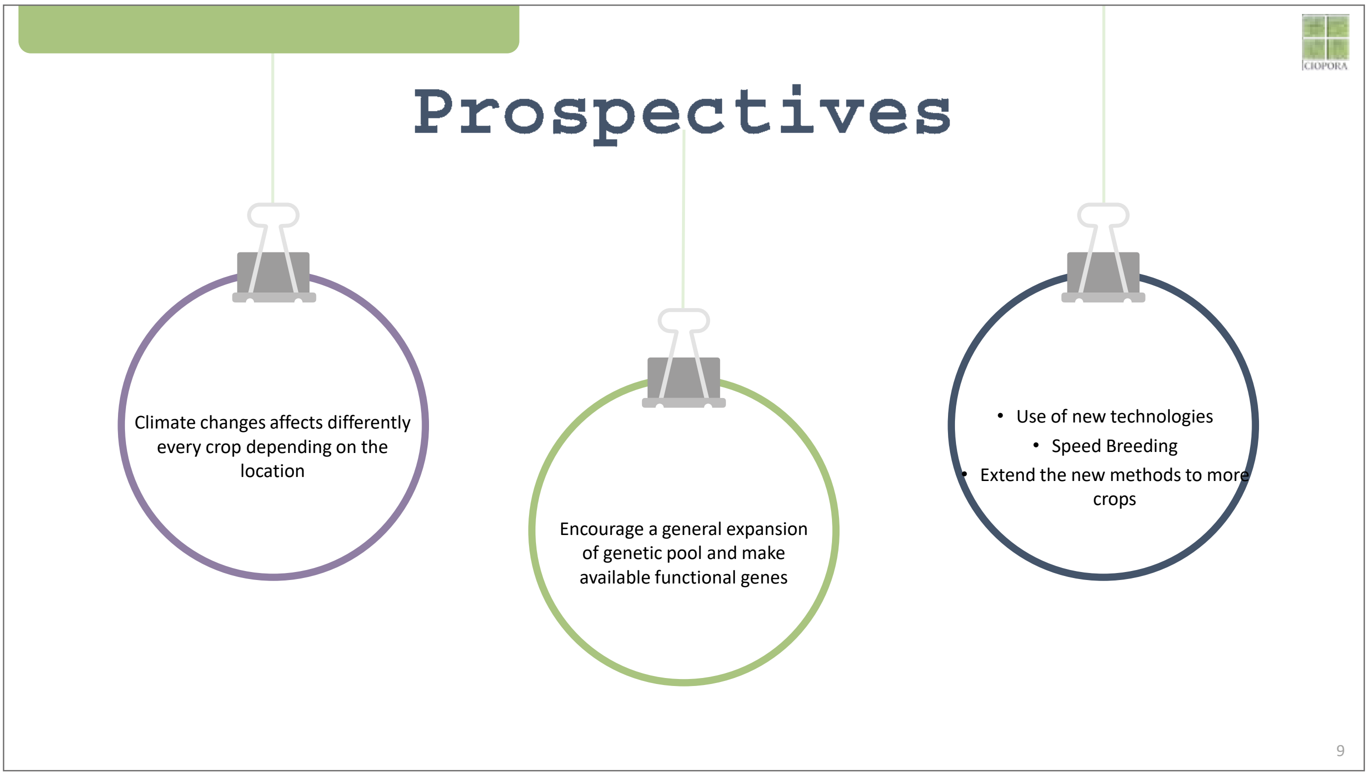
Heat stress
A combined effect of heat and water-deficit stress leading to a reduction in plant

Food insecurity
Climate change impacts agricultural production, supply chains, and food pricing




Grapevine breeding
CIOPORA


adaptation
CIOPORA
Optimizing CRISPR Systems
Plant regeneration methods
Accelerated Plant Breeding
Securing genetic diversity
Finding "lost traits"
Predictive breeding
Should be extended to vulnerable crops
Speed breeding
Accelerating crop research and breeding


CIOPORA
Prospectives
Climate changes affects differently every crop depending on the location
Encourage a general expansion of genetic pool and make available functional genes
• Use of new technologies
• Speed Breeding
• Extend the new methods to more crops
9


Thank you for your attention
CIOPORA
UNITING BREEDERS
PROTECTING INNOVATION

QUESTIONS

1) Questions after Keynote speaker: Mr. John Derera

VALSTAR Marien (Mr.), President of the Council, UPOV (moderator)

We have a few questions. I am just making the connection right now.

VAN DER HEIJDEN Stefan (Mr.), Associate, Innova Connect, Netherlands (speaker)

My name is Stefan van der Heijden. Thank you very much for your very interesting presentation. I'm just wondering, you are mentioning -- incredible yield improvements also in the future. But if you are going to breed for more resilience to unknown and unexpected adverse conditions, there will be certainly a trade-off. How do you envisage that aspect?

VALSTAR Marien (Mr.), President of the Council, UPOV (moderator)

Thank you for your question, Stefan. John?

DERERA John (Mr.), Senior Director, Plant Breeding and Pre-Breeding, Consultative Group on International Agricultural Research (CGIAR) (speaker)

Thank you so much for the question. Definitely, yes, in general, we know there is a trade-off between yield and breeding for resistance to pest and diseases but what we are looking at now is locating new breeding tools that can help us to offset that. One of the things I've shown there is the use of biotechnology through incorporation of the -new traits within high-yielding varieties already. We're also looking at pursuing other practices, such as application of genomic selection as ways of potentially increasing the yield in most crops, and I'm sure we'll be able to break the yield plateau. There's also a potential to look at genome editing as well. But most importantly, the genomic selection approach gives a better promise. Thank you.

VALSTAR Marien (Mr.), President of the Council, UPOV (moderator)

Thank you, John. And it's good to hear your optimism. There's another question still waiting.

BUCHER Etienne (Mr.), Research group leader "Crop Genome Dynamics", Agroscope, Switzerland (speaker)

Thank you very much for this very interesting presentation. You sort of already answered my question concerning new breeding technologies, but I wanted to have your input there. What do you think is the potential impact, for example, for drought resistance, or salt stress, and so on, you know, really climate change directly related stresses? What is the potential there for improving crops?

VALSTAR Marien (Mr.), President of the Council, UPOV (moderator)

John, the floor is yours.

DERERA John (Mr.), Senior Director, Plant Breeding and Pre-Breeding, Consultative Group on International Agricultural Research (CGIAR) (speaker)

So the main impact that we see in breeding for stress tolerance, especially drought and heat, we're seeing that in some areas, especially in the Sahel region, there's an expanded area where maize can be grown because of adaptation to heat and the drought. And we've also seen some increases of yield going from 5%, even to 10%. Wind-drought tolerant varieties have been grown. That's one other area. So we monitor this through the seed sales for varieties coming through the drought tolerant projects that have been undertaken during the past 10 to 15 years that we've more than doubled the amount of sales of maize seed, but going into challenging environments in Africa. Thank you.

VALSTAR Marien (Mr.), President of the Council, UPOV (moderator)

Thank you, John. There was a question by a certain Daisy, but then she took her hand down. Is that question still relevant, Daisy? If so, please, show your hand. And if not, then we will finalize this part. I don't see any hand raised by Daisy, so maybe next time, Daisy.

(2) Questions after speaker: Ms. Arianna Guiliodori (WFO)

VALSTAR Marien (Mr.), President of the Council, UPOV (moderator)

There is a question from Etienne Bucher. Etienne, the floor is yours.

BUCHER Etienne (Mr.), Research group leader "Crop Genome Dynamics", Agroscope, Switzerland (speaker)

Yes. Thank you very much for this very inspiring talk. I really enjoyed it very much. So, my main question is, so as I understood it right, the farmers want to have innovative technologies to help them for their work, so what is your message, for example, to European researchers who actually work, let's say, on genetically modified organism (GMO) technologies but cannot give this to farmers? What shall we do?

VALSTAR Marien (Mr.), President of the Council, UPOV (moderator)

Arianna, are you happy to answer that question?

GIULIODORI Arianna (Ms.), Secretary-General, World Farmers' Organization (WFO) (speaker)

So, the short answer that I can give from the farmers community to the European researchers, but let me add that we don't take any regional perspective being a global farmers voice, we tend, as a farmers community, close to researchers, as long as researchers and the scientific community is able to join forces with the producers listening to their needs and expectations. So -- and we don't choose for one option or the other. I am aware personally that, in Europe, there are particular -- a specific vision on the GMO technologies, and we don't have a position at WFO on it because it's a choice of each region and each country to regulate that. As far as we are concerned on innovation, the position of WFO, there was recently approved in the General Assembly of 2022 in Budapest, is that the way we see innovation is as an enabler, and we do work for the farmers to have the biggest and most diversified toolbox, but then it's up to them as entrepreneurs to make the right choice for what fits or does not fit with their cultural and economic environment.

(3) Questions after speaker: Mr. Edgar Krieger (CIOPORA)

VALSTAR Marien (Mr.), President of the Council, UPOV (moderator)

Looking at the time, I will only allow for one question to be asked, and I already see a hand from Stefan van der Heijden. Stefan, the floor is yours.

VAN DER HEIJDEN Stefan (Mr.), Associate, Innova Connect, Netherlands (speaker)

Yes. In general, I have to question seeing the challenges we have as a global society, what we can deliver to our customers, and that are the people in the world, with regard to breeding, and where we find other solutions, because now I have the feeling that many solutions will come from breeding. And although I'm a trained plant breeder, I have some doubts. So, sometimes I think we have to find the solution in a chain, and therefore I think we need to have a very good dialogue in the chain where we can find different solutions and where we have to focus on. So, especially from the point of view from what Edgar Krieger is telling, how can we find the solutions, and what is the point when we are looking to the smaller crops, how we can find solutions there?

VALSTAR Marien (Mr.), President of the Council, UPOV (moderator)

Thank you, Stefan. I guess that's, indeed, a very wide topic you started, and I think it will come up later also during this seminar. But Edgar, if you feel inclined to give a part of an answer, please go ahead.

KRIEGER Edgar (Mr.), Secretary General, International Community of Breeders of Asexually Reproduced Horticultural Plants perspective CIOPORA (speaker)

Thank you very much. Stefan, that is a heavy, very valid question. And I think especially for the small crops and for the small breeders, cooperation is key because we see that especially small breeders sometimes don’t have the financial means to deal with all these new technologies together. But we also see a growing cooperation of breeders who merge and join forces in companies who can apply new technologies and think that is cooperation in between the breeders but also cooperation with other parts of the added value chain, like the growers, like the lighter trade, and I think that is one of the key elements which we have to see.

VALSTAR Marien (Mr.), President of the Council, UPOV (moderator)

Okay. Thank you, Edgar. And indeed, maybe even how can we make consumers -- how can we make sure that consumers know what they’re buying because they set the whole chain also from their side into action.

THEMATIC SESSION 2:

Strategies to address climate change in agriculture

Moderator: Mr. Yehan Cui, Vice-President of the Council, UPOV

European Union strategy to address climate change in agriculture

Mr. Herwig Ranner, Team Leader – Climate change and agriculture,
Unit for Sustainable Agriculture, Directorate General for Agriculture and Rural Development (DG AGRI), European Commission

Climate change: an opportunity for innovation in agriculture
Mr. Solomon Gyan Ansah, Director of Agriculture & Head of the Seed Unit,
Directorate of Crop Services, Ministry of Food and Agriculture, Ghana

The role of plant breeding for adaptation to climate change in Mexico

Ms. Sol Ortíz García, General Director of Prospective Policies and Climate Change,
Ministry of Agriculture, Mexico

Mitigation of climate change in agriculture

Mr. Alexandre Lima Nepomuceno, Researcher,
Brazilian Agricultural Research Corporation (EMBRAPA), Brazil

Adaptation of agriculture/ farming systems to climate change: exploring genetic options

Mr. George Prah, Deputy Director, Directorate of Crop Services,Ministry of Food and Agriculture,
Queensland Alliance for Agriculture and Food Innovation, Ghana

Questions

Conclusion of the session

Moderator: Mr. Yehan Cui, Vice-President of the Council, UPOV

EUROPEAN UNION STRATEGY TO ADDRESS CLIMATE CHANGE IN AGRICULTURE

Presentation made at the Seminar

European Commission
1.134.199 follower
2 giorni •

Deal on the Climate Law!

The European Climate Law turns our European Green Deal targets into legal obligations:
- reducing net greenhouse gas emissions by at least 55% by 2030
- reaching climate neutrality by 2050

Today's deal between the co-legislators also introduces:
- a process for setting a 2040 climate target
- a commitment to negative emissions after 2050
- the establishment of European Scientific Advisory Board on Climate Change
- stronger provisions on adaptation to climate change

Climate neutrality will shape the EU's green recovery and a socially just green transition.

More here → https://europa.eu/!dn66PW

#EUGreenDeal #EuropeanUnion #ClimateAction

'Fit for 55'

On 14 July 2021, the Commission presented proposals for revision of main pieces of legislations to deliver EU's 2030 Climate Target (-55%) on the way to climate neutrality.

Targets

- Stronger ETS including in aviation
- Extending ETS to maritime, road transport, and buildings
- Updates Energy taxation Directive
- New Carbon Border Adjustment Mechanism
- Updated ESR
- Updates LULUCF Regulation
- Updated Renewable Energy Directive

Rules

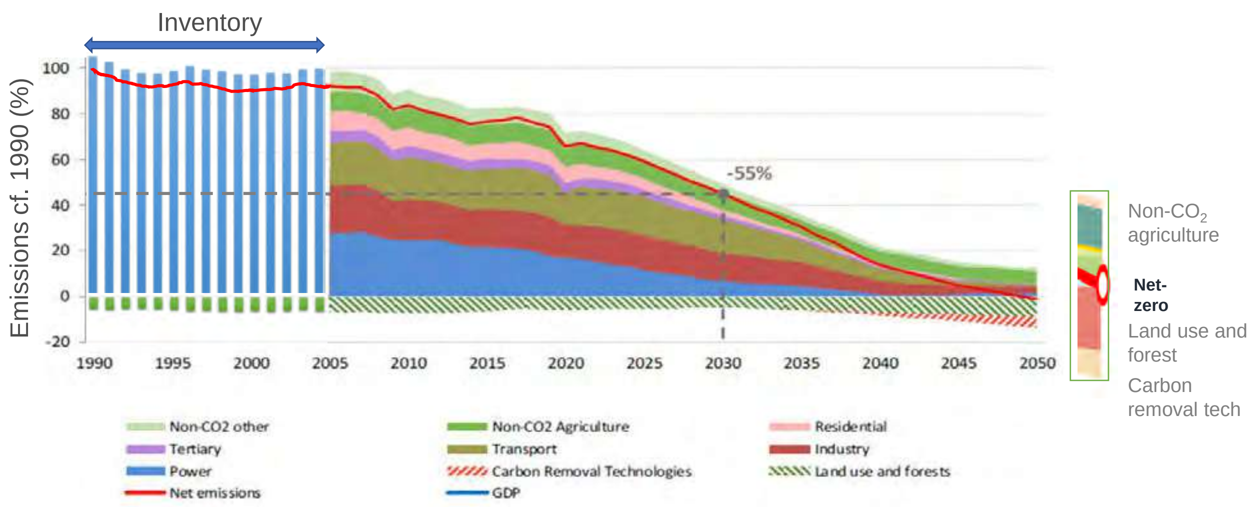
- Stricter CO2 performance for car & vans
- New infrastructure for alternative fuels
- ReFuelEU: more sustainable aviation fuels
- FuelEU: cleaner maritime fuels

Support measures

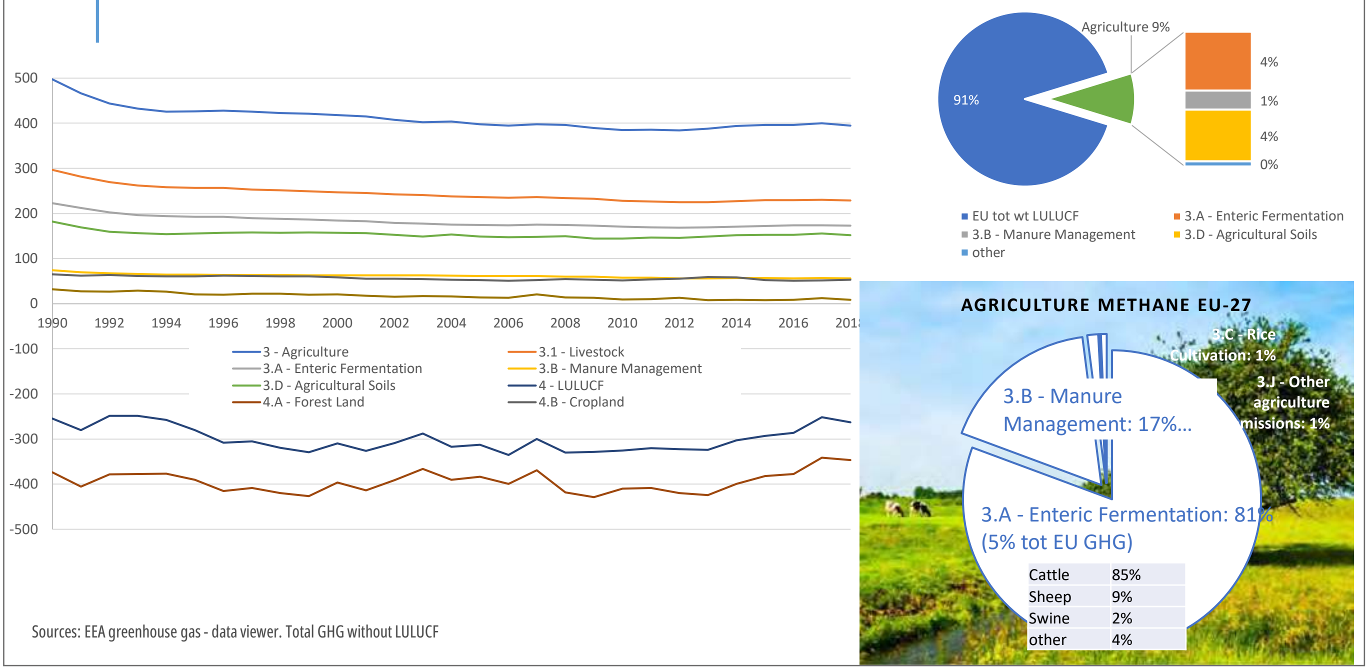
- Using revenues and regulations to promote innovation, build solidarity and mitigate impacts for the vulnerable, notably through the new Social Climate Fund and enhanced Modernization and Innovation Funds.

Pathway to climate neutrality in the impact assessment

- The impact assessment showed that 55% by 2030 can be achieved in a responsible way
- Economic growth can be decoupled from resource use
- All economic sectors should contribute



EU27 GHG emissions from Agriculture



EU strategy to reduce methane emissions

European Commission @EU_Commission · Oct 14
Methane is the second most powerful greenhouse gas contributor and an important cause of air pollution, causing serious health problems.

Our Methane strategy adopted today will be key to reduce our greenhouse-gas emissions to at least 55% by 2030.

#EUGreenDeal

Energy4Europe @Energy4Europe · Oct 14
The EU #MethaneStrategy aims to **#reducemethane** in all relevant sectors: energy ⚡ agriculture 🚜 waste 🗑 with partner countries and mobilise an international coalition to support emission reduction. #EUGreenDeal
🔹 news europa.eu/!uU86kn
🔹 factsheet europa.eu/!dV78xc

Combine concrete cross-sectorial and sector-specific actions withih EU and promoting internationally

Monitoring, reporting, verification, reduction in all sectors

Legislative proposal in 2021

Sectoral actions in the EU methane strategy – Agriculture

“balance technologies, markets and dietary changes, reduced fossil hydrocarbon inputs and that ensure a livelihood and sustainable business opportunities for farmers”

Expert group — first half of 2021
- analyse life-cycle methane emissions metrics, including new technologies and practices

Inventory of best practices and technologies — end of 2021
- in cooperation with sectoral experts, key stakeholders and Member States
- to explore and promote the wider uptake of innovative mitigating actions
- Special focus on methane from enteric fermentation
- update this inventory with technologies gradually coming onto the market

Carbon-balance calculations at farm level — 2022
- template and guidelines on common pathways for the quantitative calculation of greenhouse gas emissions and removals

Carbon farming — Starting in 2021
- promote the uptake of mitigation technologies through the wider deployment of ‘carbon farming’ in Member States and their Common Agricultural Policy Strategic Plans

Targeted research — 2021 - 2024
- Horizon Europe strategic plan 2021-2024
- consider proposing data on the different factors that effectively lead to methane emission reductions
- focusing on technology and nature based solutions
- factors leading to dietary shift
- Waste to biomethane technologies (waste sector)

Achieving the higher targets for the EU sink (LULUCF regulation)

Simpler, more transparent and effective compliance rules and targets > move to reported data

Increase EU carbon removals to at least 310 Mt by 2030 > single EU target for the sink

LULUCF 2030 target = **15% higher than the current** level of sink

Climate neutral EU land sector by 2035

Combining CO2 net removals from the land sector
- forestry
- agriculture
- peatlands
- settlements

with non-CO2 emissions
- CH4 from enteric fermentation and manure managements
- N2O from use of fertilizers and manure management

Big challenge to protect the current sink, as it has been decreasing substantially

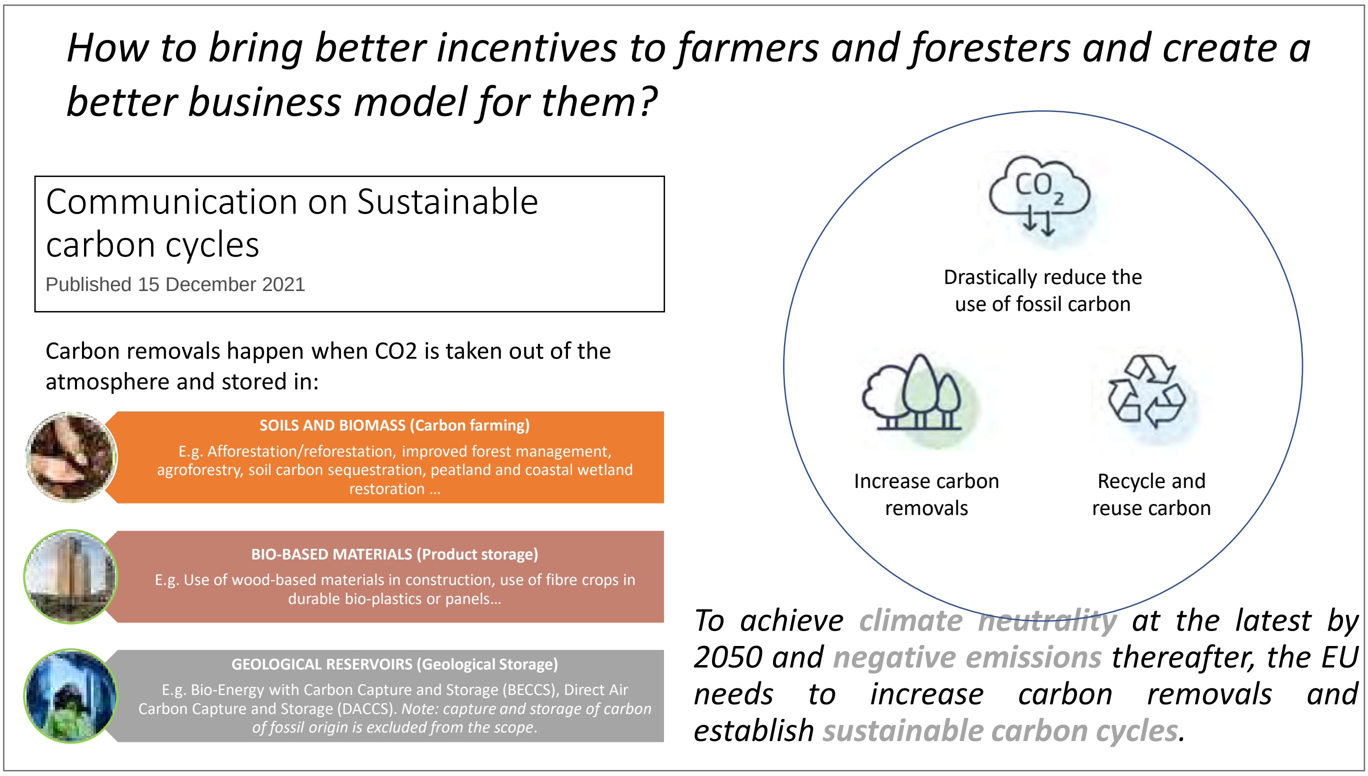
(e.g. the EU27 sink in 2013 was -324 Mt CO2eq, in less than 7 years we lost more than 62 Mt CO2eq, higher than what we need to reach 310 MtCO2eq in 10 years).

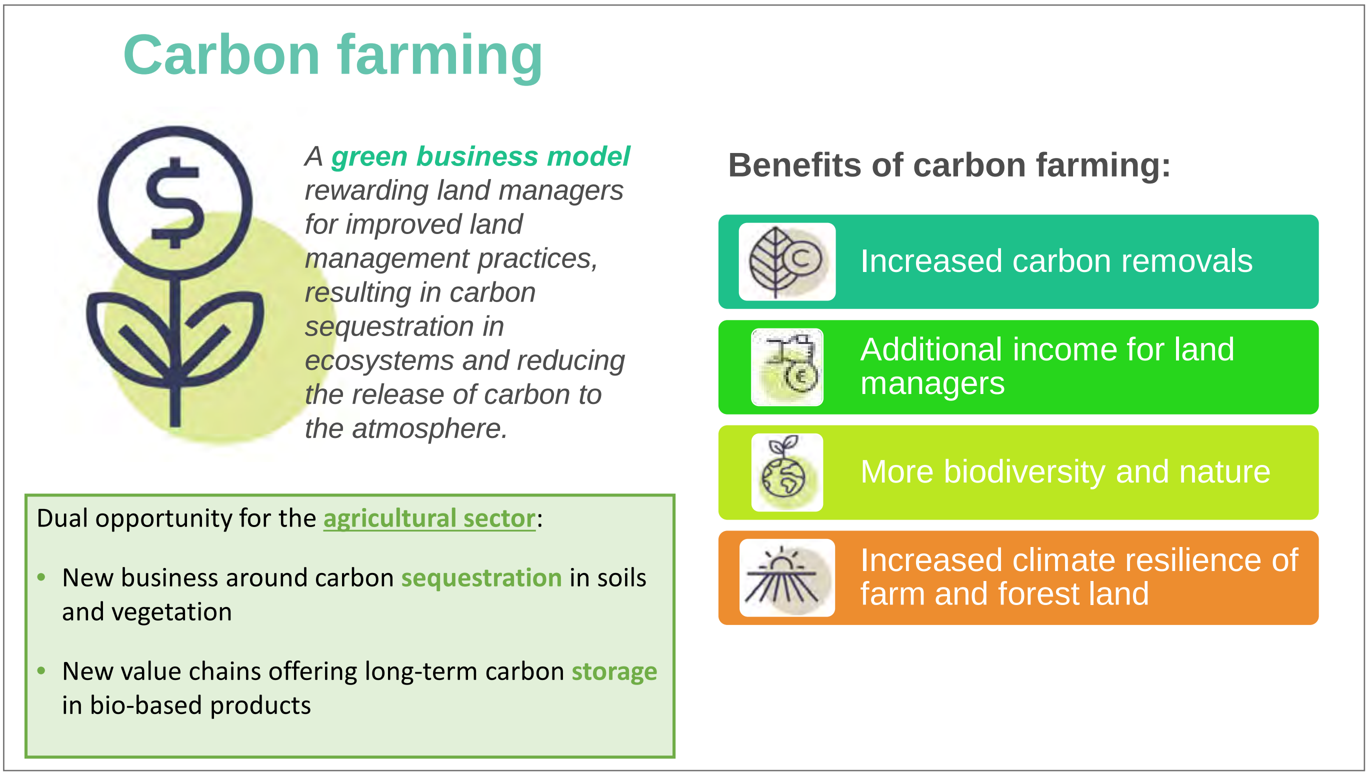
Climate neutral EU land sector by 2035

Neutrality can be reached by different **combinations** between LULUCF and non-CO2 agricultural mitigation practices.
Different mitigation potentials are related to **carbon price**.
Carbon removals with **NBS** have low mitigation costs (EUR 10 per ton).
For examples, fallowing histosols shows high mitigations already at low carbon price.

Increase net carbon removals by 20%
- Rewetting of drained peatlands
- Afforestation and reforestation
- Soil management
- Agroforestry
- Carbon Storage Products, Harvested Wood Products

Reduce non-CO2 emissions by 20%
- Precision farming
- Efficient fertiliser use
- Anaerobic digestion
- Feed additives and breeding


How to bring better incentives to farmers and foresters and create a better business model for them?
Communication on Sustainable carbon cycles
Published 15 December 2021
Carbon removals happen when CO2 is taken out of the atmosphere and stored in:
SOILS AND BIOMASS (Carbon farming)
E.g. Afforestation/reforestation, improved forest management, agroforestry, soil carbon sequestration, peatland and coastal wetland restoration …
BIO-BASED MATERIALS (Product storage)
E.g. Use of wood-based materials in construction, use of fibre crops in durable bio-plastics or panels…
GEOLOGICAL RESERVOIRS (Geological Storage)
E.g. Bio-Energy with Carbon Capture and Storage (BECCS), Direct Air Carbon Capture and Storage (DACCS). Note: capture and storage of carbon of fossil origin is excluded from the scope.
CO_2
Drastically reduce the use of fossil carbon
Increase carbon removals
Recycle and reuse carbon
To achieve climate neutrality at the latest by 2050 and negative emissions thereafter, the EU needs to increase carbon removals and establish sustainable carbon cycles.


Carbon farming
A green business model rewarding land managers for improved land management practices, resulting in carbon sequestration in ecosystems and reducing the release of carbon to the atmosphere.
Dual opportunity for the agricultural sector:
New business around carbon sequestration in soils and vegetation
New value chains offering long-term carbon storage in bio-based products
Benefits of carbon farming:
Increased carbon removals
Additional income for land managers
More biodiversity and nature
Increased climate resilience of farm and forest land

Next step

A regulatory framework for the certification of carbon removals

Call for Evidence* (Q1 2022)

Conference (31 January 2022)

Legislative proposal (Q4 2022)

Set **robust requirements** for quality criteria for monitoring, reporting and verification of the carbon removed from the atmosphere

Ensure a high level of **environmental integrity** and biodiversity protection

Enhance the **uptake** of market-based carbon removal solutions, give prospects to carbon farming and industrial projects that **invest** in carbon removals

Establish an effective **governance framework** for effective, cost-efficient and transparent implementation

Involve **stakeholders** (Call for evidence, conference, expert group)

* Inception Impact Assessment open for feedback; Open Public Consultation until 2nd May.

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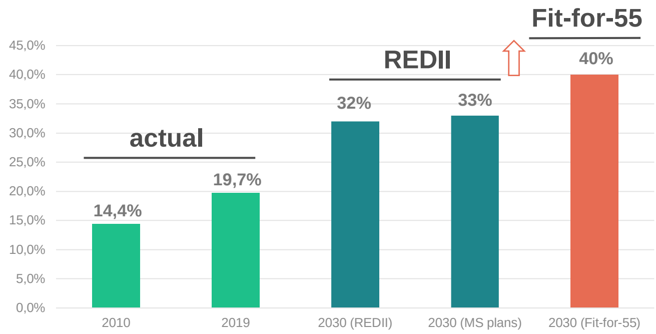
Overall ambition – the EU-level target

	REDII		REDII revision
Overall Renewable Energy Share (RES)	**At least 32%** EU binding MS contributions + indicative formula	→	**At least 40%** EU binding MS contributions + indicative formula



Bioenergy sustainability: targeted strengthening EU criteria

	REDII (enhanced sustainability criteria being implemented)		REDII revision (targeted strengtening)
Sustainaiblity criteria (no-go areas)	**Land criteria for agricultural biomass** Biodiversity/climate criteria for forest biomass (risk-based approach)	→	**New land criteria for forest biomass:** No sourcing from primary and highly biodiverse forests, peatland and wetland Minimise large clear-cuts
Application of EU bioenergy & GHG saving criteria	Only applicable to heat and power installations equal or above **20 MW** **GHG saving criteria** only for new installations	→	Application also to small-scale installations equal or above e.g. **5 MW** **GHG saving criteria** apply also to **existing** installations
Cascading principle	MS required to design support schemes with the aim of **avoiding undue distortions** of the raw material market	→	MS to minimise distortions of biomass market **No support** for saw & veneer logs, stumps/roots Delegated Act on **cascading use of biomass** From 2026, no support for installations producing electricity with forest biomass*

+
Revised ETD (different taxation rates for sustainable/non-sustainable energy sources)
Revised ETS (zero rating for biomass/biogas only if REDII compliant)
Revised Energy Efficiency Directive (EU and national energy savings obligations)

* With certain exceptions for coal regions in transition

The EU Green Deal: for a new 'green growth'

The new EU forest strategy

key objectives effective **afforestation**, and forest **preservation** and **restoration** in Europe, to help to increase the absorption of CO2, reduce the incidence and extent of **forest fires**, and promote the **bio-economy**, in full respect for ecological principles favourable to **biodiversity**.

The national strategic plans under the **common agricultural policy** should incentivise forest managers to preserve, grow and manage forests sustainably.

... plus **international dimension**

The EU as a global leader

The European Green Deal communication of 11 December 2019

> *"Building on the 2030 biodiversity strategy, the Commission will prepare a new EU forest strategy covering the whole forest cycle and promoting the many services that forests provide.*
> *The new EU forest strategy will have as its key objectives effective afforestation, and forest preservation and restoration in Europe, to help to increase the absorption of CO2, reduce the incidence and extent of forest fires, and promote the bio-economy, in full respect for ecological principles favourable to biodiversity."*

From 'Farm to Fork'
designing a fair, healthy and environmentally-friendly food system

Main targets in the Farm to Fork strategy

The use of pesticides in agriculture contributes to pollution of soil, water and air. The Commission will take actions to:

- ✓ **reduce by 50%** the use and risk of chemical pesticides by 2030.
- ✓ **reduce by 50%** the use of more hazardous pesticides by 2030.

The **excess of nutrients** in the environment is a major source of air, soil and water pollution, negatively impacting biodiversity and climate. The Commission will act to:

- ✓ **reduce nutrient losses by at least 50%**, while ensuring no deterioration on soil fertility.
- ✓ **reduce fertilizer use by at least 20%** by 2030.

Antimicrobial resistance linked to the use of antimicrobials in animal and human health leads to an estimated 33,000 human deaths in the EU each year. The Commission will **reduce by 50% the sales of antimicrobials for farmed animals and in aquaculture by 2030**.

Organic farming is an environmentally-friendly practice that needs to be further developed. The Commission will boost the development of EU organic farming area with the aim to achieve **25% of total farmland under organic farming by 2030**.

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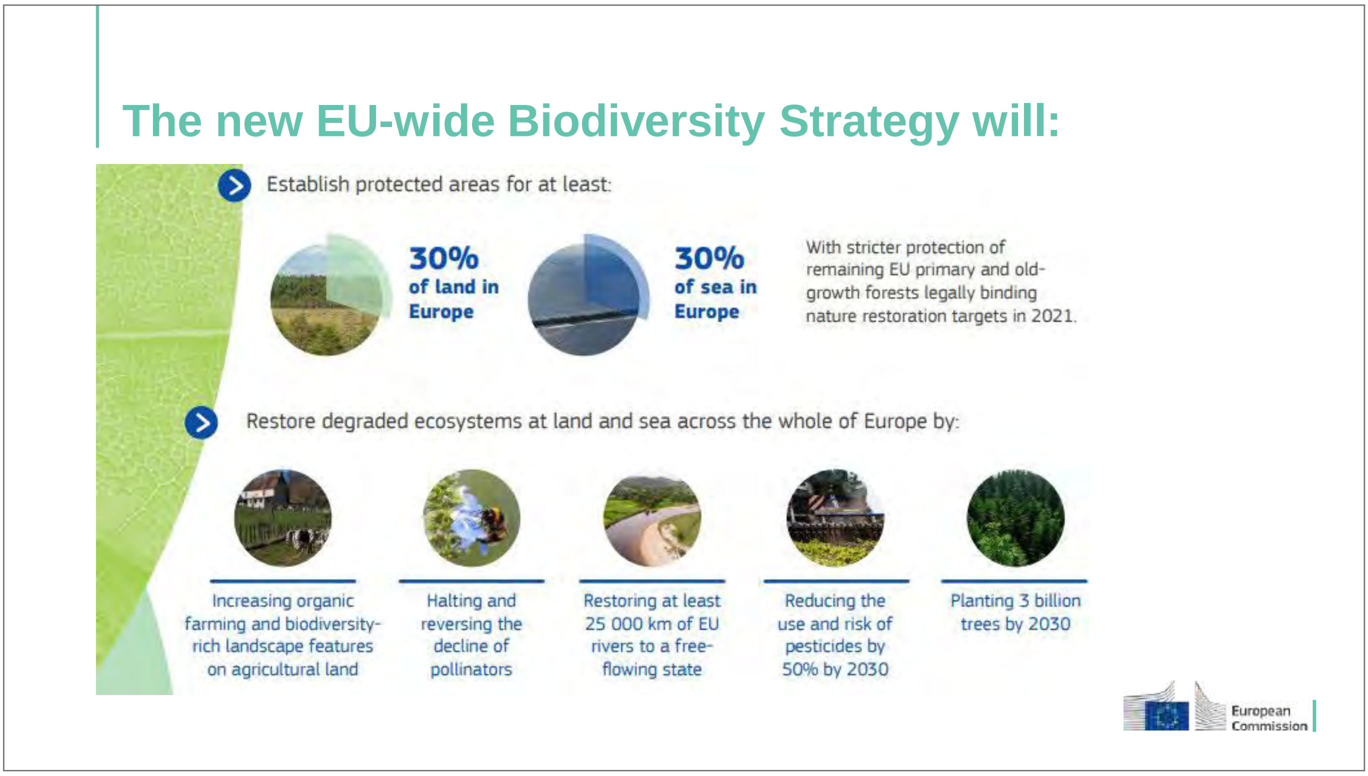
The new EU-wide Biodiversity Strategy will:
Establish protected areas for at least:
30% of land in Europe
30% of sea in Europe
With stricter protection of remaining EU primary and old-growth forests legally binding nature restoration targets in 2021.
Restore degraded ecosystems at land and sea across the whole of Europe by:
Increasing organic farming and biodiversity-rich landscape features on agricultural land
Halting and reversing the decline of pollinators
Restoring at least 25 000 km of EU rivers to a free-flowing state
Reducing the use and risk of pesticides by 50% by 2030
Planting 3 billion trees by 2030
European Commission


CAP common specific objectives
Competitiveness
Power in Food Chain
Climate Change
contribute to CC mitigation and adaptation, as well as sustainable energy
Viable Income
9 common specific CAP OBJECTIVES
Resource Management
Food and Health, Animal welfare
Cross-cutting objective KNOWLEDGE & INNOVATION
Landscapes & Biodiversity
Rural Areas
promote employment, growth, social inclusion and local development in rural areas, including bio-economy and sustainable forestry
Generational Renewal

CAP after 2020 – Increased environment and climate ambition

- Environmental and climatic objectives clearly mentioned among the objectives
- Specific indicators for climate mitigation
- CAP Strategic Plans: Higher level of flexibility, coherence of intervention to meet the needs
- Consistency with EU political priorities and national policies on the ground
- Higher level of responsibility: Result-based policy
- Requirement of no backsliding
- Wider and stronger portfolio of policy tools (conditionality and eco-scheme)
- Green Deal recommendation to MS, reinforced links with key pieces of legislation related to climate goals
- Strategic plans for the CAP
- National recovery and resilience plans

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Upscaling climate actions with CAP

Public funding opportunities :

Common Agricultural Policy

- Good Agricultural and Environmental Conditions obligations (Basic conditionality for Direct Payments):
  - preserving carbon stock (GAEC 1 - Maintenance of permanent grassland)
  - protection of carbon-rich soils (GAEC 2 - Protection of wetland and peatland)
  - maintenance of soil organic matter (GAEC 3 - Ban on burning arable stubble)
  - others
- Support to carbon farming practices through **eco-schemes** or **rural development measures** (e.g. Commission list of potential agricultural practices)
- EIP-AGRI and new Agricultural Knowledge Information System, supports cooperation and testing of new approaches
- Advisory services, knowledge exchange, training, collective and cooperation approaches and innovation actions,
- Limitations: land eligible to CAP, timeframe, administrative burdens for a robust MRV for carbon credits

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CAP Plans are built on the objectives

Under the CAP Strategic Plans (2023-2027, Regulation 2021/2115), interventions are programmed by 10 Specific Objectives

Coming CAP (2023-2027)

- (a) to foster a smart, competitive, resilient and diversified agricultural sector ensuring long-term food security; 6.12.2021 EN Official Journal of the European Union L 435/27
- **(b) to support and strengthen environmental protection, including biodiversity, and climate action and to contribute to achieving the environmental and climate-related objectives of the Union, including its commitments under the Paris Agreement;**
- (c) to strengthen the socio-economic fabric of rural areas.

Reg. 2115/2021 – art. 5

SO4: to contribute to **climate change** mitigation and adaptation, including by reducing greenhouse gas emissions and enhancing carbon sequestration, as well as to promote sustainable energy;

- *Minimum 25% of Direct Payments to be dedicated to eco-schemes*
- *Minimum 35% of the EAFRD should be dedicated to environmental and climate objectives*
- *Reinforced links with key pieces of legislation related to climate goals*
- *Impact and Result indicator (e.g. R.14 Share of agricultural area that receives support to reduce emissions or store carbon in soils and biomass)*

Other: R.17 Afforested land, R.19 Improving and protecting soils. R.34 Preserving landscape features.

The role of the CAP

- **Support the 3 pillars of sustainability**
- Integrate CAP data in the National inventories (CAP as source of data)
- Promote practices and technologies to reduce non-CO2 emissions
- Promote soil carbon protection (in grassland and peatlands)
- Promote practices for soil carbon increase in depleted soils
- Promote afforestation and agroforestry
- Promote production of sustainable biomass
- Cover upfront investments, support advisory, transation costs, innovation
- Support piloting with bottom-up innovation projects with farmers, knowledge transfer.

R&I related to carbon farming in Horizon Europe – new projects, open calls

- Topics in **WP 2022** (open until 27 September):
  - Network on *carbon farming* for agricultural and forest soils (Soil Mission, CSA, 3M €)
  - *Monitoring, reporting and verification* of soil carbon and greenhouse gases balance (Soil Mission, RIA, 14M €)
  - Demonstration *network* on climate-smart farming – boosting the role of *advisory service* (Cluster 6, CSA, 20M €)

Research lines and innovation needs

- Improve monitoring, reporting and verification (use of remote sensing, field measurements and multisectorial integrated modelling, set standards for GHG accounting systems)
- Ecosystem monitoring of GHG fluxes. Understand dynamics with future climate scenarios
- Push the reduction of emissions in the agricultural sector, with techonology mainly (to ensure food secutirty) > feed additives; small scale biodigestors, precision agriculture, sustainable fertilization, nutrient recovery, circular economy
- LCA and GHG calculators for farmers, foresters, and policy makers, labelling sustainbility
- Understand forest vulnerability (ensure biomass supply for the bioeconomy)
- Best management of peatlands and wetlands
- Carbon farming (how to reward for C sequestration), how to define C credits
- Land use modelling for land availability and land dynamic > production of non-food crops
- Enzimatic processes for the production of biofuels from lignocellulosic material
- Understand drivers of biodiversity and halt losses
- Citizen involvemnent
- Stricter link bertween research results and policy making and its implementation (EU vision).

> Science.based policy making

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Links

- Call for Evidence on Carbon Removal Certification Certification of carbon removals – EU rules (europa.eu)
- Watch the recording of the Conference on Sustainable Carbon Cycles, 31 January 2021 Sustainable Carbon Cycles Conference - About (b2match.io)
- Our webpage and our press release on the Sustainable Carbon Cycles communication
- Our webpage on Carbon Farming (europa.eu)
- Commission list of potential eco-schemes https://europa.eu/!yb74nC
- Study on Carbon Farming: https://data.europa.eu/doi/10.2834/594818
- Study on Wood in construction: https://dx.doi.org/10.2834/421958
- Legislative proposal on a new Regulation for Land use, forestry, and agriculture Delivering the European Green Deal | Climate Action (europa.eu)

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Thank you

Slide "Sustainable bioeconomy – examples": picture BECCS, source: https://www.stockholmexergi.se; picture timber in construction, source: https://www.build-in-wood.eu ; picture fiber crops, source: http://news.europeanflax.com/

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CLIMATE CHANGE:
AN OPPORTUNITY FOR INNOVATION IN AGRICULTURE

Mr. Solomon Gyan Ansah
Director of agriculture and head of seed unit, Directorate of crop services, Ministry of food and agriculture,Ghana

Climate change has moved from just a scientific subject to become an increasingly important development issue that requires focused attention by all. Globally, climate change is one of the developmental challenges of the 21st century, hence the need to intensify efforts and collaborations to address its impacts on agriculture and food systems. Global warming as a result of climate change is having devastating effects on our agriculture. Climate change is putting extreme stress on our natural resources, thus resulting in degradation of land (soils) and water resources. Some of the effects of climate change cause unexpected drought and floods which destroy our crops and livestock as well as affecting fisheries production. These effects are of concern because of the high dependence of our agriculture and food systems on climatic factors. It is therefore important to take a critical look at current climatic threats and adjust our production systems to suit the current trends of variable climatic conditions.

Climate change perhaps presents us with an opportunity. It reinforces the need to make greater progress on the transfer and dissemination of existing knowledge and technologies and to speed up the development and transfer of new innovations. Innovation is vital to build resilience and competitiveness in agriculture and to meet the urgent challenges presented by climate change. Features of innovation are divergence, curiosity, multidisciplinary (teamwork) and resilience (test, iterate, which means continuous testing). Among the various features of innovation, none requires technology. Innovation is a human-centered perspective and process. The process requires experimentation and iteration, a diverse team and a desire to learn while failing. Innovative solutions might result in a new technology, but innovation does not equal technology. Innovation can be intangible, as opposed to technology, which is tangible. You can apply the innovation process to your everyday life. Technology can be used to implement innovation, but the technology itself does not produce innovation.

Depending on the problem, innovation does not necessarily have to be complicated or require super advanced technology that perhaps cannot even be used by the target audience. It might just lead to simple solutions that were not thought or before, and can easily be applied for the benefit of our intended users.

Some of the objectives we consider for climate smart agriculture in the areas over which innovations are centered include but are not limited to:

I. drought resistance (early maturity, drought tolerant);

II. resistance to existing and new emerging diseases and pest (e.g. cassava brown streak virus, maize lethal necrotic virus disease, fall armyworm etc.);

III. nitrogen and water use efficient crop varieties.

Typical examples of innovations that have emanated from Climate Smart Agriculture (CSA) include:

I. the use of drones and advanced image data analytics which can enable the early identification of pests and diseases, while early warning systems offer information to farmers via their mobile phones that can advise them on when to plant. This reduces their risks and losses and boosts food and livelihood security;

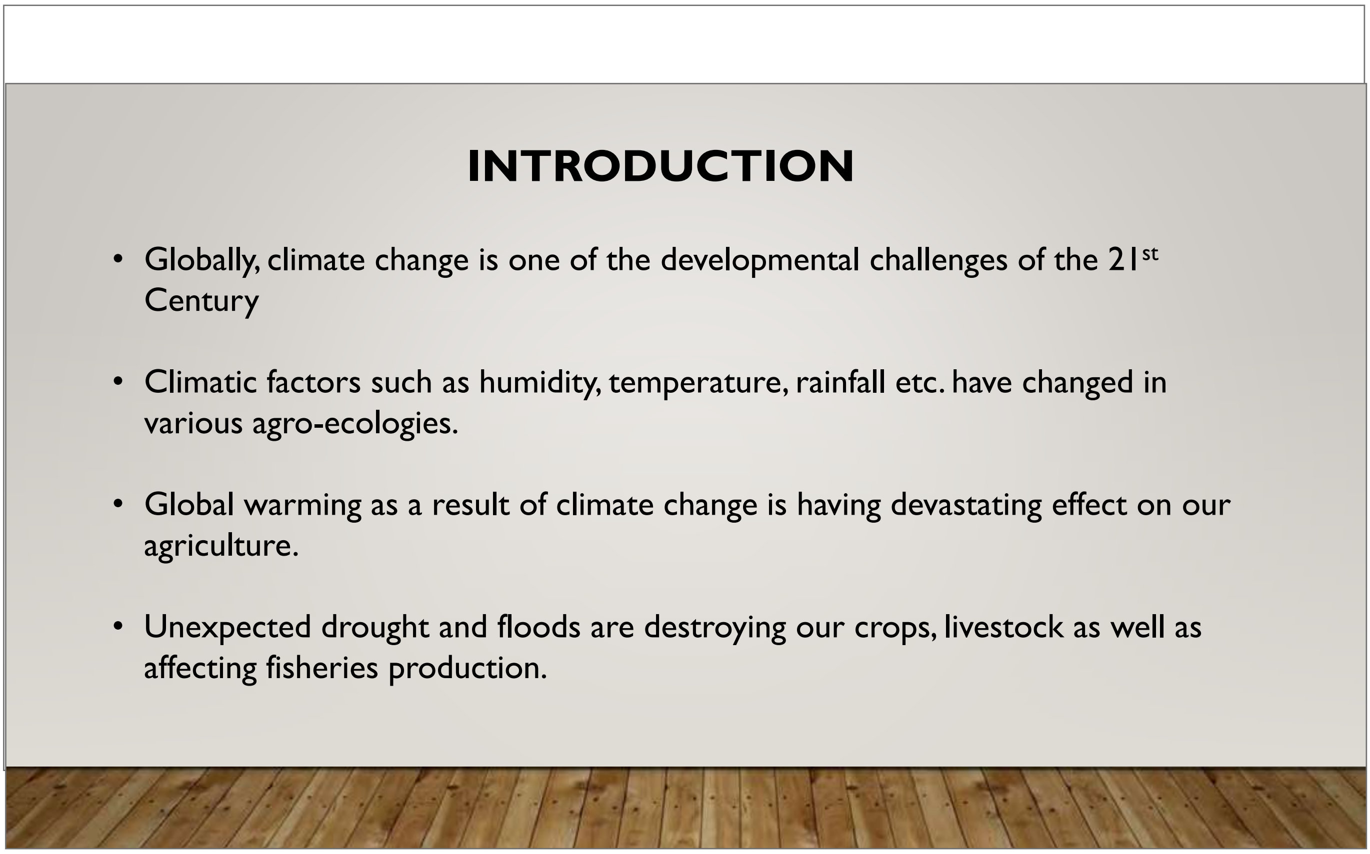
II. strengthening climate resilience by accelerating the use of agrometeorological information, improved irrigation technologies and renewable energy in food processing units;

III. distribution of improved, drought-tolerant seeds, more efficient irrigation and conservation agriculture techniques to benefit farmers.

There are, however, some constraints to innovation in relation to climate change. Some of these constraints include inadequate investment in technology and infrastructure. Additionally, the unpredictable growing conditions could hamper the farmer’s ability to assess the value of new technologies such as drought tolerance.

It is therefore recommended that research programs should be aimed at developing climate smart technologies and management methods, early warning systems, risk insurance and other innovations that promote resilience and combat climate change. In addition, there is the need for increased investments in research and development of soil testing and analysis; climate-resilient, high-yielding, disease- and pest-resistant, short-duration crop varieties, taking into account consumer health and safety. Additionally, the policy environment should be friendly for the private sector and institutions strengthened to support climate change-related innovations.

Presentation made at the Seminar



INTRODUCTION CONT'D

- Climate change perhaps presents us with an opportunity; It reinforces the need to make greater progress on the transfer and dissemination of existing knowledge and technologies and to speed up the development and transfer of new innovations.
- Innovation is vital to build resilience and competitiveness in agriculture and to meet the urgent challenges presented by climate change.
- Innovations applied to agriculture has made agriculture climate smart

SOME FOCUS AREAS WHERE INNOVATION IS APPLIED TO CLIMATE SMART AGRICULTURE

These include:

a. Early maturity, drought tolerant, Nitrogen and water use efficient crop varieties
b. Resistance to existing and new emerging diseases and pests (eg cassava brown streak virus, maize lethal necrotic virus disease, fall army worm etc)
c. Conservation Agriculture;
e. Artificial Intelligence
f. Meteorological data to predict rainfall or drought, pest evasion etc
g. Investment in irrigation and water harvesting structures

EXAMPLES OF INNOVATIONS THAT HAS EMANATED FROM CLIMATE SMART AGRICULTURE (CSA)

- The use of drones and advanced image data analytics can enable the early identification of pests and diseases.
- Early warning systems offer information to farmers via their mobile phones that can advise them on when to plant.
- The use of agrometeorological information which has strengthen climate resilience
- Improved irrigation technologies and the use of renewable energy in food processing units.
- Development of improved early maturing/drought-tolerant seeds, etc.
- More efficient irrigation and conservation agriculture techniques that benefit farmers

SOME CONSTRAINTS TO INNOVATION

- Inadequate investment in technology and infrastructure especially in the developing countries;
- Unpredictable growing conditions which can hamper farmer’s ability to assess the value of new technologies such as drought tolerance

RECOMMENDATIONS

- The policy environment should be friendly and institutions strengthened to support climate change related innovations.
- Research programs should be aimed at developing climate- smart technologies and management methods, early warning systems, risk insurance and other innovations that promote resilience and combat climate change.
- The need for increased investments in research and development of soil testing and analysis; climate resilient, high yielding, disease and pest resistant, short duration crop varieties, taking into account consumer health and safety.
- The process of innovation requires experimentation and iteration, a diverse team, and a desire to learn while failing and these process must be ongoing in the phase of climate change to come out with better innovations.

THANK YOU

THE ROLE OF PLANT BREEDING FOR ADAPTATION TO CLIMATE CHANGE IN MEXICO

Ms. Sol Ortíz García
General Director Of Policies, Prospection And Climate Change, Secretaría De Agricultura Y Desarrollo Rural, Mexico

INTRODUCTION

Plant genetic resources for food and agriculture (PGRFA) are genetic material of plant origin of actual or potential value for food and agriculture (FAO 2010). PGRFA comprise modern cultivars, breeding lines, genetic stocks, obsolete cultivars, ecotypes, farmers' varieties, landraces and weedy races, as well as crop wild relatives and wild species harvested for food (FAO 2019).

PGRFA contribute to food security by being the basic constituent of food. They contribute to nutrition both by diversified diets and with different composition of vitamins and minerals in different food plant resources. Also, planting a diversity of varieties has allowed farmers to be more readily responsive to changing market demands or environmental variations that might affect crop production, hence contributing to economic development and alleviating poverty. Crop genetic diversity also has the potential to enhance specific ecosystem functions like pollination efficiency, pest and disease control, soil processes (nutrient cycling, decomposition and erosion control) and carbon sequestration (Hajjar *et al.* 2008).

Climate change affects PGRFA in many ways, including via non-biotic factors, such as rising temperatures, changing precipitation patterns, increasing frequency of extreme weather events and rising concentration of CO2 in the atmosphere, and biotic factors, such as the emergence of new pests and diseases and changes in the virulence of existing ones. While impacts vary from crop to crop and with the location and the type of production system, there is scientific consensus that rising temperatures will be detrimental to crop production. Although PGRFA can adapt to changes in the climate via evolution, it is unclear whether this will happen quickly enough to keep up with the pace of climate change (CGRFA-18 2021). The fact that climate change affects different biological interactions, including agricultural diversity, clearly illustrates the strong interlinkages between agriculture, biodiversity and climate change.

Mexico is considered a mega-diverse country, and a center of origin and diversity of many important crops for the agri-food sector, examples of which are corn, beans, avocado, tomato and chili. Having this agrobiodiversity becomes very important in order to face the challenge of climate change in Mexico. Mexico presents high climatic variability, with a tendency to temperature increases, recurrent droughts and unpredictable rainfall.

Due to the great diversity of orographic regions, geographical conditions, weather regime and water availability, only 27% of the agricultural area in Mexico is produced under irrigation; the remaining 73% is carried out under rainfed conditions, with the risk of increasingly changing weather conditions. Native varieties are frequently used in rainfed agriculture whereas improved varieties are used in irrigated crop land.

In this context, the National Seed Policy (2020) differentiate the following types of region based on their productivity and potential:

- Regions with high productive potential with access to state-of-the-art technology, information, supplies, irrigation or very good weather, financing and seeds of improved varieties with high productive potential according to the region. In general, they have all the conditions for high productivity that have allowed their development, reaching in the last years an internationally competitive production per hectare. Such is the case of regions such as the northwest of the country (Sinaloa, Sonora, Baja California and Baja California Sur) with the production of corn, vegetables, wheat, potatoes, strawberries and other products, and also the regions of high productivity in the Bajío, the West and other targeted regions. These regions have turned the country into a producing and exporting power for some crops.

- There are other regions with lower productivity because they are subject to climatic conditions; although their conditions are generally favorable, characterized by good weather in most years, they suffer from limited access to inputs, technology and financing. In these conditions we find regions within Veracruz, Jalisco, the Bajío region, Nayarit, the center and parts of Valles Altos de Chiapas and transition zones of the states of Mexico, Puebla, Hidalgo and Queretaro.
- Regions that, although they present favorable weather conditions, for various social factors, such as land ownership and access to inputs, they have not been able to develop the productive potential of the region. Such is the case of Southeast Mexico. These regions have high performance potential, but low technology application.
- Finally, regions with a medium to unstable rain regime can be observed. In these regions, production continues to be through seeds selected from the previous harvest and mostly from native varieties, with little or no access to inputs, whose production is carried out with little technology. These regions are characterized by significant fragmentation in land ownership and a low investment power for the development of productivity. In this case, it is possible to mention localities of the Altiplano of San Luis Potosí, Aguascalientes, Coahuila, Chihuahua and Valles Altos in the center of the country, as well as regions in the southeast of the country.

MEXICO’S AGRICULTURAL CHALLENGES UNDER CLIMATE CHANGE

According to the climate stability index map, elaborated by the National Commission for the Knowledge and Use of Biodiversity of Mexico (CONABIO, 2019), with a Representative Concentration Pathway (RCP) 4.5 the most optimistic scenario, results from modeling show that the main agricultural areas in Mexico are those that will experience greater climatic variability (unpublished data from the Ministry of Agriculture and Rural Delevopment). These include different types of crops, such as cereals, vegetables and legumes, where the largest areas planted are expected to experience high climatic variability, particularly in northern Mexico, but also in the central region for vegetables and legumes, and, in the case of cereals, parts of southern Mexico.

This means that adaptation, as defined by the United Nations Framework Convention on Climate Change, (UNFCCC 2023) including adjustments in ecological, social or economic systems in response to actual or expected climatic stimuli and their effects or impacts, is needed for most of the country and for many crops.

Mexico has been considering this with regard to its public policies within the agricultural sector. For example, the Sectorial Program for Agriculture and Rural Development (2020–2024) has three main objectives: (i) to achieve food self-sufficiency by increasing production and productivity of agriculture, livestock and aquaculture-fishing; (ii) to contribute to the well-being of the rural population through the inclusion of historically excluded farmers in rural and coastal productive activities, taking advantage of the potential of the territories and local markets; and (iii) to increase sustainable production practices in the agricultural and aquaculture-fishing sector in the face of agro-climatic risks. This last objective particularly addresses the challenges faced by climate change.

The actions that are included in this Sectorial Program also contribute to the Sustainable Development Goals of the 2030 Agenda, particularly to SDGs 1 – no poverty, 2 – zero hunger, 5 – gender equality, 6 – clean water and sanitation, 12 – responsible consumption and production, 13 – climate action, 14 – life below water and 15 – life on land. And these contribute indirectly to the rest of the SDGs.

The objectives and strategic lines in this Sectorial Program have different public policy instruments for their implementation. Two are directly related to PGRFA: The National Seed Policy and the Multiannual Work Program of the Sectorial Committee on Genetic Resources for Food and Agriculture (CSRGAA).

NATIONAL SEED POLICY

The National Seed Policy (NSP 2020) aims to enhance coordinated actions between the actors involved and interested in the seed sectors (government, academia and institutions of research, seed-producing companies, associations of producers, marketers and farmers) to organize the management of the gene pool and the generation of varieties, the production of quality seed, the trade of seeds and the quality and regulations of seeds. With this, the goal is to strengthen the seed sectors and ensure the supply (regional approach and market) that the farmer requires to increase his productivity, face the challenges of climate change and soil degradation, and to be able to contribute to achieving food self-sufficiency and family welfare.

The main driver of productivity and prosperity in agriculture is research and development with a systematic transfer of innovations to production. The main element of agricultural innovation is the generation of new varieties that satisfy both the market and the needs of the farmers. First there is the need to take advantage of existing varieties that fulfill the needs of farmers. In Mexico there are more than 5,000 registered varieties in 139 crops; of these, 1,903 have plant breeders' rights, 2,396 are in the national listing the National Catalog of Plant Varieties and 110 have both types of registration. The plant varieties protected in Mexico with breeders' title originated in 26 different countries, including the United States with 36% of the registered varieties, followed by Mexico with 32% and Netherlands with 18%.

Second, Mexico is working with a differentiated policy that must consider the diversity of the country's production systems to promote the development, adoption and use of new varieties, since the country will have important agricultural production areas where climatic variability is expected to be higher and yield stability in an unpredictable and variable climate can be maintained through phenotypic plasticity, diversity within the population and traits that directly confer resistance to biotic or abiotic stresses. These are the main characteristics that breeding programs must tackle. These breeding options also consider different approaches according to the types of production systems. For commercial crops it is important to use improved varieties adapted to drought, salinity, resistance to local pests and diseases, and low soil fertility. For farmers with local landraces, it is very important to promote local seed systems, improve selection for self-consumption, develop and maintain community seed banks and facilitate participatory breeding and native seed production. Ideally, both approaches could integrate scientific, technical, local and traditional knowledge.

Third, and along with the previous two points, for the generation of varieties according to the needs of the farmers and to satisfy the demand of the markets, Mexico needs to take advantage of the public research institutions that are developing improvement programs. Public research institutions improve crop varieties where private companies do not see revenues. In Mexico these institutions generate 90% and 80% of varieties of beans and wheat, respectively. These varieties can be used by small national companies that do not have their own improvement programs.

For example, the National Institute of Forestry, Agricultural and Livestock Research (INIFAP) has the greatest number of records in the National Catalog of Plant Varieties in corn, bean and rice crops, for various regions. In the case of maize, many of the selection approaches aim to have varieties with shorter cycles, and traits that confer resistance to new pests. INIFAP also has improvement programs in 48 crops (NSP 2020). In the case of genetic improvement of vegetables, they apply different breeding strategies to increase the yield of bulb, fruit and tuber. The species that have been studied are garlic, onion, chili, tomato, potato and husk tomato. As a result of these investigations, researchers of INIFAP have 19 varieties for garlic, 10 for onion, 21 for chili, 29 for potato and 2 for husk tomato (González Pérez *et al.* 2021).

MULTIANNUAL WORK PROGRAM OF THE SECTORIAL COMMITTEE ON GENETIC RESOURCES FOR FOOD AND AGRICULTURE

The Secretary of Agriculture and Rural Development recently established the Sectorial Committee on Genetic Resources for Food and Agriculture (CSRGAA) with the aim to promote the conservation, management, fair and equitable distribution of benefits and sustainable use of Genetic Resources for Food and Agriculture (GRFA), through inter-institutional and interdisciplinary coordination in the sector. The committee contributes technical elements for the management of financial resources and national and international technical cooperation that promote the conservation, management and sustainable use of genetic resources for food and agriculture.

The CSRGAA is organized in four subcommittees: 1) genetic resources for agriculture; 2) genetic resources livestock; 3) genetic resources for fisheries and aquaculture; and 4) genetic resources for invertebrates and microorganisms. Each subcommittee includes several different stakeholders involved and interested in contributing to the main goals of the CSRGAA. In a participatory exercise their members have developed the Multiannual Work Program: genetic diversity for sustainable production, adaptation to climate change and wellbeing (MWP 2022–2024).

This MWP acknowledges the importance of plant breeding, including it in one of its seven main lines of action: 1) conservation of genetic diversity; 2) characterization of genetic resources; 3) genetic improvement; 4) technology transfer; 5) capacity building; 6) added value and sustainable use; and 7) access and distribution of benefits. These lines of action convey a sequential order, although they can also be implemented in parallel. With genetic resources that have characterization at some level, breeding programs will be developed to optimize productivity and resistance to biotic and abiotic factors, and to improve nutritional qualities, guaranteeing the maintenance of genetic diversity in end products, which have the potential to be transferred to producers for the generation of food and other products.

The National System for the Inspection and Seed Certification (SNICS) coordinates the subcommittee of genetic resources for agriculture, and is strengthening the network of germplasm banks, adding to the National Center of Genetic Resources and to different conservation centers the creation and maintenance of community seed banks that temporarily preserve local seeds. SNICS also leads a national effort for the conservation of native crops, with more than 64,000 accessions from more than 1,300 species, including crop wild relatives.

Genetic improvement programs in national research institutions still need more coordination. In general, conventional improvement is carried out and in some specific projects new improvement techniques are incorporated for breeding programs. For example, a committed group of researchers at the Center for Research and Advanced Studies (CINVESTAV) are using genomics to accelerate the characterization and improvement of strategic crops in Mexico. They already have the genome of nine species: Agave tequilana, Persea americana, Capsicum annum, Phaseolus vulgaris, Citrus aurantifolia, Zea mays, Carica papaya, Vanilla planifolia and Rubus ulmifolius. For example, in papaya, Genotyping-By-Sequencing (GBS) for domestication traits, disease resistance, abiotic stresses and fruit characteristics are being studied. Since these programs are subject to availability of public resources for their operation which have restrictions due to reallocation of funds to deal with the COVID pandemic, advances are still limited. However, this effort illustrates that breeding programs should be updated through the incorporation of innovative tools, and the linkage and coordination of all the actors of the seed area.

Adaptation to climate change through plant breeding needs to be complemented with other strategies that include in situ conservation of genetically diverse populations to allow evolution to continue and the generation of adaptive traits, and ex situ conservation to ensure the maintenance of diversity of species, populations and varieties, including those from areas expected to be highly affected by climate change.

In certain regions where beans and corn are planted, the conditions of the rainy season, soil and access to inputs are insufficient for the development of these crops. It is necessary to reconvert these regions to crops with fewer requirements, both water and inputs, to increase productivity and profitability for the farmers in these regions.

Diversified farming systems with management practices that increase diversity to increase resilience to the various effects of climate change should be implemented. For example, multi-cropping systems like milpa and milpa with fruit trees as well as agrosilvopastoral systems, crop rotation, use of cover crops and multiple varieties with a range of adapted traits. Sustainable soil management practices that also contribute to mitigation to reduce greenhouse gas emissions and enhance carbon sinks are usually also linked to adaptation, considering nature-based solutions with a watershed approach.

Finally, to achieve adaptation and mitigation to climate change there is the need to constantly generate knowledge to better understand and prepare for potential future effects of climate change. There is the need to coordinate better within and among public and private institutions, research institutions, extensionist and farmer organizations, including farmers in local communities and indigenous peoples. Fostering communication and a dialogue among involved stakeholders should contribute to more effective collaborations, connecting all the needed elements and maintaining a long-term commitment to fight against the negative effects of climate change.

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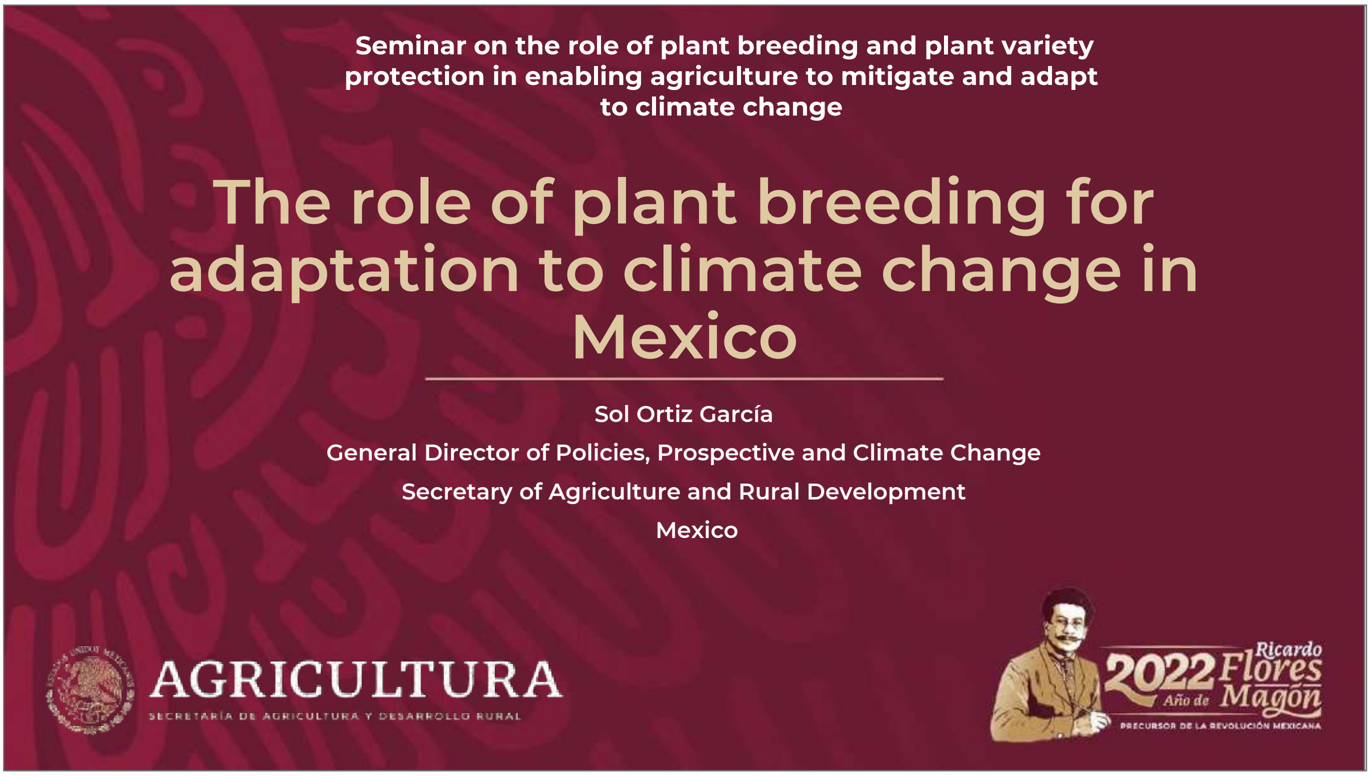
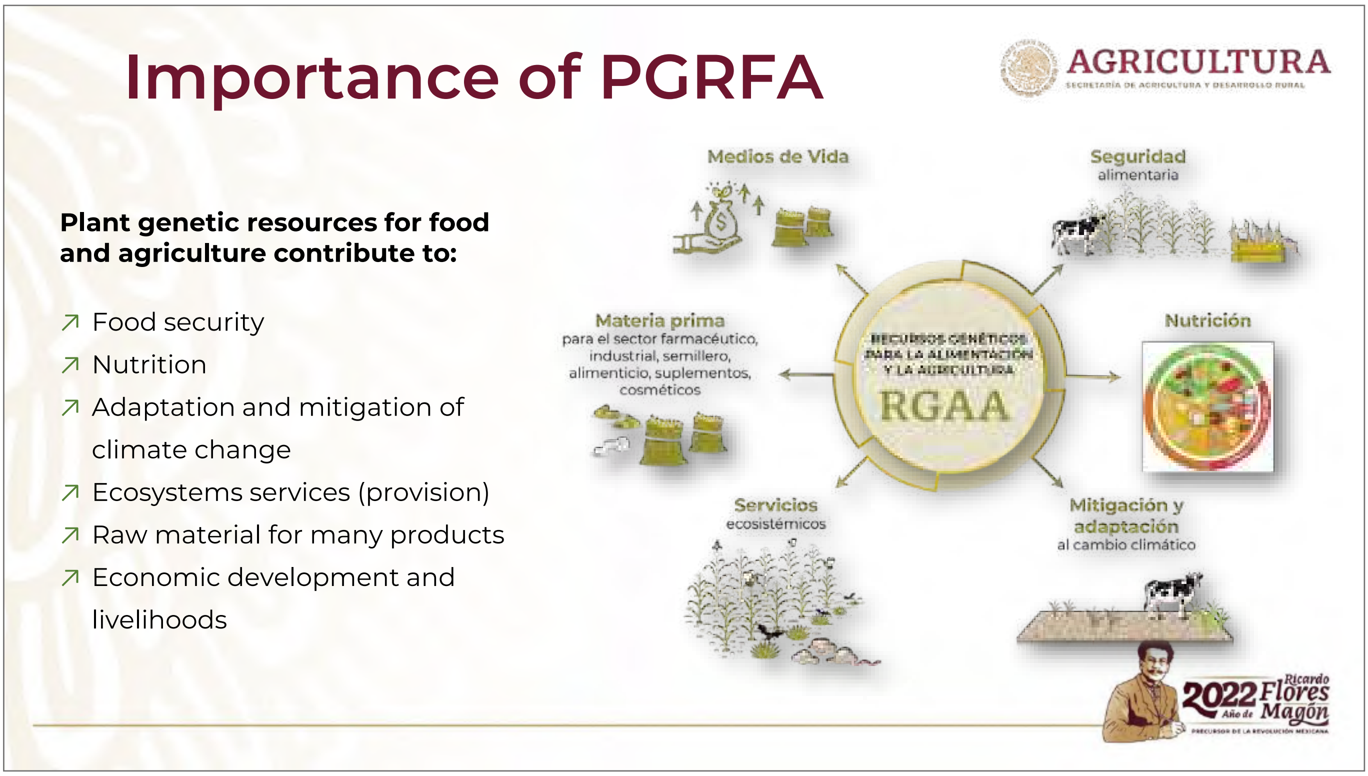
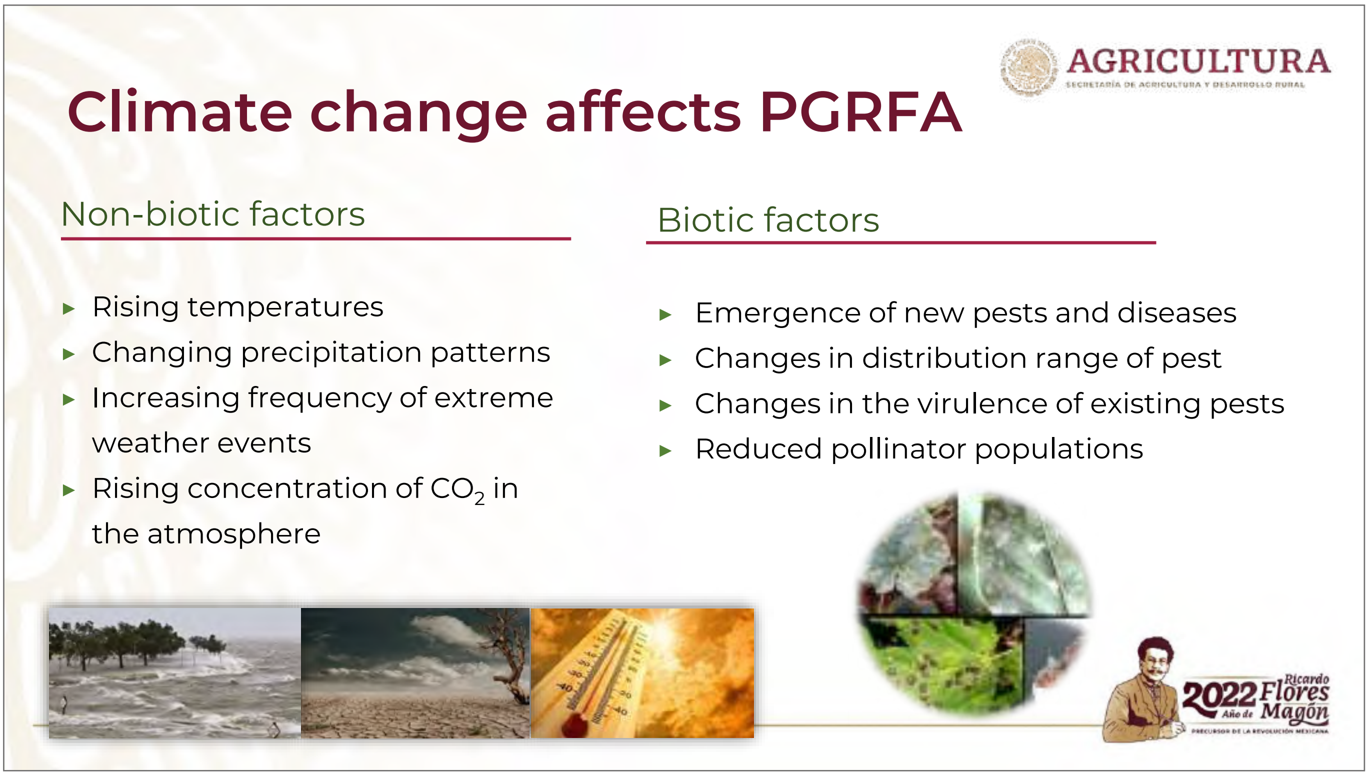
Presentation made at the Seminar






AGRICULTURA
SECRETARÍA DE AGRICULTURA Y DESARROLLO RURAL
Climate change affects PGRFA
Non-biotic factors
Rising temperatures
Changing precipitation patterns
Increasing frequency of extreme weather events
Rising concentration of CO_2 in the atmosphere
Biotic factors
Emergence of new pests and diseases
Changes in distribution range of pest
Changes in the virulence of existing pests
Reduced pollinator populations
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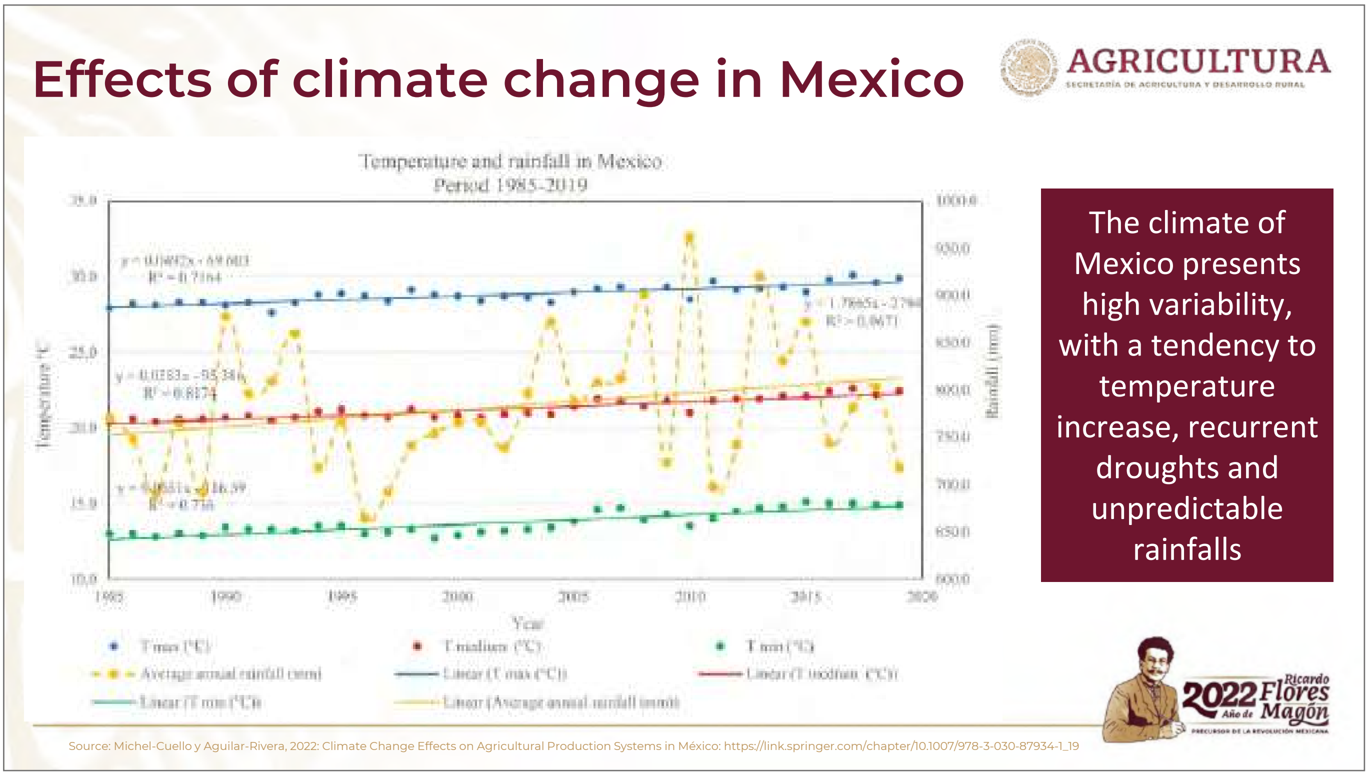
Effects of climate change in Mexico
AGRICULTURA
SECRETARÍA DE AGRICULTURA Y DESARROLLO RURAL
Temperature and rainfall in Mexico
Period 1985-2019
Temperature °C
Rainfall (mm)
Year
The climate of Mexico presents high variability, with a tendency to temperature increase, recurrent droughts and unpredictable rainfalls
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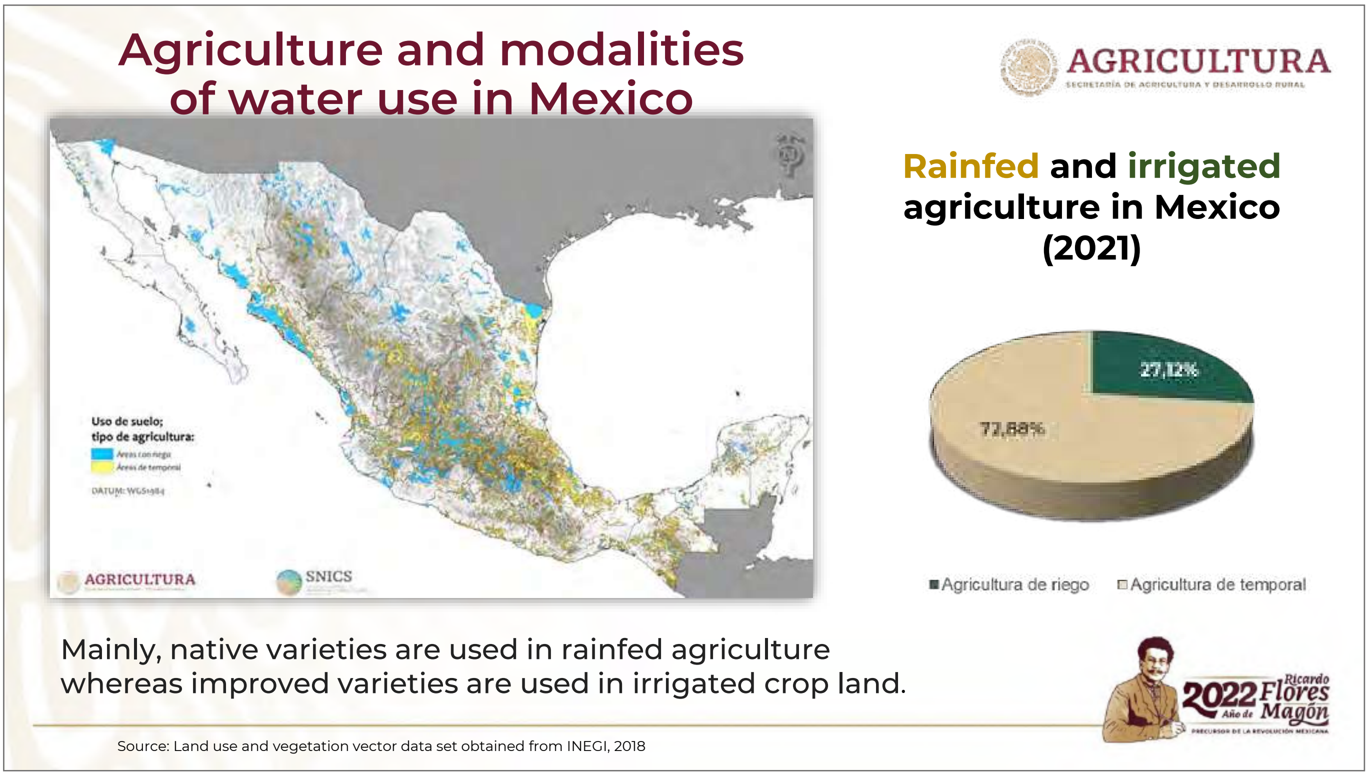
Source: Michel-Cuello y Aguilar-Rivera, 2022: Climate Change Effects on Agricultural Production Systems in México: https://link.springer.com/chapter/10.1007/978-3-030-87934-1_19


Agriculture and modalities of water use in Mexico
AGRICULTURA
SECRETARÍA DE AGRICULTURA Y DESARROLLO RURAL
Rainfed and irrigated agriculture in Mexico (2021)
Uso de suelo; tipo de agricultura:
AGRICULTURA
SNICS
27,12%
72,88%
Agricultura de riego
Agricultura de temporal
Mainly, native varieties are used in rainfed agriculture whereas improved varieties are used in irrigated crop land.
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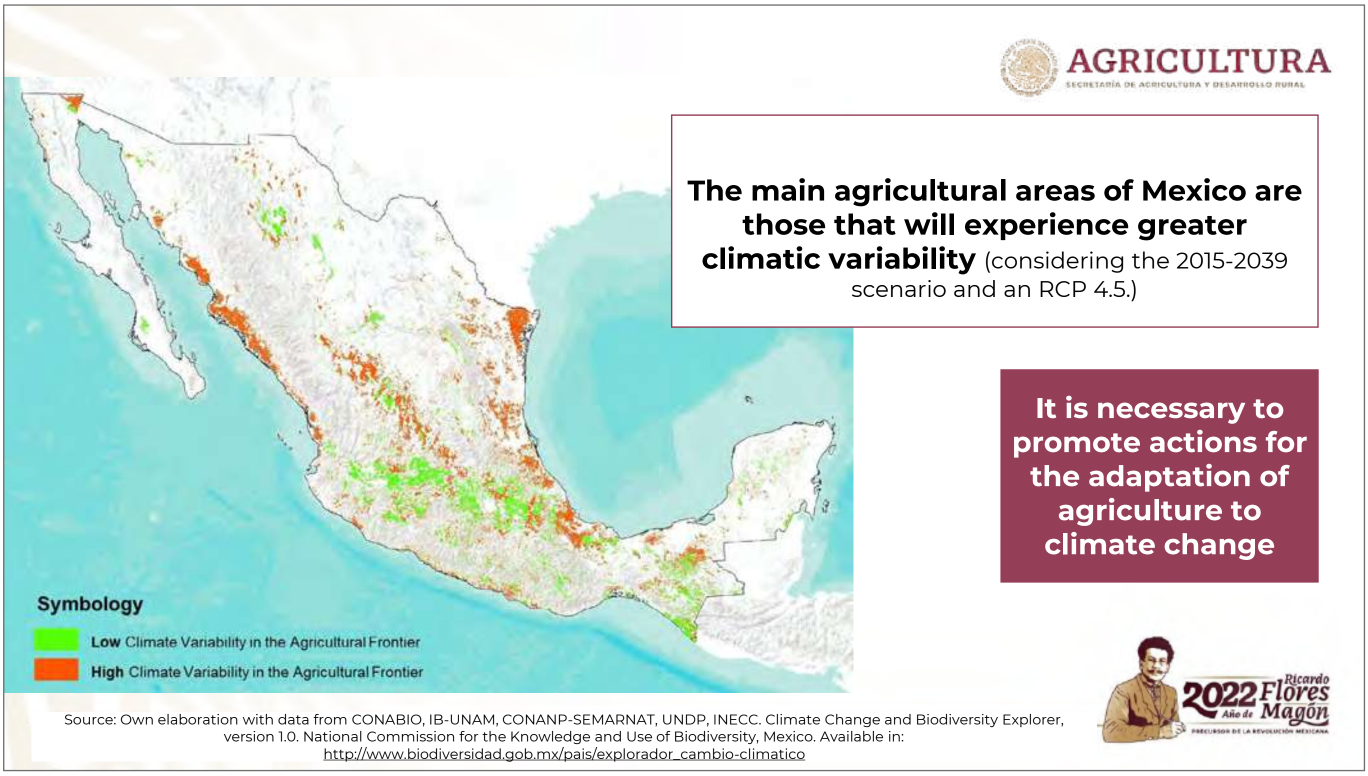
Source: Land use and vegetation vector data set obtained from INEGI, 2018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SECRETARÍA DE AGRICULTURA Y DESARROLLO RURAL
The main agricultural areas of Mexico are those that will experience greater climatic variability (considering the 2015-2039 scenario and an RCP 4.5.)
It is necessary to promote actions for the adaptation of agriculture to climate change
Symbology
Low Climate Variability in the Agricultural Frontier
High Climate Variability in the Agricultural Frontier
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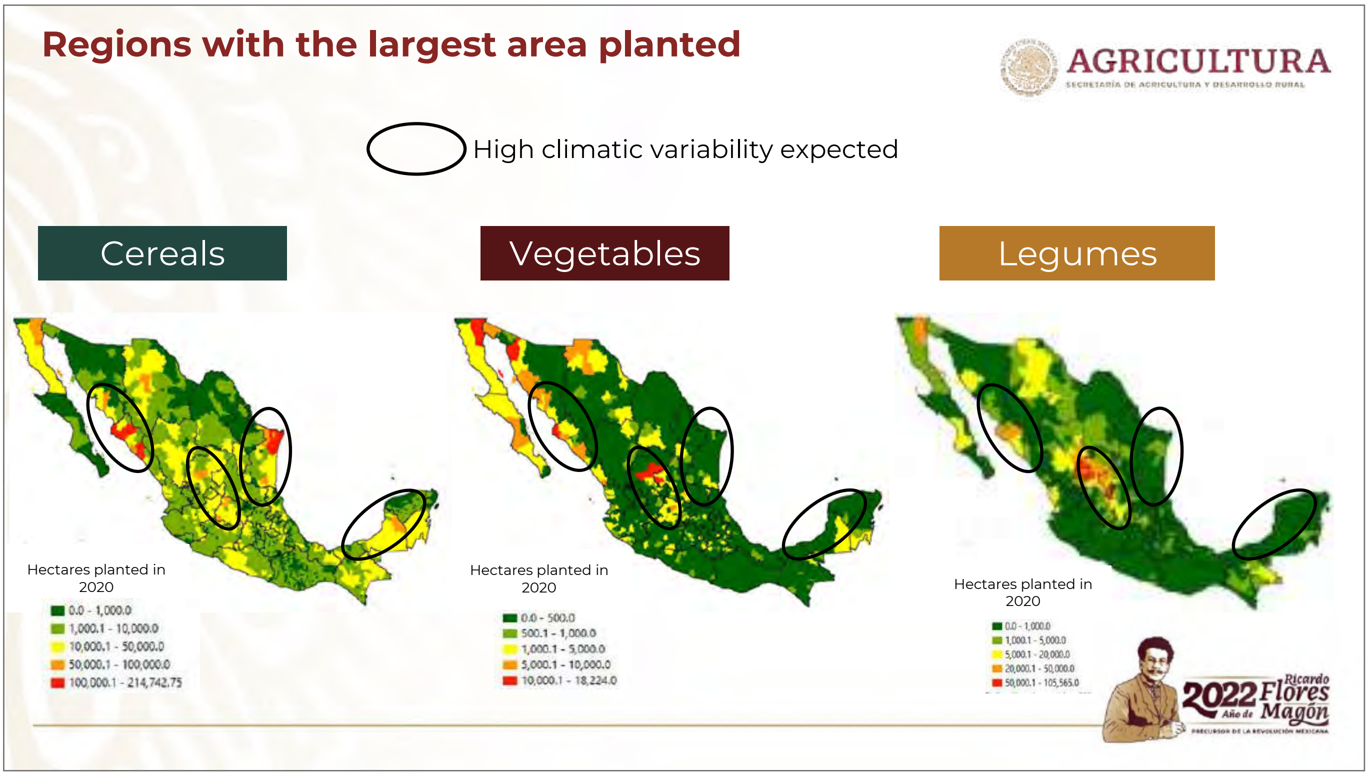
Source: Own elaboration with data from CONABIO, IB-UNAM, CONANP-SEMARNAT, UNDP, INECC. Climate Change and Biodiversity Explorer, version 1.0. National Commission for the Knowledge and Use of Biodiversity, Mexico. Available in: http://www.biodiversidad.gob.mx/pais/explorador_cambio-climatico


Regions with the largest area planted
AGRICULTURA
SECRETARÍA DE AGRICULTURA Y DESARROLLO RURAL
High climatic variability expected
Cereals
Vegetables
Legumes
Hectares planted in 2020
0.0 - 1,000.0
1,000.1 - 10,000.0
10,000.1 - 50,000.0
50,000.1 - 100,000.0
100,000.1 - 214,742.75
Hectares planted in 2020
0.0 - 500.0
500.1 - 1,000.0
1,000.1 - 5,000.0
5,000.1 - 10,000.0
10,000.1 - 18,224.0
Hectares planted in 2020
0.0 - 1,000.0
1,000.1 - 5,000.0
5,000.1 - 20,000.0
20,000.1 - 50,000.0
50,000.1 - 105,565.0
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Public policies to achieve food security
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SECRETARÍA DE AGRICULTURA Y DESARROLLO RURAL
Mexico. Sectorial Program for Agriculture and Rural Development 2020-2024
Productivity
Sustainability
Inclusion
Food self-sufficiency
1.- Achieve food self-sufficiency by increasing production and productivity of agriculture, livestock, and aquaculture-fishing.
2.- Contribute to the well-being of the rural population through the inclusion of historically excluded farmers in rural and coastal productive activities, taking advantage of the potential of the territories and local markets.
3.- Increase sustainable production practices in the agricultural and aquaculture-fishing sector in the face of agro-climatic risks.
1 NO POVERTY
2 ZERO HUNGER
5 GENDER EQUALITY
6 CLEAN WATER AND SANITATION
12 RESPONSIBLE CONSUMPTION AND PRODUCTION
13 CLIMATE ACTION
14 LIFE BELOW WATER
15 LIFE ON LAND
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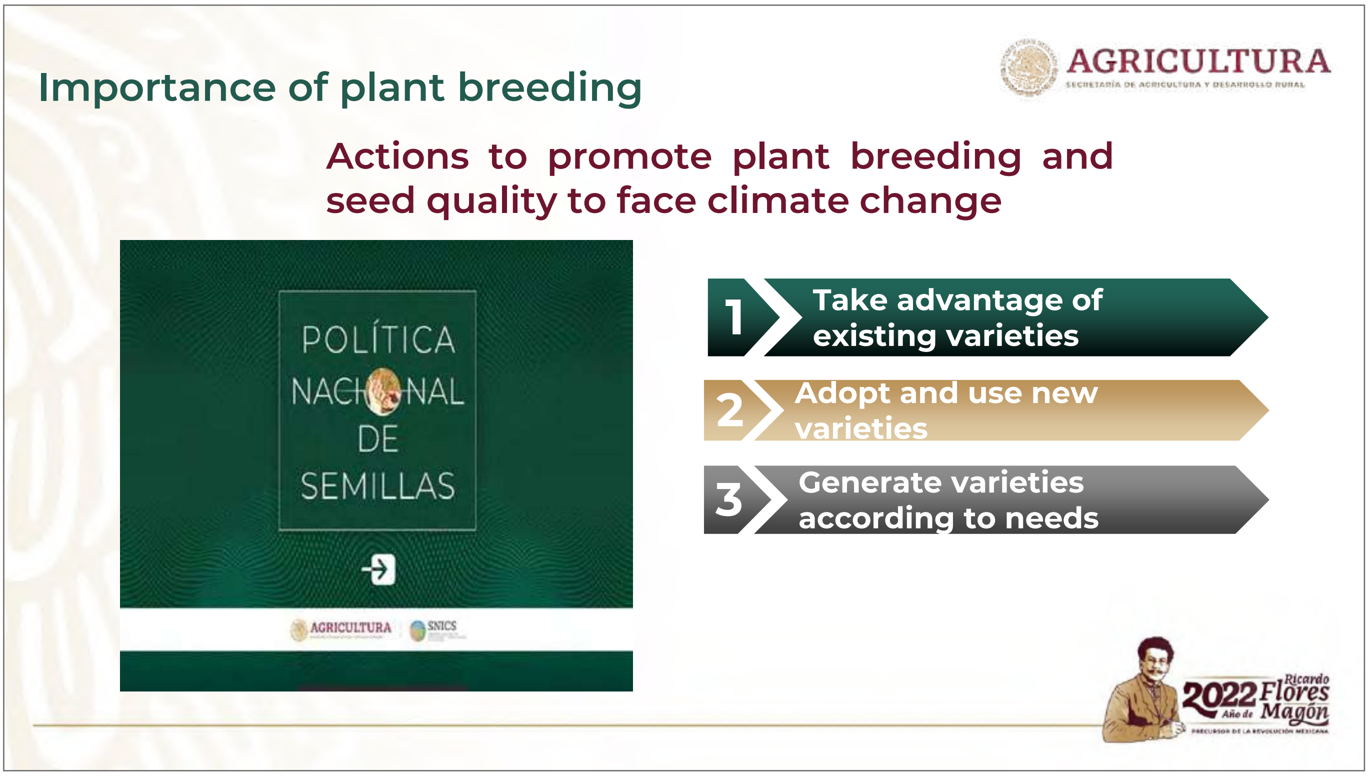
Importance of plant breeding
AGRICULTURA
SECRETARÍA DE AGRICULTURA Y DESARROLLO RURAL
Actions to promote plant breeding and seed quality to face climate change
POLÍTICA NACIONAL DE SEMILLAS
AGRICULTURA
SNICS
1 Take advantage of existing varieties
2 Adopt and use new varieties
3 Generate varieties according to needs
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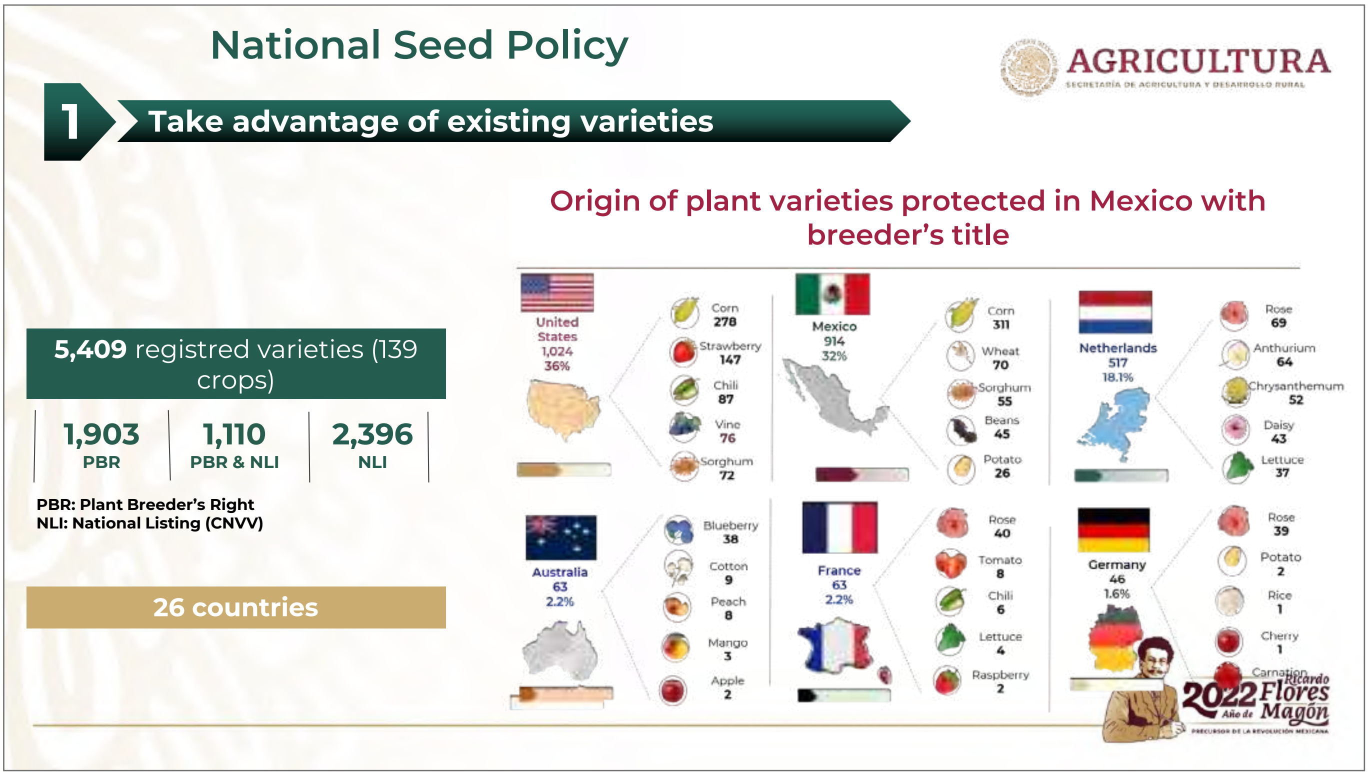
National Seed Policy
AGRICULTURA
SECRETARÍA DE AGRICULTURA Y DESARROLLO RURAL
1 Take advantage of existing varieties
Origin of plant varieties protected in Mexico with breeder's title
5,409 registred varieties (139 crops)
1,903 PBR
1,110 PBR & NLI
2,396 NLI
PBR: Plant Breeder's Right
NLI: National Listing (CNVV)
26 countries
United States 1,024 36%
Corn 278
Strawberry 147
Chili 87
Vine 76
Sorghum 72
Mexico 914 32%
Corn 311
Wheat 70
Sorghum 55
Beans 45
Potato 26
Netherlands 517 18.1%
Rose 69
Anthurium 64
Chrysanthemum 52
Daisy 43
Lettuce 37
Australia 63 2.2%
Blueberry 38
Cotton 9
Peach 8
Mango 3
Apple 2
France 63 2.2%
Rose 40
Tomato 8
Chili 6
Lettuce 4
Raspberry 2
Germany 46 1.6%
Rose 39
Potato 2
Rice 1
Cherry 1
Carnation
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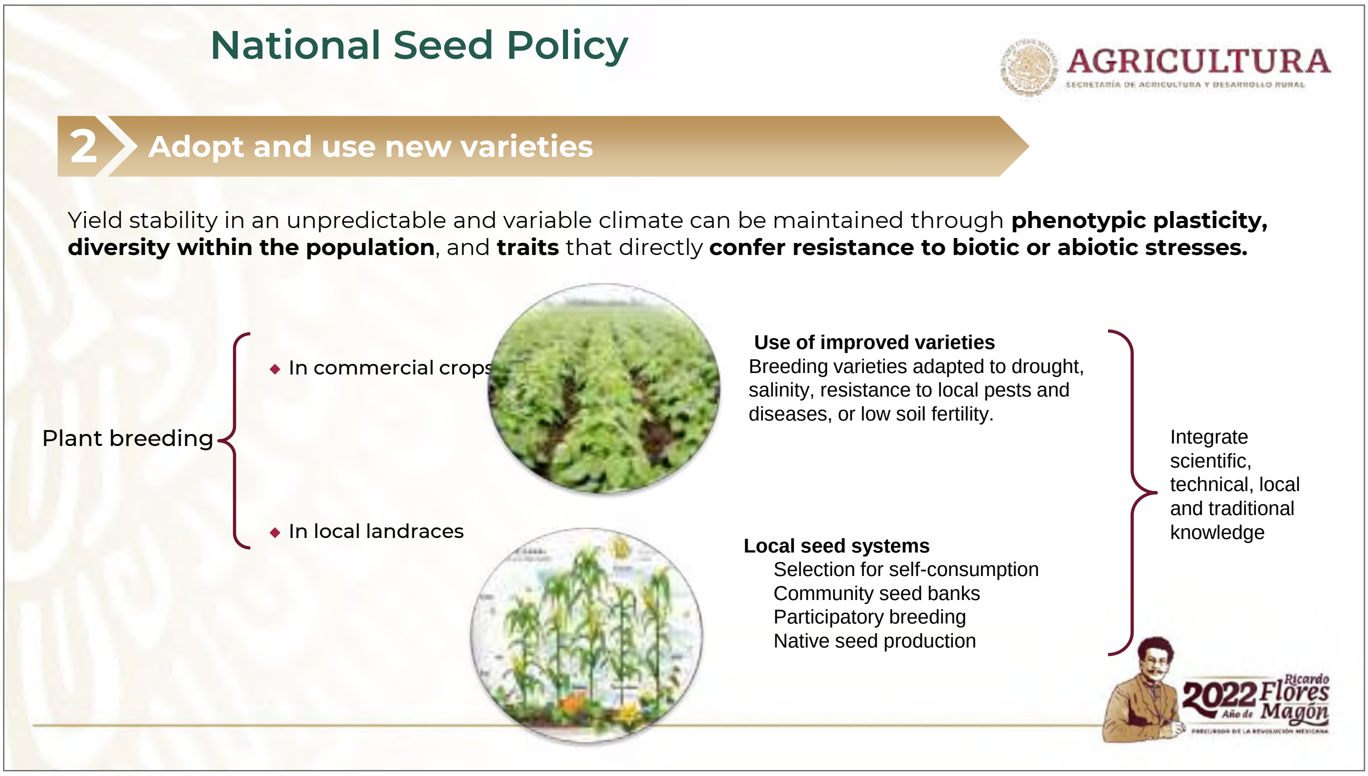
National Seed Policy
AGRICULTURA
SECRETARÍA DE AGRICULTURA Y DESARROLLO RURAL
2 Adopt and use new varieties
Yield stability in an unpredictable and variable climate can be maintained through phenotypic plasticity, diversity within the population, and traits that directly confer resistance to biotic or abiotic stresses.
Plant breeding
In commercial crops
In local landraces
Use of improved varieties
Breeding varieties adapted to drought, salinity, resistance to local pests and diseases, or low soil fertility.
Local seed systems
Selection for self-consumption
Community seed banks
Participatory breeding
Native seed production
Integrate scientific, technical, local and traditional knowledge
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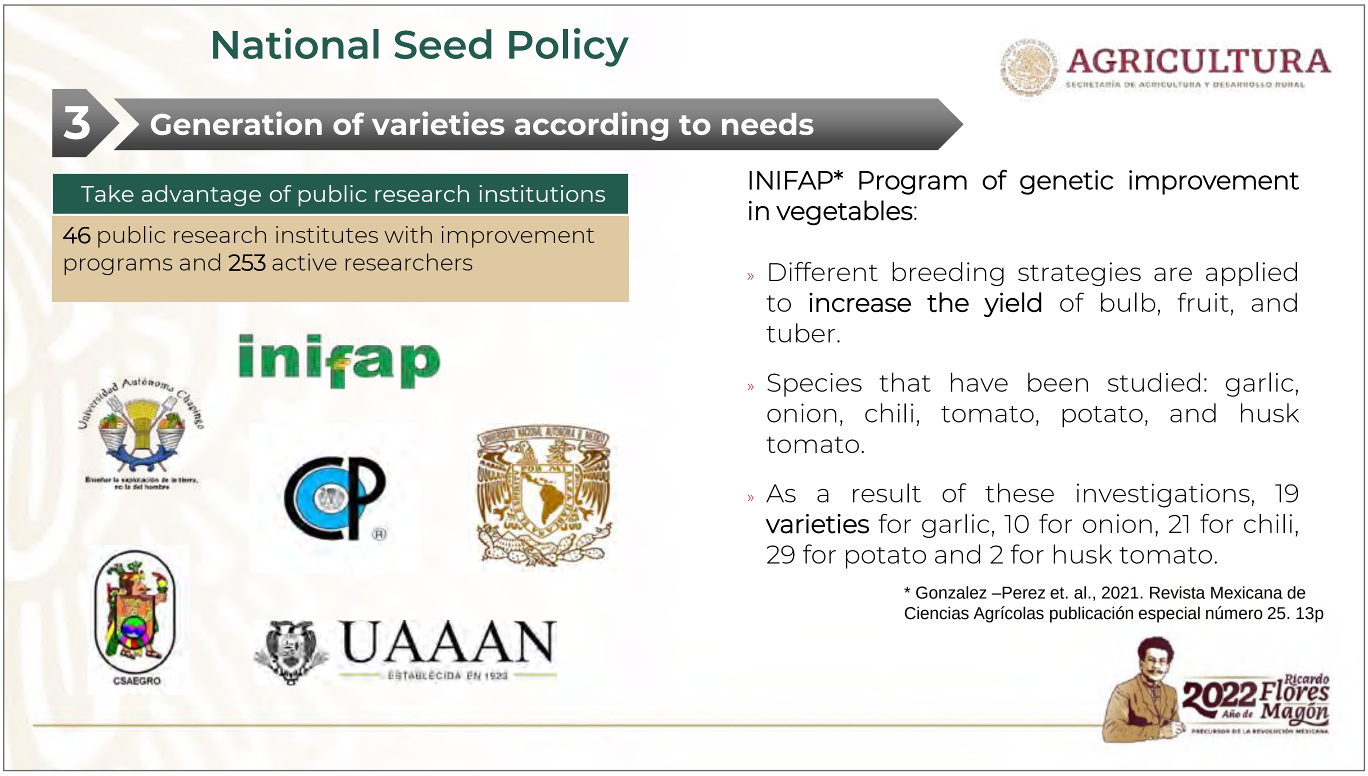
Año de


National Seed Policy
AGRICULTURA
SECRETARÍA DE AGRICULTURA Y DESARROLLO RURAL
3 Generation of varieties according to needs
Take advantage of public research institutions
46 public research institutes with improvement programs and 253 active researchers
INIFAP* Program of genetic improvement in vegetables:
Different breeding strategies are applied to increase the yield of bulb, fruit, and tuber.
Species that have been studied: garlic, onion, chili, tomato, potato, and husk tomato.
As a result of these investigations, 19 varieties for garlic, 10 for onion, 21 for chili, 29 for potato and 2 for husk tomato.
* Gonzalez –Perez et. al., 2021. Revista Mexicana de Ciencias Agrícolas publicación especial número 25. 13p
inifap
Universidad Autónoma Chapingo
CSAEGRO
UAAAN
ESTABLECIDA EN 1923
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AGRICULTURA
SECRETARÍA DE AGRICULTURA Y DESARROLLO RURAL

Creation of the Sectorial Committee on Genetic Resources for Food and Agriculture (CSRGAA)

- Legally established on July 16, 2020.
- Multiannual Work Program: Genetic Diversity for sustainable production, **adaptation to climate change**, and wellbeing.
- Consolidation of 4 Subcommittees on GRFA
  - GR Agriculture
  - GR Livestock
  - GR Fisheries and aquaculture
  - GR Invertebrate and microorganisms

General objective:

Promote **the conservation, management, fair and equitable distribution of benefits, and sustainable use of these genetic resources**, through inter-institutional and interdisciplinary coordination in the sector.

Specific objectives:

Contribute with technical elements for the management of financial resources and national and international technical cooperation that promote the **conservation, management, and sustainable use of genetic resources for food and agriculture.**

Available in:
https://www.gob.mx/cms/uploads/attachment/file/759874/Recursos_geneticos_extendido__1__compressed.pdf

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Importance of plant breeding

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SECRETARÍA DE AGRICULTURA Y DESARROLLO RURAL

Multiannual Work Program of the CSRGAA:

Line of action 1: Conservation of genetic diversity
Line of action 2: Characterization of genetic resources
Line of action 3: **Genetic improvement**
Line of action 4: Technology transfer
Line of action 5: Capacity building
Line of action 6: Added value and sustainable use
Line of action 7: Access and distribution of benefits

With the genetic resources that have characterization at some level, **breeding programs will be developed to optimize productivity, resistance to biotic and abiotic factors and to improve nutritional qualities**, guaranteeing **the maintenance of genetic diversity** in end products, which have the potential **to be transferred to producers** for the generation of food and other products.

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Sectoral Committee on Genetic Resources for Food and Agriculture (CSRGAA)

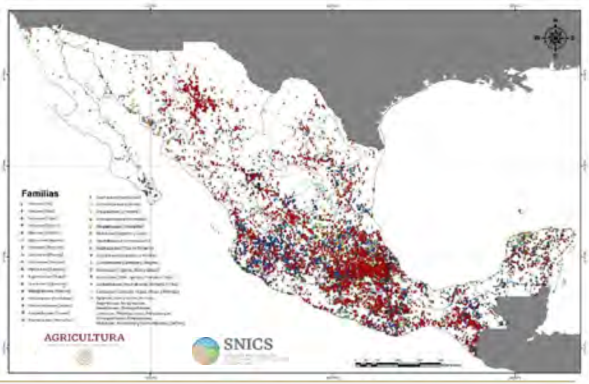
AGRICULTURA

México 2021

Conservation of GRFA:

Network of Germplasm Banks

Seed Conservation for native crops



64,000 accessions from 1,301 species

Genomes of Mexican crops

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SECRETARÍA DE AGRICULTURA Y DESARROLLO RURAL

Crop		Genome	
Common name	**Species**	**Size**	**Status**
Agave	*Agave tequilana*	2.7 Gbp	Finished
Avocado	*Persea americana*	920 Mbp	Published
Chili*	*Capsicum annum*	3. 5 Gbp	Published
Beans	*Phaseolus vulgaris*	590 Mbp	Published
Mexican lime	*Citrus aurantifolia*	350 Mbp	Finished
Maize	*Zea maize*	2.3 Gbp	Published
Papaya	*Carica papaya*	507 Mbp	Finished
Vainilla	*Vanilla planifolia*	3.2 Gbp	Finished
Blackberry	*Rubus ulmifolius*	246 Mpb	Finished

*Not generated by Mexicans

Genomics to accelerate the characterization and improvement of strategic crops in Mexico

Cinvestav
UGA - LANGEBIO

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Año de
PRECURSOR DE LA REVOLUCIÓN MEXICANA

Papaya

Cinvestav UGA - LANGEBIO

AGRICULTURA SECRETARÍA DE AGRICULTURA Y DESARROLLO RURAL

GBS for domestication traits, disease resistance, abiotic stresses, and fruit characteristics.

- **Maradol (5 accessions)**
- **Mulata (9 accessions),**
- **Red Passion (6 accessions),**
- **Intenzza (6 accessions):**
  - Biotic and non biotic stress, maturation
- **Wild relative (8 accessions):**
  - Domestication
- **Hybrids and segregants (154 accessions):**
  - Pathogen resistance (fungi, bacteria & virus), non biotic stress.
- **Other species (10 accessions):**
  - Evolution analysis and variation of genes of interest.

Wild papaya

Commercial Papaya Maradol

Wild papaya tree (Veracruz)

Domesticated papaya tree

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What else is needed for adaptation to climate change

AGRICULTURA SECRETARÍA DE AGRICULTURA Y DESARROLLO RURAL

- **In situ conservation** of genetically diverse populations to allow evolution to continue and the generation of adaptive traits;
- **Ex situ conservation** to ensure the maintenance of diversity of species, populations and varieties, including those from areas expected to be highly affected by climate change;
- **Diversified farming systems**: management practices that increase diversity tend to increase resilience to the various effects of climate change;
- **Sustainable soil management** practices that also contribute to mitigation;
- Knowledge, coordination, communication, collaboration, connection & commitment (6C).

Ricardo Flores Magón PRECURSOR DE LA REVOLUCIÓN MEXICANA


¡Thank you!
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2022 Año de Ricardo Flores Magón
PRECURSOR DE LA REVOLUCIÓN MEXICANA

MITIGATION OF CLIMATE CHANGE IN AGRICULTURE

Mr. Alexandre Lima Nepomuceno
Researcher, Brazilian Agricultural Research Corporation (EMBRAPA), Brazil

Ms. Liliane Henning
Researcher, Brazilian Agricultural Research Corporation (EMBRAPA), Brazil

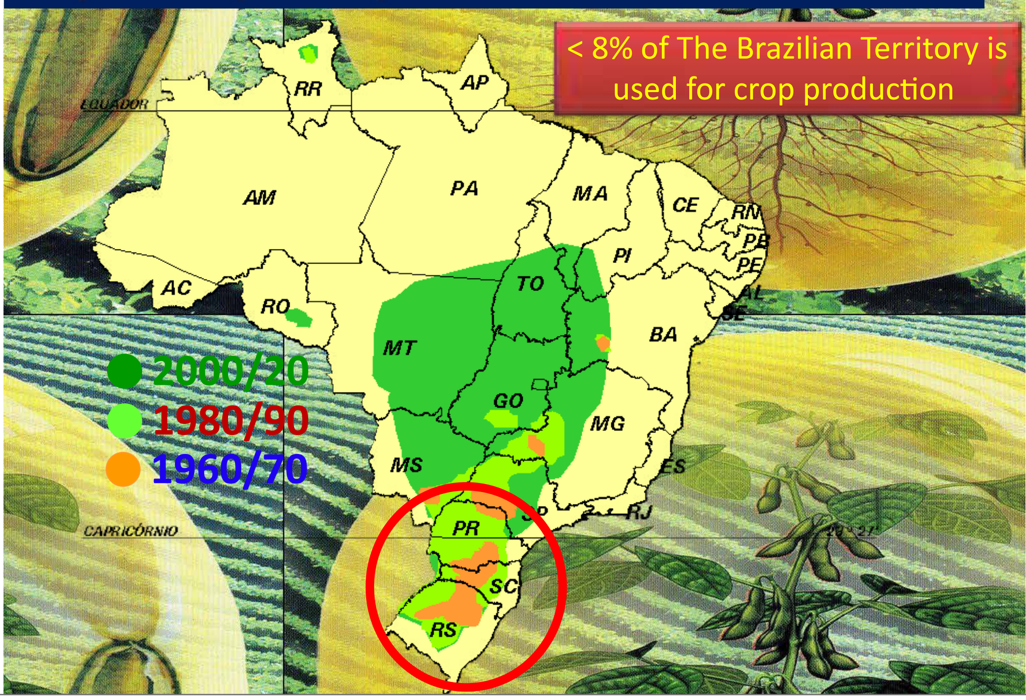
Brazil is a major food and agriculture related goods producer in the world, and one of the few that could considerably increase its production in the next decades. It has also great potential to become the leading biofuels producer and supplier. Differently from most developed countries, where agro-energy production may compete with food production, Brazil can incorporate more than 50 million hectares from degraded pasture areas to increase agricultural production, without new deforestation and reconversion of food-producing areas. However, like other countries, Brazil is affected also by the problems climatic changes cause on the planet. The Brazilian Agricultural Research Corporation (Embrapa) is developing drought-tolerant soybean lines based on information from molecular studies involving model plants to help mitigate the problem. We also searched the soybean genome for genes conferring drought tolerance to elucidate the mechanisms regulating the identified genes. Based on our findings, we generated new soybean lines, which have been evaluated under greenhouse and field conditions to identify the most drought-tolerant lines. Additionally, we determined combinations of drought-tolerance genes and promoters and introduced these combinations into soybean cells using Agrobacterium tumefaciens-based methods. We evaluated the stress tolerance of the resulting transgenic plants in the greenhouse and in the field, observing that some transgenic soybean lines exhibited increased drought tolerance. These lines may be useful for mitigating the effects of climate change. The generated transgenic soybean lines may help stabilize or increase soybean production in Brazil. Those plants are transgenic and, because of that, costs to deregulate and place the varieties on the market in different countries are very high, and practically prohibitive. However, in the last 10 years, new genome edition tools were developed that allow us to replicate some of the transgenic soybean results without the necessity of a gene from another specie. In many countries, including Brazil, genome-edited plants, on a case-by-case basis, will not be considered transgenics. While biosafety is preserved, the costs to develop a commercial variety can drop around 40–60%. Thus, many institutions like Embrapa are changing from transgenesis strategies to genome edition strategies so the use of biotechnology in agriculture can become more democratic again. Although the use of transgenesis is still a very important tool to help mitigate problems caused by climatic changes, unfortunately, because of the costs, only a few companies can develop commercial varieties using it.

Presentation made at the Seminar

Embrapa

Brazilian Agricultural Research Corporation

Soybean (Grain) Evolution in Brazil: 2014



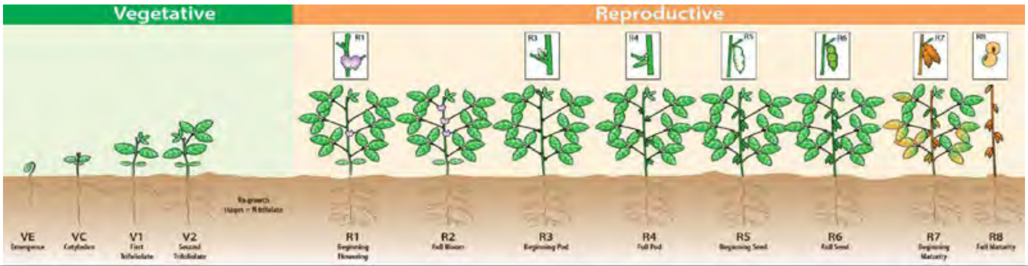
Harvest Season 2021/22
Biggest Drought of the last 93 years

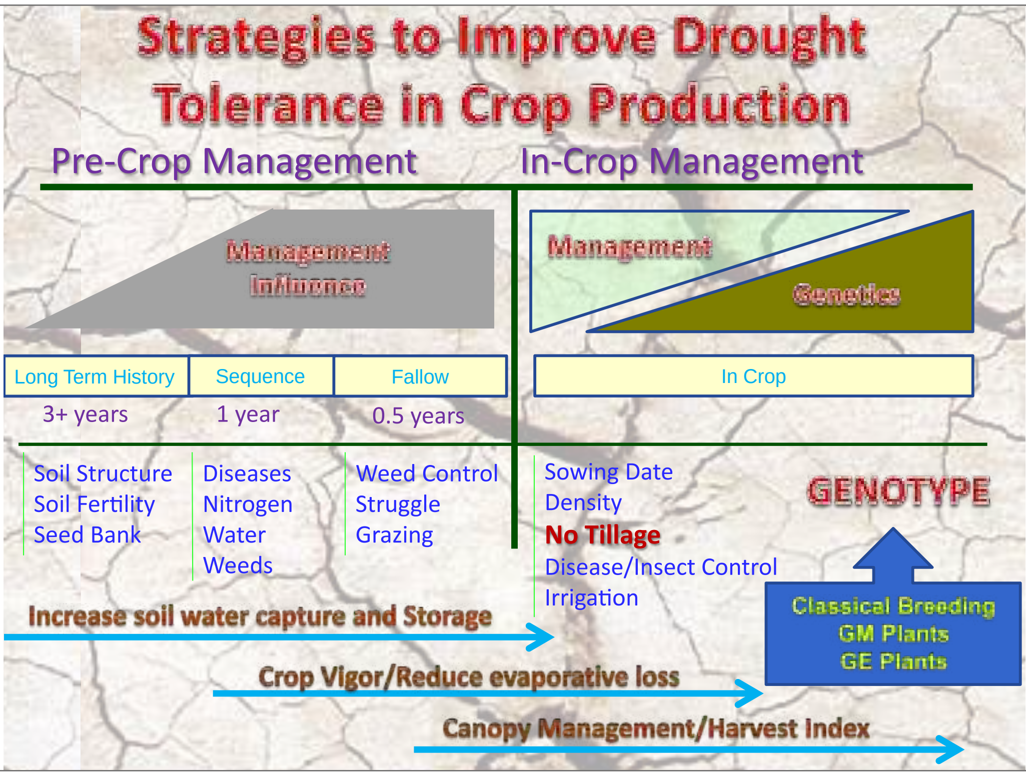
State	Productivity (Ton/ha)		Losses (Ton/ha)	Sowed Area (ha x million)	Losses (U$ billion)
	Expected	Actual			
RS	3,300	1,620	-1,680	6,4	6,07
SC	3,480	2,880	-600	0,7	0,24
PR	3,660	2,040	-1,620	5,7	5,23
MS	3,600	2,520	-1,080	3,5	2,20
					↓ 13,74

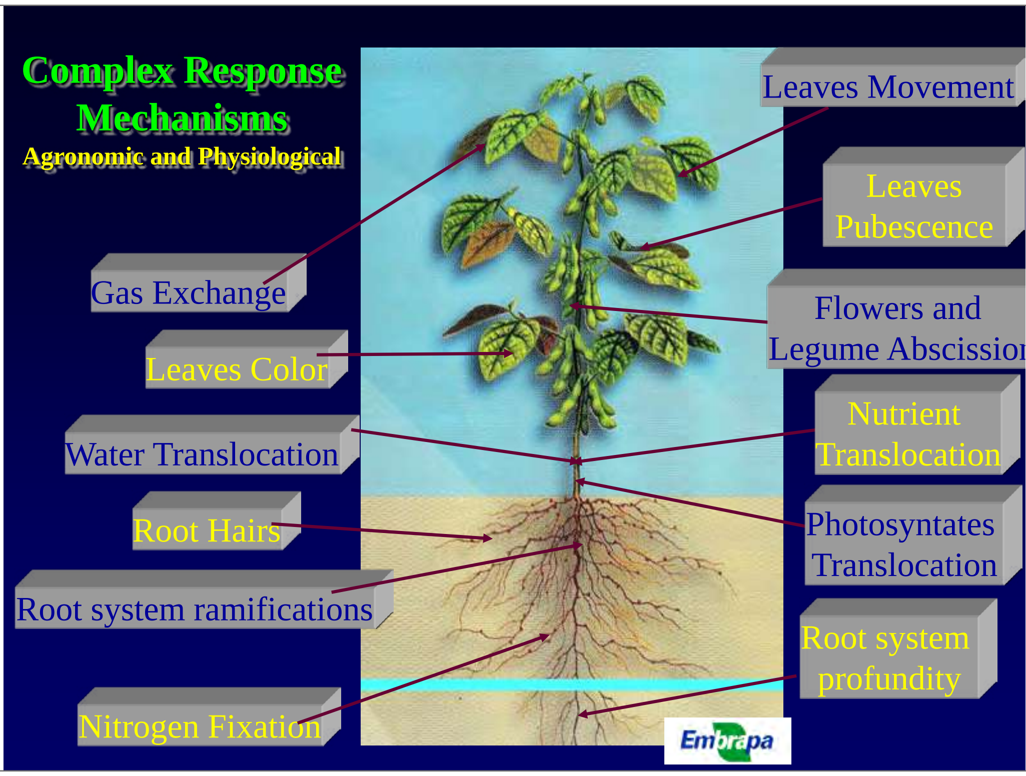
Source: Embrapa Soybean, 2022

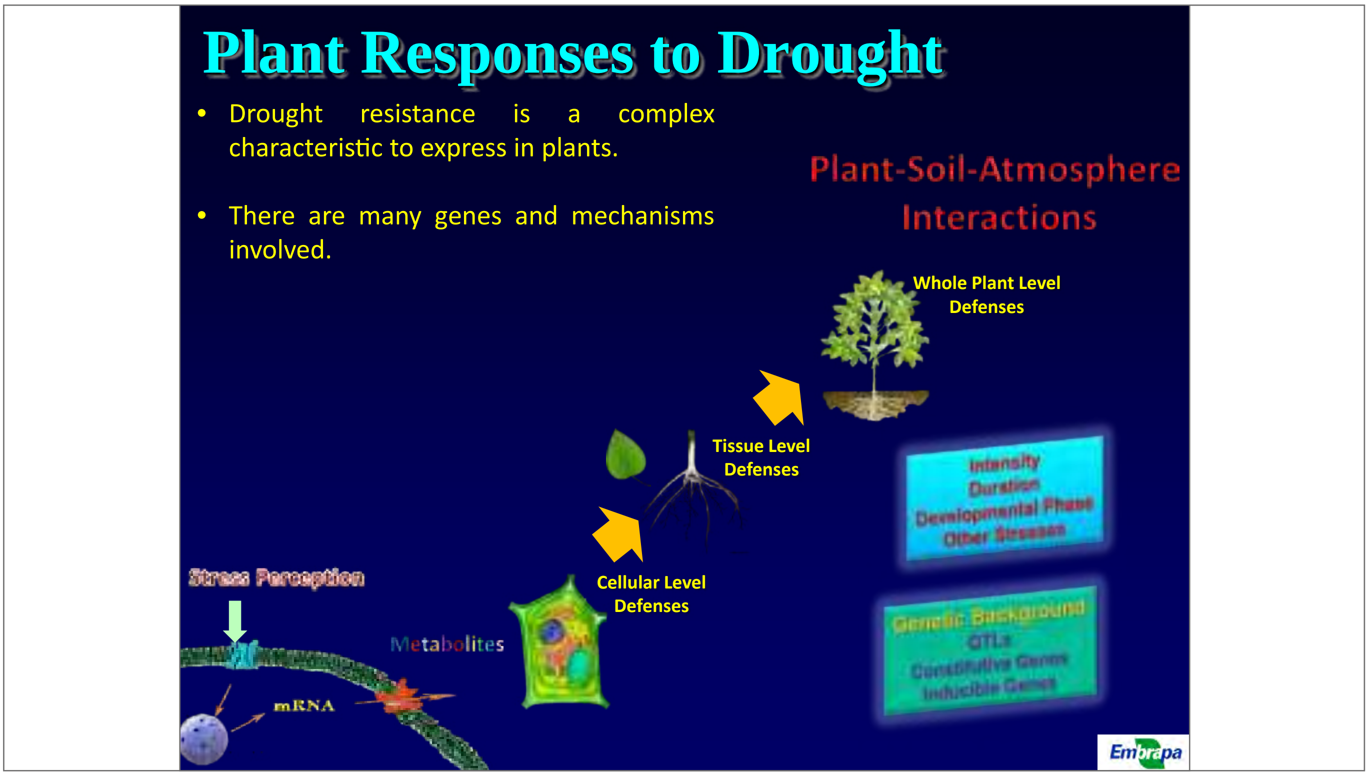
Drought
High unpredictability and high level of economical damage

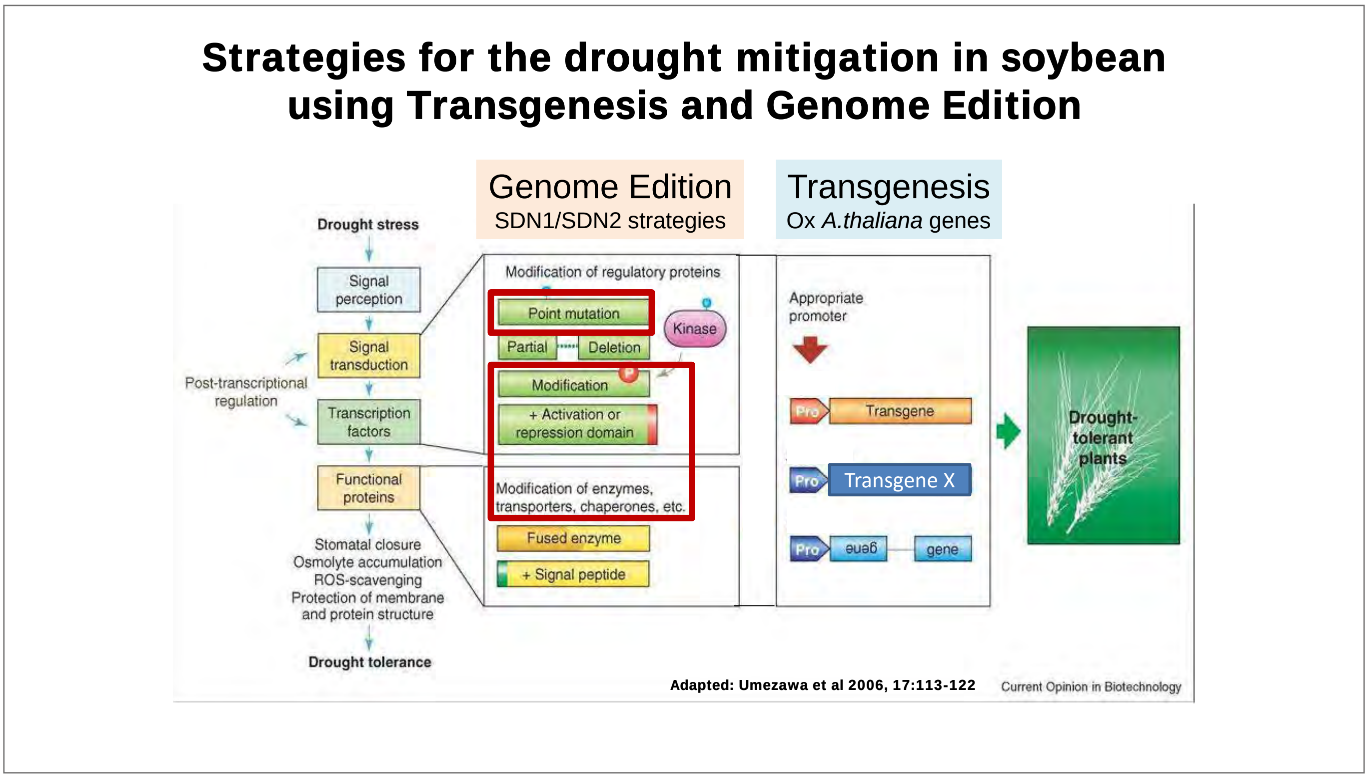
~24 Million Ton not harvested

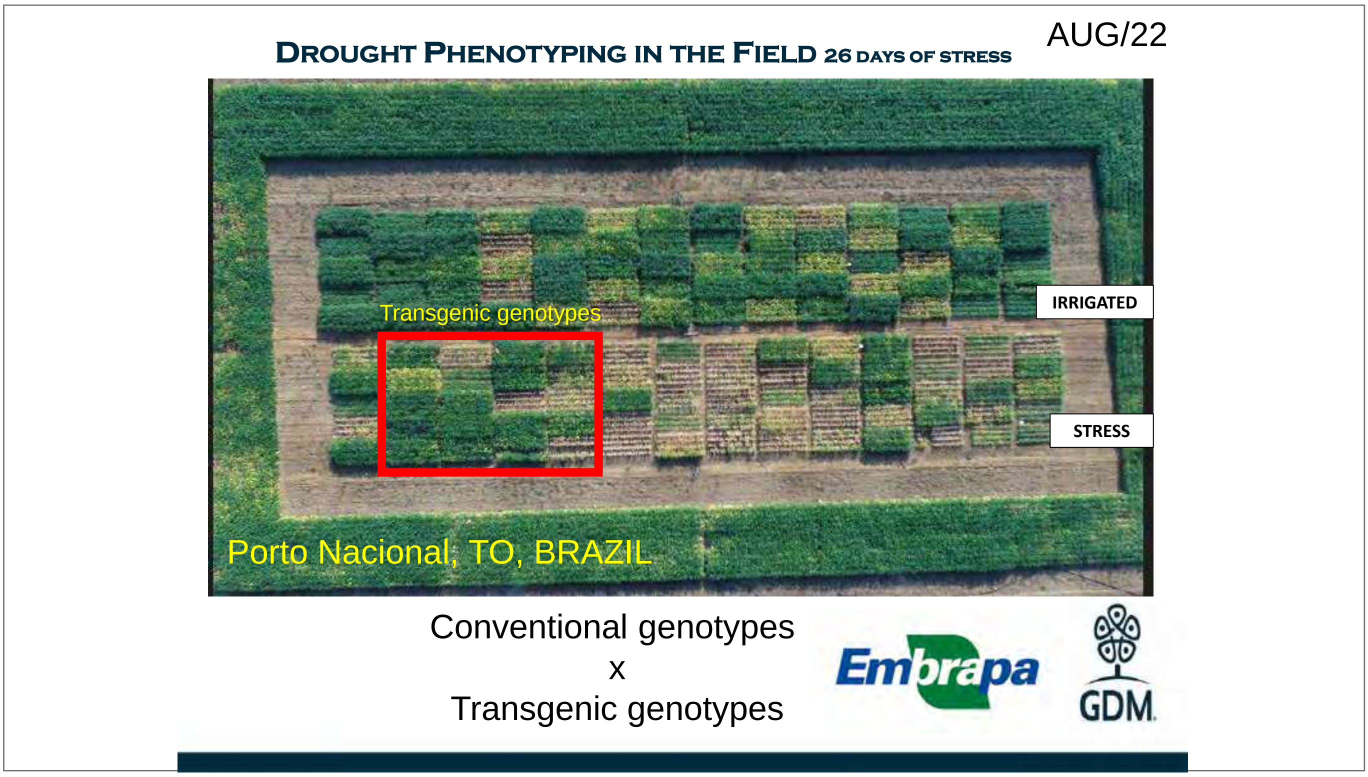


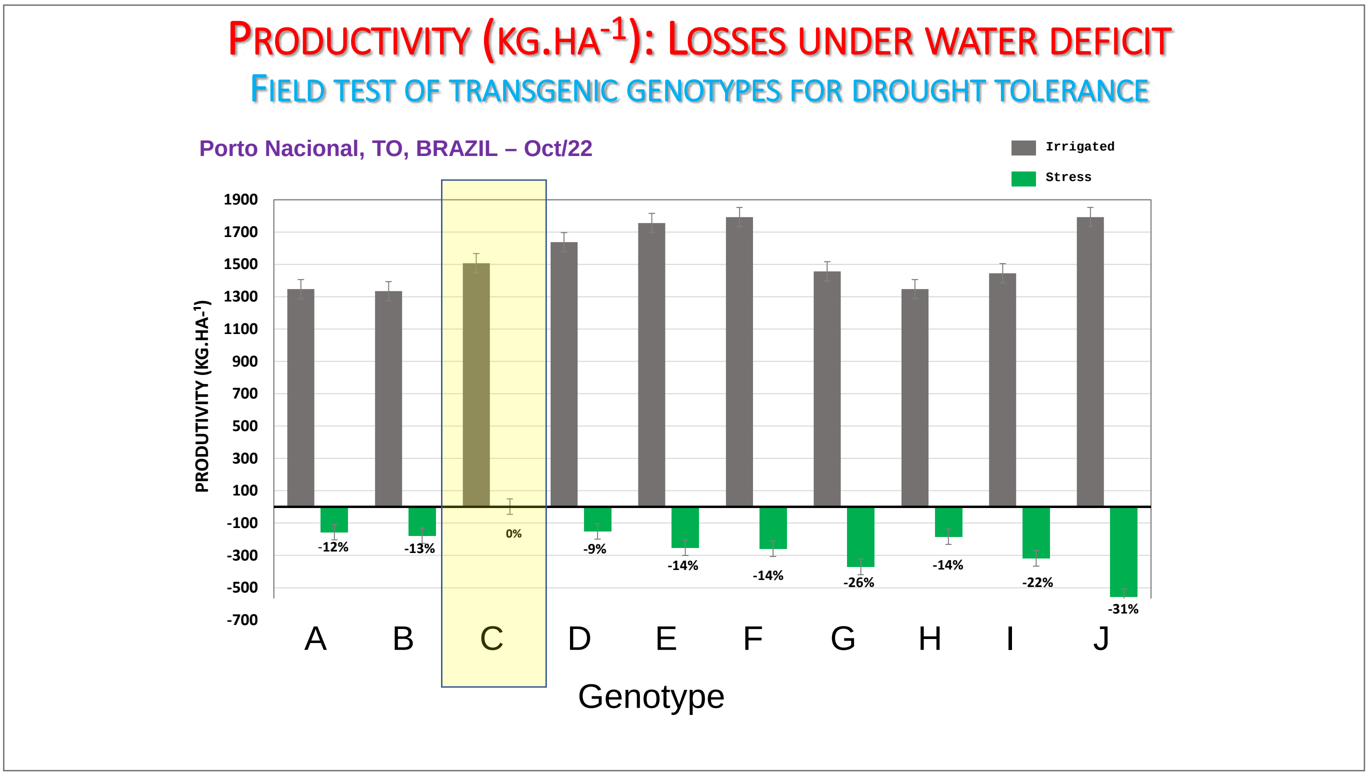

Strategies to Improve Drought Tolerance in Crop Production
Pre-Crop Management
In-Crop Management
Management Influence
Management
Genetics
Long Term History
Sequence
Fallow
In Crop
3+ years
1 year
0.5 years
Soil Structure
Soil Fertility
Seed Bank
Diseases
Nitrogen
Water
Weeds
Weed Control
Struggle
Grazing
Sowing Date
Density
No Tillage
Disease/Insect Control
Irrigation
GENOTYPE
Classical Breeding
GM Plants
GE Plants
Increase soil water capture and Storage
Crop Vigor/Reduce evaporative loss
Canopy Management/Harvest Index

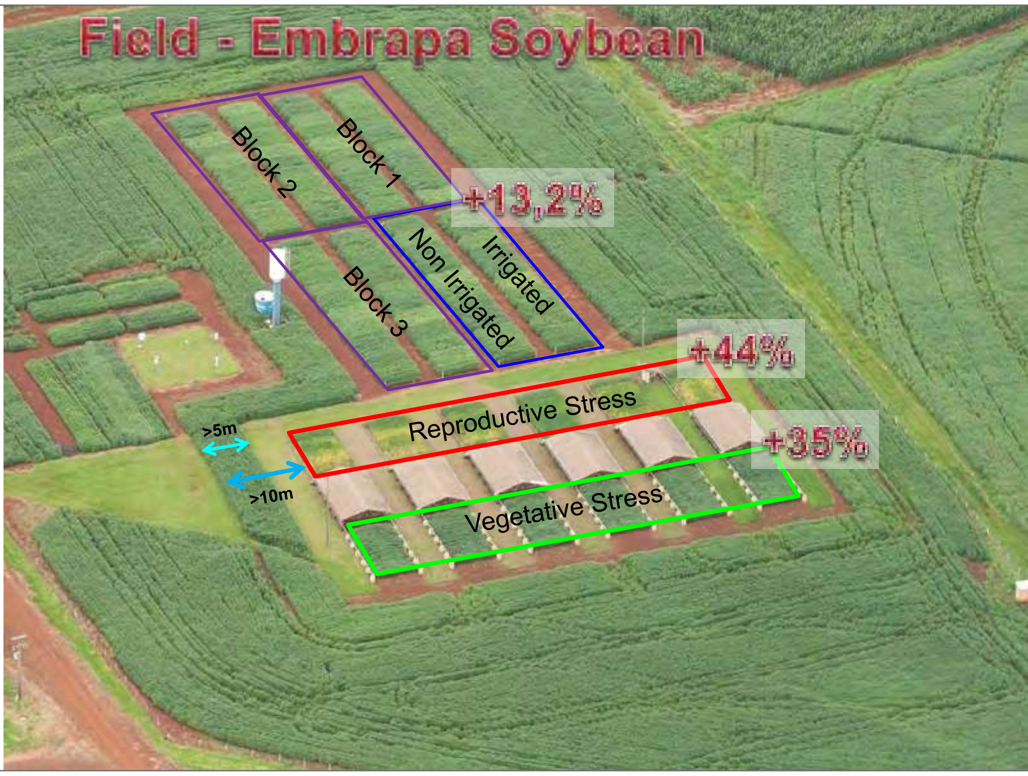

Complex Response Mechanisms
Agronomic and Physiological
Gas Exchange
Leaves Color
Water Translocation
Root Hairs
Root system ramifications
Nitrogen Fixation
Leaves Movement
Leaves Pubescence
Flowers and Legume Abscission
Nutrient Translocation
Photosyntates Translocation
Root system profundity
Embrapa


Plant Responses to Drought
• Drought resistance is a complex characteristic to express in plants.
• There are many genes and mechanisms involved.
Plant-Soil-Atmosphere Interactions
Whole Plant Level Defenses
Tissue Level Defenses
Cellular Level Defenses
Intensity
Duration
Developmental Phase
Other Stresses
Genetic Background
QTLs
Constitutive Genes
Inducible Genes
Stress Perception
Metabolites
mRNA
Embrapa


Strategies for the drought mitigation in soybean using Transgenesis and Genome Edition
Genome Edition
SDN1/SDN2 strategies
Transgenesis
Ox A.thaliana genes
Drought stress
Signal perception
Signal transduction
Post-transcriptional regulation
Transcription factors
Functional proteins
Stomatal closure
Osmolyte accumulation
ROS-scavenging
Protection of membrane and protein structure
Drought tolerance
Modification of regulatory proteins
Point mutation
Kinase
Partial
Deletion
Modification
+ Activation or repression domain
Modification of enzymes, transporters, chaperones, etc.
Fused enzyme
+ Signal peptide
Appropriate promoter
Pro
Transgene
Pro
Transgene X
Pro
gene
gene
Drought-tolerant plants
Adapted: Umezawa et al 2006, 17:113-122
Current Opinion in Biotechnology


DROUGHT PHENOTYPING IN THE FIELD 26 DAYS OF STRESS
AUG/22
Transgenic genotypes
IRRIGATED
STRESS
Porto Nacional, TO, BRAZIL
Conventional genotypes
x
Transgenic genotypes
Embrapa
GDM


PRODUCTIVITY (KG.HA-1): LOSSES UNDER WATER DEFICIT
FIELD TEST OF TRANSGENIC GENOTYPES FOR DROUGHT TOLERANCE
Porto Nacional, TO, BRAZIL – Oct/22
Irrigated
Stress
PRODUTIVITY (KG.HA-1)
1900
1700
1500
1300
1100
900
700
500
300
100
-100
-300
-500
-700
-12%
-13%
0%
-9%
-14%
-14%
-26%
-14%
-22%
-31%
A
B
C
D
E
F
G
H
I
J
Genotype


Field - Embrapa Soybean
Block 2
Block 1
+13,2%
Irrigated
Non Irrigated
Block 3
+44%
Reproductive Stress
>5m
>10m
+35%
Vegetative Stress


Publications
Plant Mol Biol Rep
DOI 10.1007/s11105-012-0541-4
ORIGINAL PAPER
Overexpression of the ABA-Dependent *AREB1* Transcription Factor from *Arabidopsis thaliana* Improves Soybean Tolerance to Water Deficit
Elton Gargioni Grisoste Barbosa · Juliana Paula Leite · Silvana Regina Rockenbach Marin · Juliane Prela Marinho · Josirley de Fátima Corrêa Carvalho · Renata Fuganti-Pagliarini · José Renato Bouças Farias · Norman Neumaier · Francismar Corrêa Marcelino-Guimarães · Maria Cristina Neves de Oliveira · Kazuko Yamaguchi-Shinozaki · Kazuo Nakashima · Kyonoshin Maruyama · Norihito Kanamori · Yasunari Fujita · Takuya Yoshida · Alexandre Lima Nepomuceno
Transgenic Res
DOI 10.1007/s11248-013-9723-6
ORIGINAL PAPER
Phenotyping soybean plants transformed with rd29A:AtDREB1A for drought tolerance in the greenhouse and field
Amanda Alves de Paiva Rolla · Josirley de Fátima Corrêa Carvalho · Renata Fuganti-Pagliarini · Cibelle Engels · Alexandre do Rio · Silvana Regina Rockenbach Marin · Maria Cristina Neves de Oliveira · Magda A. Beneventi · Francismar Corrêa Marcelino-Guimarães · José Renato Bouças Farias · Norman Neumaier · Kazuo Nakashima · Kazuko Yamaguchi-Shinozaki · Alexandre Lima Nepomuceno
Received: 13 March 2013 / Accepted: 8 June 2013
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Genetics and Molecular Biology, 36, 4, 556-565 (2013)
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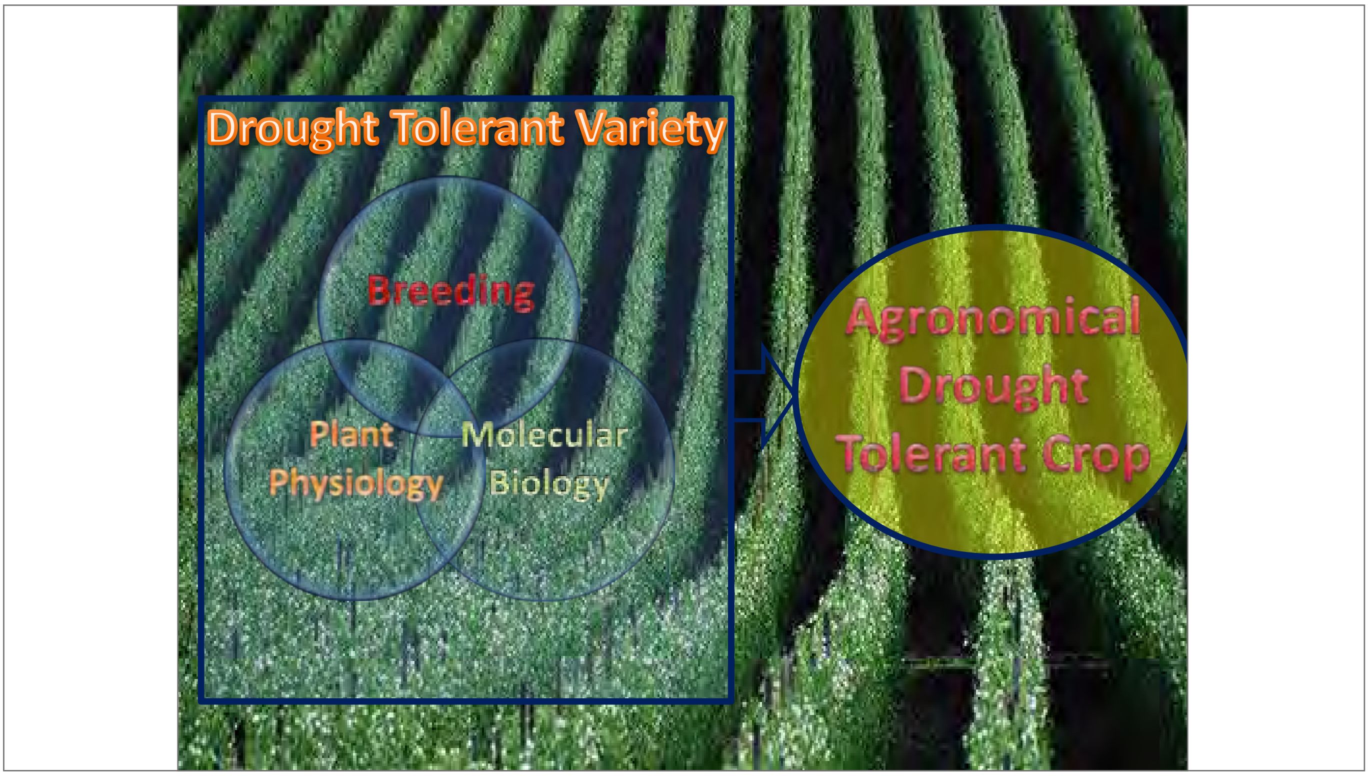
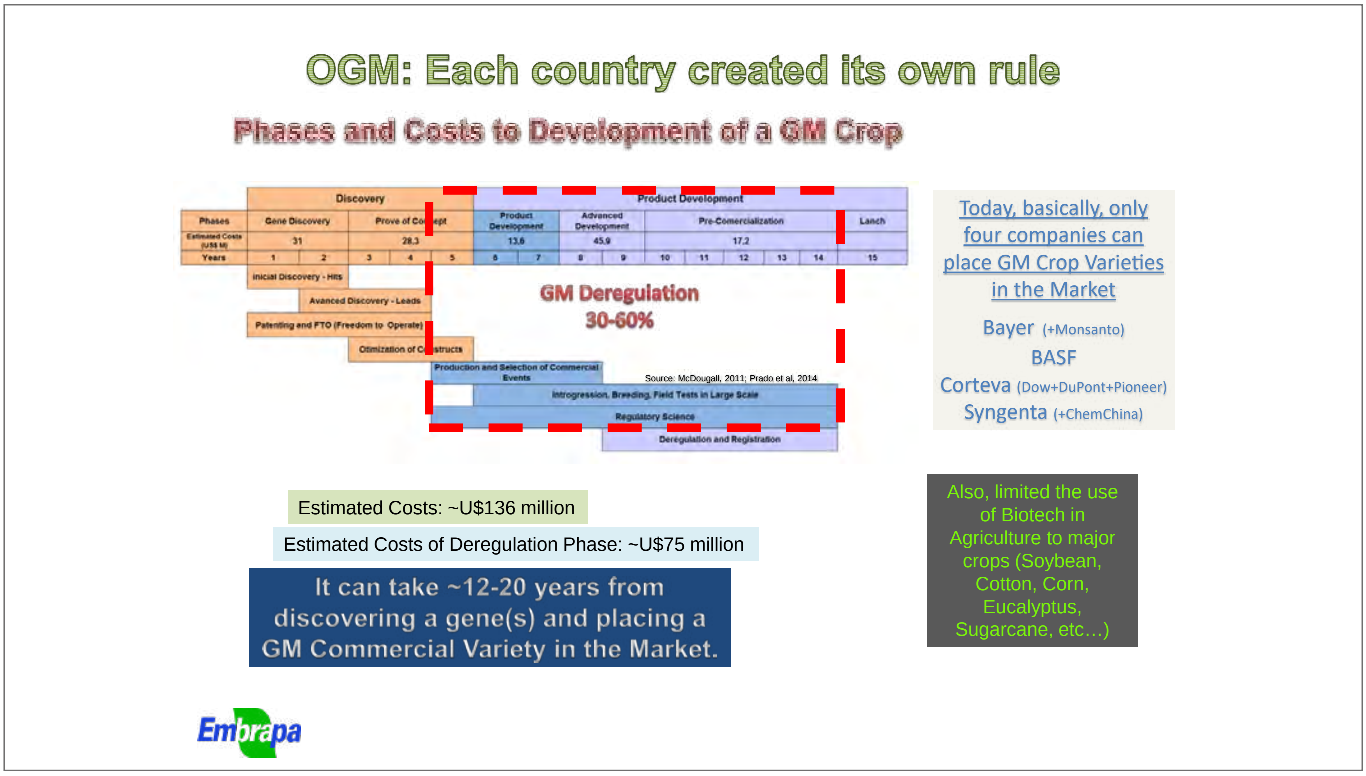
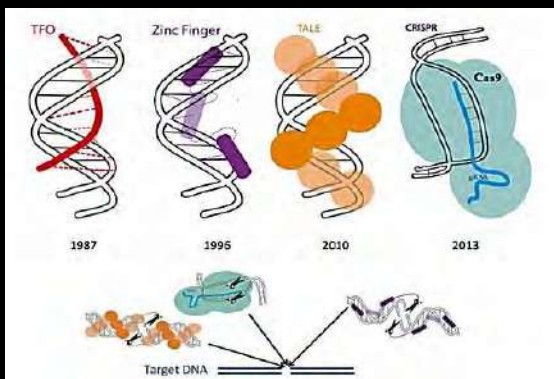
www.sbg.org.br
Research Article
Introduction of the *rd29A:AtDREB2A* CA gene into soybean (*Glycine max* L. Merril) and its molecular characterization in leaves and roots during dehydration
Cibelle Engels[1], Renata Fuganti-Pagliarini[2], Silvana Regina Rockenbach Marin[2], Francismar Corrêa Marcelino-Guimarães[2], Maria Cristina Neves Oliveira[2], Norihito Kanamori[3], Junya Mizoi[4], Kazuo Nakashima[3], Kazuko Yamaguchi-Shinozaki[3,4] and Alexandre Lima Nepomuceno[2]
GMR Genetics and Molecular Research
Molecular, anatomical and physiological properties of a genetically modified soybean line transformed with *rd29A:AtDREB1A* for the improvement of drought tolerance
A.M. Polizel, M.E. Medri, K. Nakashima, N. Yamanaka, J.R.B. Farias, M.C.N. de Oliveira, S.R.R. Marin, R.V. Abdelnoor, F.C. Marcelino-Guimarães, R. Fuganti, F.A. Rodrigues, R. Stolf-Moreira, M.A. Beneventi, A.A.P. Rolla, N. Neumaier, K. Yamaguchi-Shinozaki, J.F.C. Carvalho and A.L. Nepomuceno
Plant Mol Biol Rep (2016) 34:410–426
DOI 10.1007/s11105-015-0928-0
ORIGINAL PAPER
Characterization of Molecular and Physiological Responses Under Water Deficit of Genetically Modified Soybean Plants Overexpressing the *AtAREB1* Transcription Factor
Juliane Prela Marinho[1,2] · Norihito Kanamori[3] · Leonardo Cesar Ferreira[1] · Renata Fuganti-Pagliarini[1] · Josirley de Fátima Corrêa Carvalho[1] · Rafaela Alves Freitas[2,4] · Silvana Regina Rockenbach Marin[1,2] · Fabiana Aparecida Rodrigues[2] · Liliane Márcia Mertz-Henning[2] · José Renato Bouças Farias[2] · Norman Neumaier[2] · Maria Cristina Neves de Oliveira[2] · Francismar Corrêa Marcelino-Guimarães[2] · Takuya Yoshida[4] · Yasunari Fujita[3] · Kazuko Yamaguchi-Shinozaki[4] · Kazuo Nakashima[3] · Alexandre Lima Nepomuceno[2]

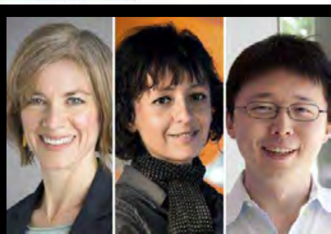

Drought Tolerant Variety
Breeding
Plant Physiology
Molecular Biology
Agronomical Drought Tolerant Crop


OGM: Each country created its own rule
Phases and Costs to Development of a GM Crop
Discovery
Product Development
Phases
Gene Discovery
Prove of Concept
Product Development
Advanced Development
Pre-Comercialization
Lanch
Estimated Costs (US$ M)
31
28.3
13.6
45.9
17.2
Years
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15
Inicial Discovery - Hits
Avanced Discovery - Leads
Patenting and FTO (Freedom to Operate)
Otimization of Constructs
Production and Selection of Commercial Events
Introgression, Breeding, Field Tests in Large Scale
Regulatory Science
Deregulation and Registration
GM Deregulation 30-60%
Source: McDougall, 2011; Prado et al, 2014
Today, basically, only four companies can place GM Crop Varieties in the Market
Bayer (+Monsanto)
BASF
Corteva (Dow+DuPont+Pioneer)
Syngenta (+ChemChina)
Estimated Costs: ~U$136 million
Estimated Costs of Deregulation Phase: ~U$75 million
It can take ~12-20 years from discovering a gene(s) and placing a GM Commercial Variety in the Market.
Also, limited the use of Biotech in Agriculture to major crops (Soybean, Cotton, Corn, Eucalyptus, Sugarcane, etc…)
Embrapa

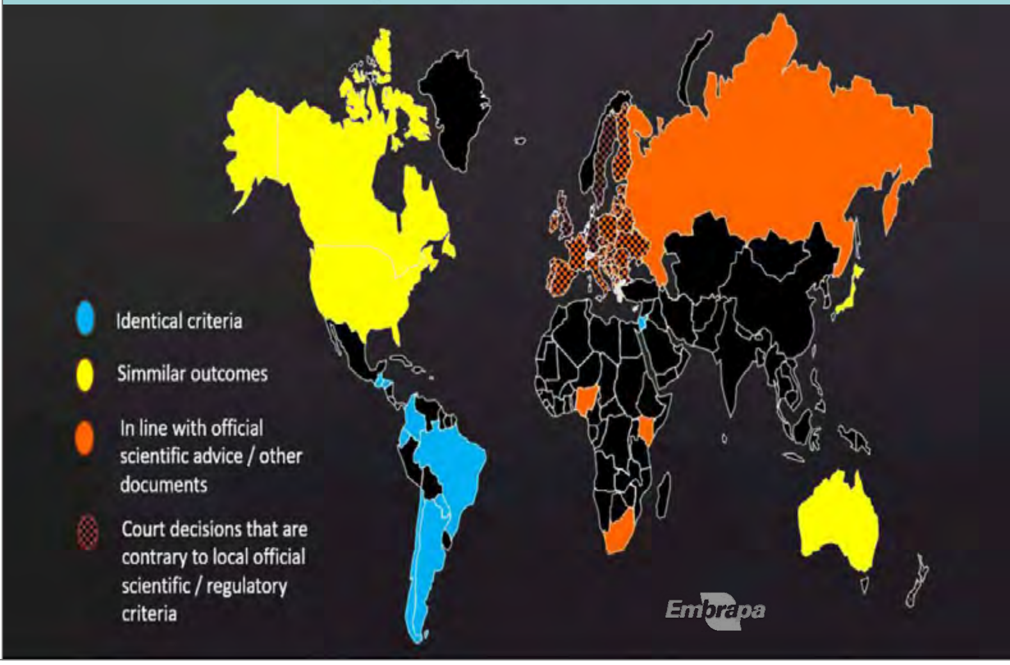
... but evolution on genetics keeps moving fast...

... CRISPRs Technology brought a revolution in Genome Editing and is democratizing the use of biotechnology in agriculture





A more assertive global legislation is DEMOCRATIZING the use of biotechnology allowing more cultures, small and medium companies to also participate in the Market.

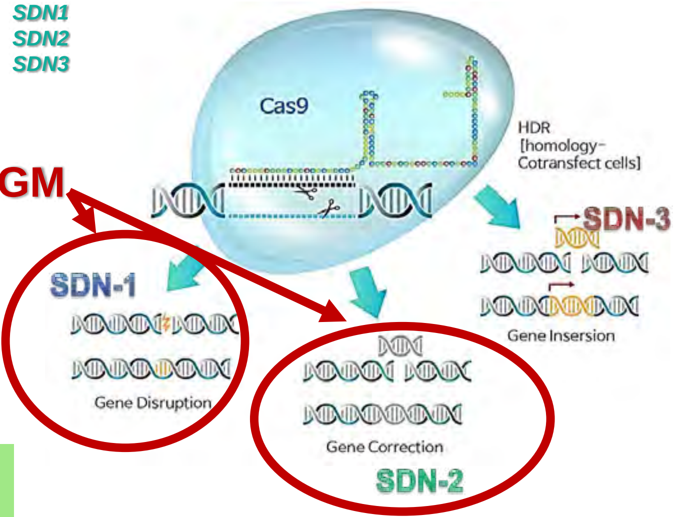


Genome Edition with CRISPR

Site Directed Mutagenesis type:
SDN1
SDN2
SDN3

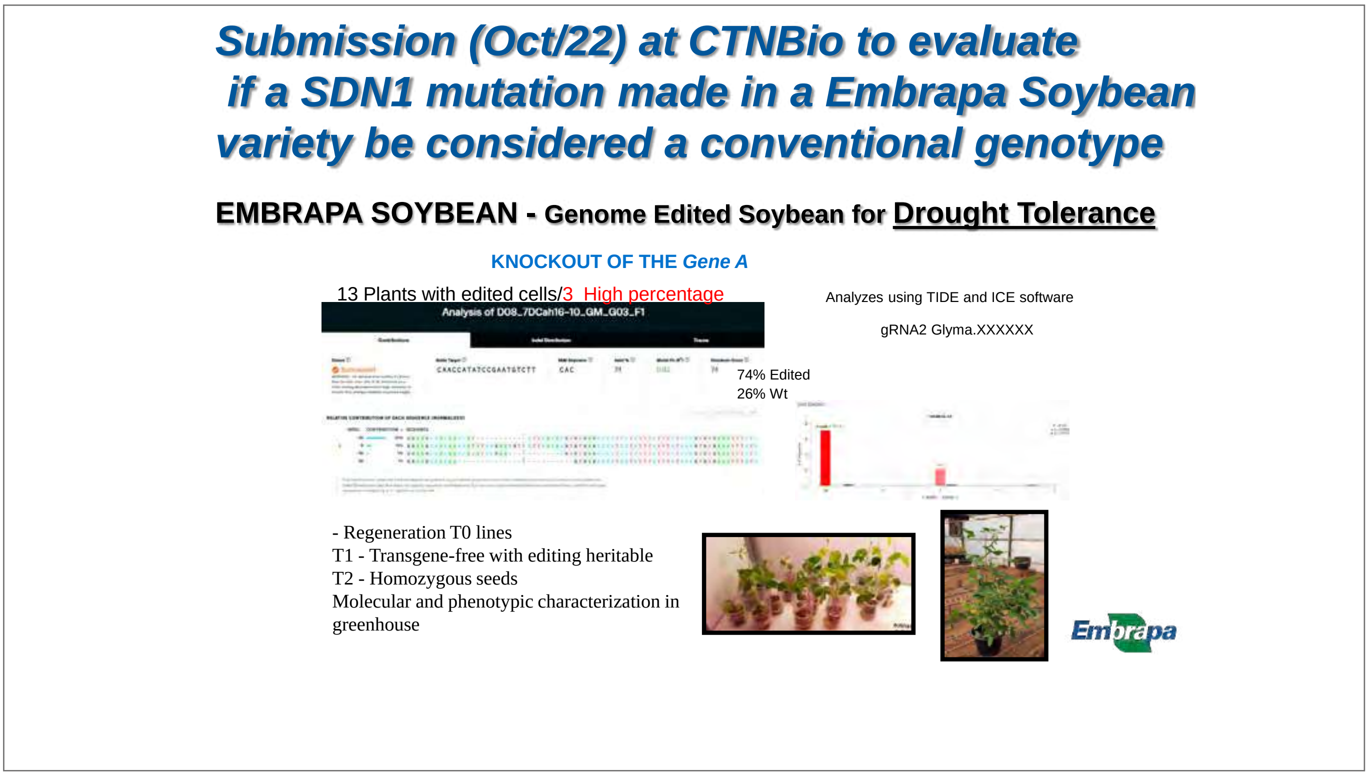
Clustered
Regularly
Interspaced
Short
Palindromic
Repeats

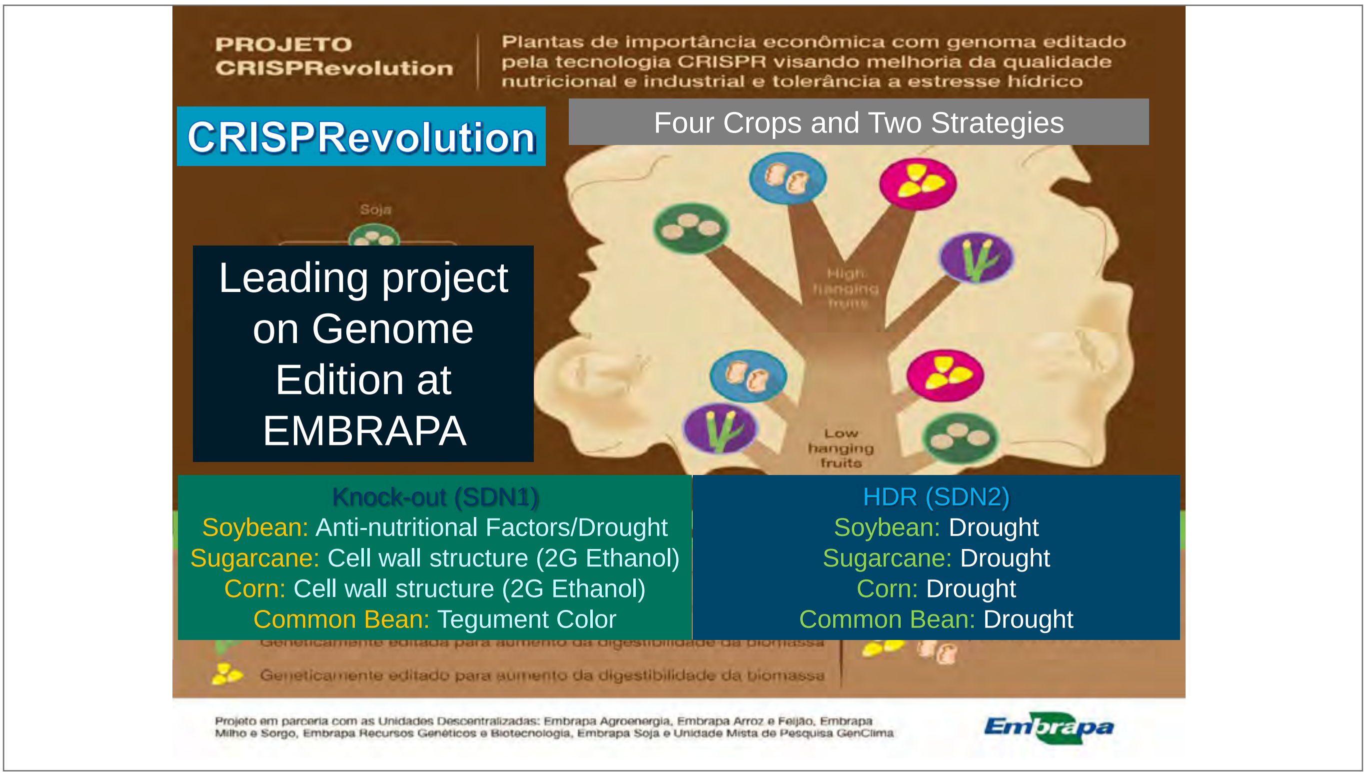
Não OGM

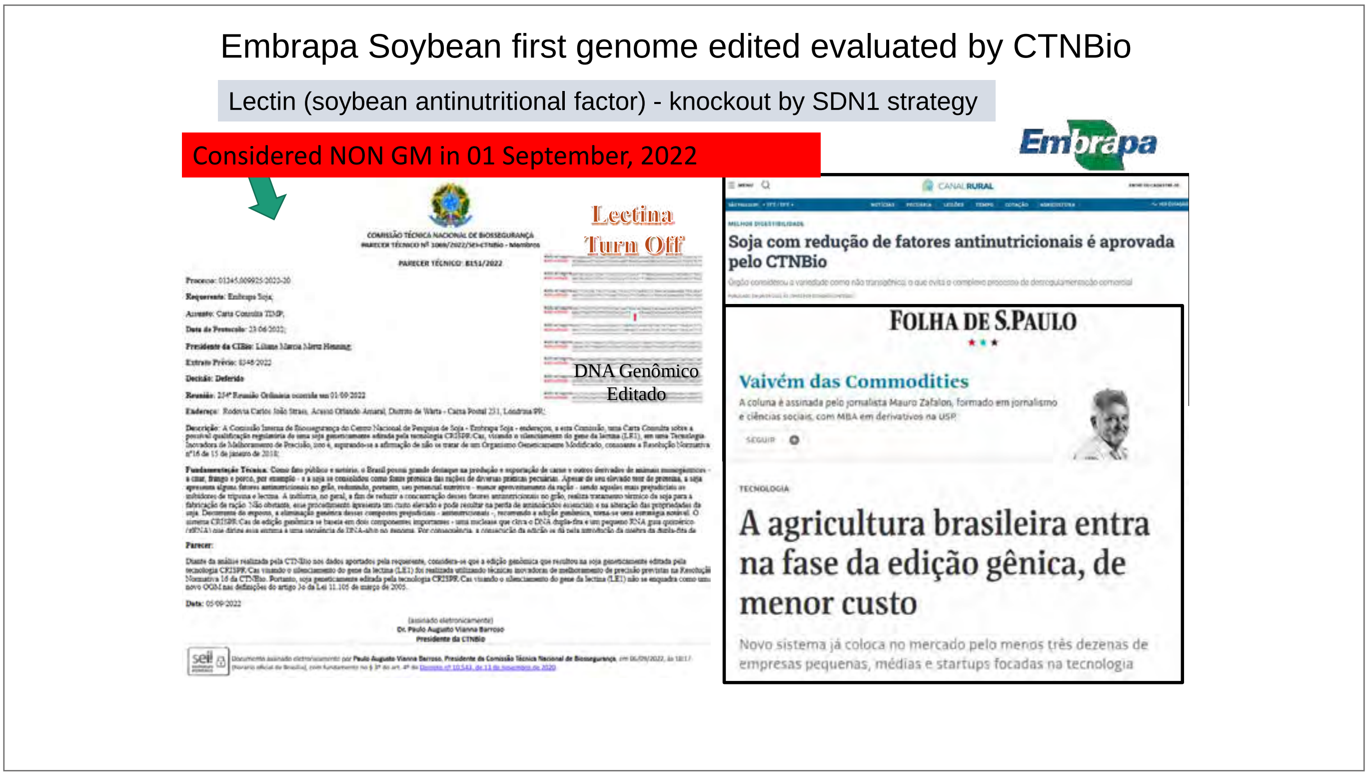


DNA cutting is done in regions (sequences) chosen with precision

Similar to mutations that occur in nature and are responsible for evolution on planet earth


Submission (Oct/22) at CTNBio to evaluate if a SDN1 mutation made in a Embrapa Soybean variety be considered a conventional genotype
EMBRAPA SOYBEAN - Genome Edited Soybean for Drought Tolerance
KNOCKOUT OF THE Gene A
13 Plants with edited cells/3 High percentage
Analysis of D08_7DCah16-10_GM_G03_F1
Analyzes using TIDE and ICE software
gRNA2 Glyma.XXXXXX
74% Edited
26% Wt
- Regeneration T0 lines
T1 - Transgene-free with editing heritable
T2 - Homozygous seeds
Molecular and phenotypic characterization in greenhouse
Embrapa


PROJETO CRISPRevolution
Plantas de importância econômica com genoma editado pela tecnologia CRISPR visando melhoria da qualidade nutricional e industrial e tolerância a estresse hídrico
CRISPRevolution
Four Crops and Two Strategies
Soja
Leading project on Genome Edition at EMBRAPA
High hanging fruits
Low hanging fruits
Knock-out (SDN1)
Soybean: Anti-nutritional Factors/Drought
Sugarcane: Cell wall structure (2G Ethanol)
Corn: Cell wall structure (2G Ethanol)
Common Bean: Tegument Color
HDR (SDN2)
Soybean: Drought
Sugarcane: Drought
Corn: Drought
Common Bean: Drought
Geneticamente editado para aumento da digestibilidade da biomassa
Projeto em parceria com as Unidades Descentralizadas: Embrapa Agroenergia, Embrapa Arroz e Feijão, Embrapa Milho e Sorgo, Embrapa Recursos Genéticos e Biotecnologia, Embrapa Soja e Unidade Mista de Pesquisa GenClima
Embrapa


Embrapa Soybean first genome edited evaluated by CTNBio
Lectin (soybean antinutritional factor) - knockout by SDN1 strategy
Considered NON GM in 01 September, 2022
Embrapa
Lectina
Turn Off
DNA Genômico
Editado
Soja com redução de fatores antinutricionais é aprovada pelo CTNBio
FOLHA DE S.PAULO
Vaivém das Commodities
A agricultura brasileira entra na fase da edição gênica, de menor custo
Novo sistema já coloca no mercado pelo menos três dezenas de empresas pequenas, médias e startups focadas na tecnologia


Thank you!
Alexandre.Nepomuceno@Embrapa.BR
General Head Embrapa Soybean
Cel/WhatsApp +55 (43) 99667 4425
BRAZIL
Embrapa
49 anos
[redacted]

ADAPTATION OF AGRICULTURE/ FARMING SYSTEMS TO CLIMATE CHANGE: EXPLORING GENETIC OPTIONS

Mr. George Prah
Mr. George Prah, Deputy Director, Directorate Of Crop Services, Ministry Of Food And Agriculture, Accra, Ghana

BACKGROUND

Climate change poses a severe threat to the future of the environment as it pertains to agriculture, biodiversity, human society and nearly every facet of our world. The primary cause of climate change is the anthropogenic addition of greenhouse gases to the atmosphere. Due to these human emissions, the average temperature of the planet has risen by nearly 1°C since 1850 (IPCC 2018; Nunez *et al.* 2019).

According to an Intergovernmental Panel on Climate Change (IPCC) special report on global warming, it states that even if warming were to be halted at 1.5°C, which would require drastic and immediate global action, long-term effects of past emissions would linger for centuries or millennia (IPCC 2018). The magnitude of the effects depends on the amount of emissions; in general, more frequent heatwaves, droughts, floods and persistent sea level rise and global temperature increases are expected (IPCC 2018). Indeed, many of these effects are already being observed (IPCC 2018; Nunez *et al.* 2019).

In both natural ecosystems and agricultural settings, plants and animals are being forced to contend with novel conditions that change more quickly than their pace of adaptation. Rising temperatures and shifting precipitation regimes will drastically alter the biological landscape, resulting in species migration, invasion and extinction (Urban 2015; Nunez et al., 2019). Other studies have also estimated that one in six species may become extinct due to the changing climate (Urban 2015). Simultaneously, global food supplies are declining as droughts and floods impact agricultural output. Under a range of warming scenarios, agricultural output is expected to decline globally. Productivity of major commodity crops is envisaged to be affected, especially those in lower latitudes where the effects of climate change on yield will be more severe.

Ghana is an agrarian economy and is highly dependent on agriculture, employing about 42% of the workforce and contributing about 19.7% of the national gross domestic product (GDP) (Ghana Statistical Service 2020). The sector is characterized by small-scale rain-fed crop and livestock farming systems with an average farm size of less than 1.2 ha, accounting for about 80% of total agricultural production. The major crops grown are maize, yam, cassava, rice, cocoa, oil palm, rubber, tobacco, sheanut, sugar cane and various varieties of fruits and vegetables based on the different agro-ecological zones.

Ghana's climate is tropical, with two main rainfall regimes: the north experiences a unimodal wet season from May to November; while the south experiences bimodal wet seasons, a longer rainy season from March to July, and short rains from September to November. However, climate change and climate variability are threatening food production systems as most agriculture in Ghana is rain-fed. Analysis of long-term climate data shows a general increase in temperature in the country with a steady annual rise of 0.06°C per year and an overall increase by about 1°C over the past 40 years (Hansel *et al.* 2012).

Between 1991 and 2008, Ghana experienced six major floods with more than 2 million people being affected. Projections of future climate show that the mean annual temperature in Ghana will increase by 1.0–3.0°C and 1.5–5.2°C by 2060 and 2090 respectively. Such changes are likely to be more pronounced and severe in the north of the country. It has been estimated that climate change and variability will cause decline in household consumption and GDP by 5–10% and 1.9–7.2% respectively in Ghana by 2050 (World Bank 2010). Arndt *et al.* (2015) also lend support to the World Bank's statement detailing implications of climate change for Ghana's Economy.

Again, crop production in Ghana is primarily rainfed and with smallholder farmers who account for a large percentage of the total crop production in Ghana, making it highly vulnerable to the impacts of climate change (Kyei-Mensah *et al.* 2019). This is exacerbated by dependence on the production of crops that are sensitive to climate change. The country is already experiencing increased extreme weather conditions, with higher incidences and more prolonged periods of flooding and droughts. High temperatures will further increase, and rainfall patterns will be less predictable. More intense rainfall is expected to increase erosion, while less total rainfall may decrease the water flow. Erratic precipitation patterns have severe consequences on production, as only 2% of the country's irrigation potential has been tapped.

Rising temperatures are projected to lower yields in major staple crops (cassava, yams, plantains, maize and rice). Cassava yields, for example, are projected to fall by 29.6% by 2080 and maize yields by 7% by 2050. Total crop failure is expected to occur approximately once every five years in Ghana's northern regions due to delayed or diminished rains. Cocoa, a major cash crop and Ghana's second leading foreign exchange earner, is sensitive to rising temperatures and drought. Areas suitable for cocoa production, which lie primarily along the coast, are contracting as temperatures rise, floods increase and soil salinization and coastal erosion continue. The projected increase in warming and droughts will lead to reduced water availability, drop in soil fertility due to increased decomposition of soil organic carbon and increased incidence of pests, diseases and weeds, leading to a decline in crop yields (Abubakari and Abubakari 2015; Kyei-Mensah *et al.* 2019). Analysis of recent rainfall conditions in West Africa, including Ghana, indicates long-term change in rainfall patterns within the semi-arid and sub-humid zones, with reduced rainy days (Ndamani and Watanabe 2015).

PROJECTED SCENARIOS FOR SOME MAJOR STAPLES (CROPS) IN GHANA

Increased temperature and extreme climate events such as floods, droughts and heatwaves are already being experienced in Ghana (Yiran *et al.* 2017), coupled with declining rainfall from the south to the north (Owusu 2018), with devastating effects on agricultural productivity. Development in the agriculture sector in Ghana will continue to be impacted adversely by the vagaries of the projected future climate, notably, the marked seasonal variability manifesting in erratic rainfall onset and cessation, shortening of length of growing period, declining seasonal rainfall totals and increased frequency and intensity of extreme climate events such as heatwaves, droughts and floods that have deleterious impacts on agricultural value chains and food systems.

Some of the major crops are currently experiencing major yield gaps. For instance, cassava, maize, sorghum, rice and yam currently have yield gaps of 57.5%, 38%, 40%, 33.33% and 40%, respectively. Despite their current state of production, these crops are expected to experience further decline in productivity due to climate change (Knox *et al.* 2012; Issahaku and Maharjan 2014).

Maize

Maize accounts for 50% of total cereal production in Ghana. Over 70% of Ghana's maize production is produced by smallholders who lack access to the required production resources for increasing productivity, making them prone to production of low yields. Although annual maize yields have been reported to be growing marginally around 1.1% , they are, however, projected to decrease in all agro-ecological zones of Ghana.

Rice

Although rice is produced in all agro-ecological zones of Ghana, production does not meet the demand of Ghanaians (Olaf and Emmanuel 2009; Aker *et al.* 2011). Rice is projected to drastically decline in all agro-ecological zones of Ghana except for the deciduous agro-ecological zone, which is likely to experience a less drastic decline.

Sorghum, groundnut and millet

Sorghum, groundnut and millet are mostly cultivated in the relatively drier Sudan Savanna and Guinea Savanna agro-ecological zones of Ghana owing to their sturdy nature. Projections of groundnut and sorghum indicate likelihood of reduced yields under all representative concentration pathways (RCPs), especially over Guinea and Sudan Savanna agro-ecological zones. Future yields of millet are likely to remain the same compared to current yield levels under all RCPs, as evidenced by the projections for Guinea and Sudan Savanna agro-ecological zones.

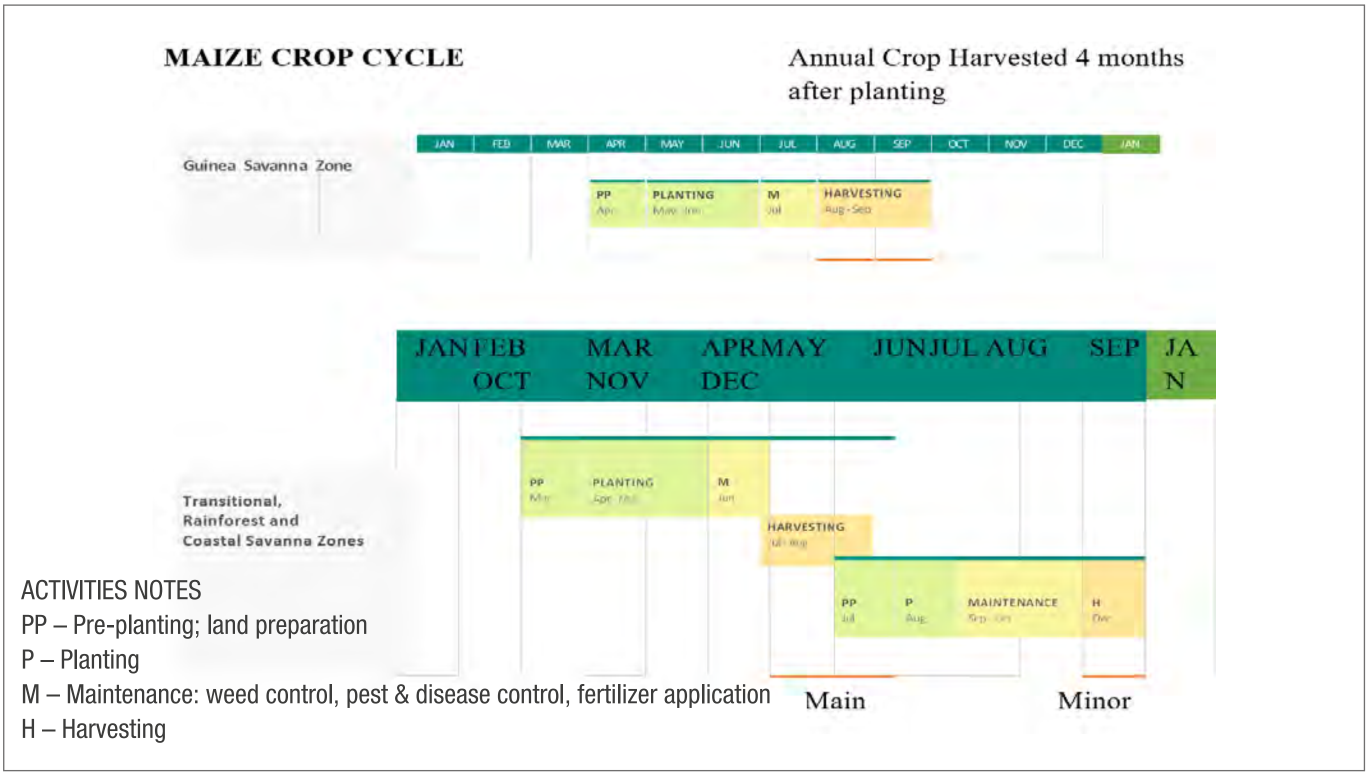


Figure 1. *A typical maize crop cycle in Ghana.*

The normal and typical crop cycle has become a challenge since rainfall patterns have changed over the years (Figure 1). It is becoming impossible to crop twice in a year in certain areas and regions due to erratic rainfall patterns or unfavorable high temperatures.
In response to these challenges, the implementation of one or more of a range of complementary strategies are required. These may include developing technologies (genotypes and production systems) to make agriculture resilient to climate change.

INNOVATIONS IN PRODUCTION SYSTEMS: ADAPTING AGRICULTURE TO CLIMATE CHANGE

In Ghana, there is a likelihood of a shift in suitable production areas for some crops due to climate change. For example, projections indicate that suitable areas for cocoa production will shift and this will mainly affect the southern area of Brong Ahafo, western regions and small sections of the northern parts of Ashanti and Volta regions as they will no long be suitable for cocoa production in Ghana by 2030 (Bunn *et al.* 2018).

The adaptation of agriculture to climate change will require the implementation of one or more of a range of complementary strategies. These include developing technology (genotypes and productions systems) to make agriculture resilient to climate change within the current footprint. This may necessitate the movement of production to new locations to follow environmental change or adopting protected agriculture. These options have important roles to play in delivering food security in response to climate change (Figure 2).

Following current opinion in plant biology (Figure 2), crop protection comes in many forms with differing degrees of control. Field-grown crops can be protected with a simple structure. That notwithstanding, field crops are likely to remain in open fields while horticultural crops, especially vegetables, are protected. Indoor production is currently mostly focused on the production of leafy vegetables. It is expedient to note that expansion to a wider range of plants will see more adoption of this technology, dramatically changing genetic requirements.

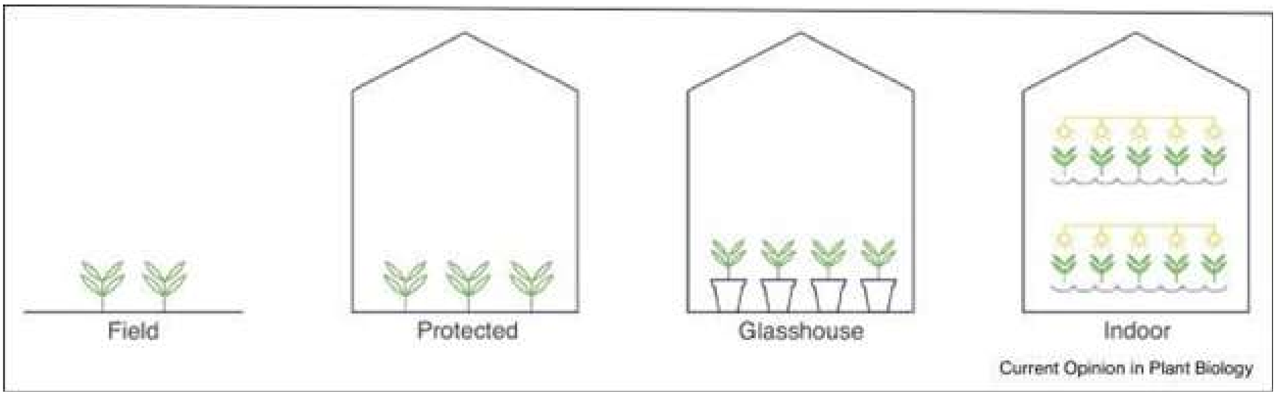


Figure 2. *Moving genetic targets for plant breeders in response to climate change driving the adoption of protected cropping.*

As a prediction, movement, or relocation of agricultural production to new areas to keep within the current environmental ranges of the current production system is an option and a possibility. Production of crops in new areas may require genetics to adapt to specific aspects of the new environment. For example, crops might easily move to areas with climates that have become suitable due to climate change, but the soils encountered may be very different and this may require genetic adaptation.

The threat of a changing and more variable climate can be avoided by moving agricultural production into protected environments. This involves moving to production in a greenhouse or a completely controlled, intensified production environment in vertical farming (Eaves and Eaves 2018). This may be considered an increasingly valuable option as food demand increases and climate change advances.

Again, according to science and research, increasing protection of crops to reduce the impact of climate change will alter the genetic targets from those designed to cope with the environment and its variation towards optimal performance in a selected, controlled environment.

RESILIENCE IN GENETICS AND AGRONOMY

Plant genetic improvement for agriculture has been supported by new technologies that have arisen at an ever-increasing rate. Plant breeding has progressed through major developments such as the application of molecular markers in selection, the use of genetic transformation and genomic selection to the recent development of gene editing. The ultimate extension of the use of molecular markers has been the use of genomic selection. The availability of technology to easily obtain complete genome sequences may make the technologies based upon genetic linkage redundant or much less powerful in relation to the current options.

Developing new genotypes of plants is one of the key options for the adaptation of agriculture to climate change. Plants may be required to provide resilience in changed climates or support the migration of agriculture to new regions. Different genotypes may be required to perform in the modified environments of protected agriculture. Consumer preferences (taste, convenience, healthy and safe food and sustainably and ethically produced food) will continue to increase, despite the greater challenges of climate.

Moving forward, the use of gene editing, also referred to as genome engineering, has emerged as a method to either aid in the adaptation of organisms to climate change or help mitigate the effects of climate change on agriculture.
Gene editing is a method to generate DNA modifications at precise genomic locations. These modifications can

result in knockout or knockdown of one or multiple genes without the permanent insertion of any foreign DNA. Alternatively, genes from within the organism's gene pool or from other organisms can be inserted into precise locations within the genome to knock-in a new trait. Transcription activator-like effector nucleases (TALENs), zinc finger nucleases (ZFNs) and CRISPR-Cas systems have all been utilized to achieve precise gene edits (Gaj *et al.* 2016; Khalil 2020).

The precision and efficiency of generating edits has been tremendously improved by the introduction of CRISPR-Cas systems, although there is certainly still a role for other gene editing technologies. The application of gene editing techniques has generated great potential for developing crops and livestock that can better manage the impositions of climate change.

The development of agricultural productions systems with greater climate resilience is an important strategy in dealing with climate change. Conventional plant breeding usually relies upon selection in the target production environment. In this way breeding adapts varieties to the test environment and climate change as it impacts on the testing environment. Selection for performance under optimal growth conditions and nutrition has been shown to also improve yield in less favorable situations (Voss-Fels *et al.* 2019). However, more rapid climate change may require a more proactive approach to climate adaptation, especially for species with genotypes with long production life or plants with a long life (such as trees). Genomics provides a key platform for understanding the response of plants to the environment and the breeding of better adapted crop varieties that might anticipate future climate changes (Abberton *et al.* 2015).

GENETIC IMPROVEMENT TECHNOLOGY

Gene editing is currently widely applied and can be used to directly generate new crop varieties. However, gene editing can also provide a very useful tool for testing the phenotype conferred by alleles discovered in germplasm, wild populations of environmentally adapted germplasm or determining the functional role of synthetic alleles (Tang and Tang 2017). The application of gene editing to breed crops adapted to tropical climates is progressing (Haque *et al.* 2018).

The combination of advances in genomic analysis and gene editing should allow a new phase of plant improvement based upon the design and building of genotypes to target specific objectives such as adaptation of crops to new field or protected environments. Table 1 shows some genetic technologies that have been applied successfully in plant improvement/breeding in Ghana.

Table 1. Genetic technologies that have been applied in plant improvement in Ghana.

Technology	Contribution to crop improvement
Phenotypic selection	Eco-geographical adaptation
Cross breeding/hybridization	High yield increases, agronomic improvement and adaptation to climatic fluctuations and mitigation
Genetic manipulation	Reduction of dependency on agrochemicals (e.g. Bt Cowpea)
Molecular markers	Resistance breeding (e.g. fall armyworm, drought, salt tolerance, aflatoxin accumulation resistance, etc.)
Genomic selection	Increased rate of genetic gain (e.g. food crop and animal breeding)
Gene editing	Novel products (e.g. golden rice, tomato, maize etc.)

CAPTURING MORE BIODIVERSITY AND KNOWLEDGE OF NATURAL SYSTEMS

Plant biodiversity remains a relatively poorly exploited source of variation that is available to support the breeding of crops adapted to new climates. More diverse germplasm from the domesticated gene pool may need to be utilized. Genomics provides access to diversity in crop wild relatives by facilitating genome sequencing (Brozynska *et al.* 2015) and novel allele identification. Crop wild relatives contain a reservoir of genetic diversity to support adaptation of crops to climate change. This is probably also a great place to search for new variations that might suit the completely new optimized environments possible in indoor farming.

Studies of wild plant populations growing in diverse environments can reveal how plants adapt to climate difference under natural selection (Cronin *et al.* 2007). This knowledge can guide efforts to breed crop varieties with climate resilience (Henry and Nevo 2014).

CONCLUSIONS AND RECOMMENDATIONS

A summary of proposed ideas as a way of making the agricultural production system climate smart and resilient:

1 A focus on design or tailor-made breeding will help address some challenges associated with climate change.
1.1 Selection of desirable traits and or gene editing will be required to deliver genotypes with the targeted traits to provide the required yield and to deliver foo d with the necessary nutritional and functional traits for the new environments.
2 Future food production will rely on the continued development of new crop varieties, including novel crops and new types of plant-based foods.
2.1 Crop species that are currently underutilized will need research attention to be able to contribute to climate adaptation. This may require the domestication of new species and the extensive use of crop wild relatives, capturing much more of the available plant biodiversity.
2.2 Strategies for the capture of novel variation may include the use of techniques such as gene editing to directly introduce novel alleles or traits found in wild plants into domesticated crop varieties. This would allow the rapid and definitive evaluation of the genetic contribution of the introduced allele relative to the earlier much less effective and efficient approaches of extensive backcrossing.

- Utilization of underutilized crop species
- Domestication of new species and the improvement of existing ones
- Extensive use of wild relatives of crops capturing much more of the available climate smart plant biodiversity into elite genotypes.
- Strengthening gene banks to preserve important genotypes for future utilization
- Accessing UPOV PLUTO database to support breeding.

3 Consideration is also needed in respect of breeding options for protected systems relative to breeding for continued field production.
4 Changes in the regulation and consumer acceptance of genetic technologies will be crucial in shaping the extent to which genetics can contribute to adaptation of agriculture to climate change.
5 Advances in tools for analysis of plant performance also support the development of optimal agronomic practices.
5.1 This needs to be targeted at the crops that are likely to be grown in different and diverse environments. The potential for existing crops to be adapted to new areas or ecologies is a key consideration.

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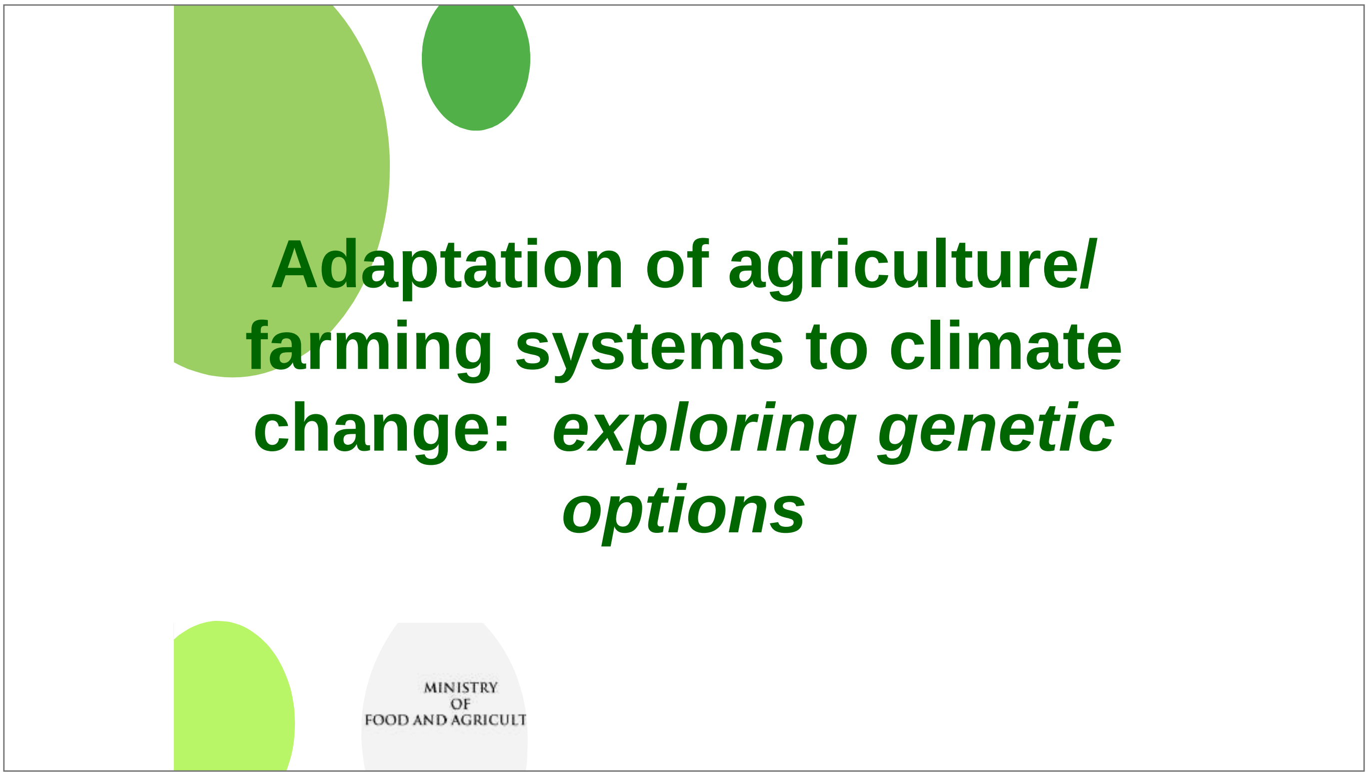
ADAPTATION OF AGRICULTURE/ FARMING SYSTEMS TO CLIMATE CHANGE: EXPLORING GENETIC OPTIONS

Presentation made at the Seminar



Outline

01 **Introduction**

02 **Developing the appropriate strategies (*Genetic Improvement Technology*)**

03 **Contribution of Genetic Improvement**

04 **Concluding Remarks**

3

Introduction

Farmers and Commodities (Plant Genera)

90-95% of farmer population (Small-scale)

Cereals

Maize, Rice, Sorghum, Millet

Legumes

Soybean, Groundnut, Cowpea, Common Bean, Bambara nut, etc.

Vegetables

Tomato, Pepper, carrot, Okra, leafy vegetables, etc

Roots & Tubers

Cassava, Sweetpotato, Yam, Cocoyam, Taro, Frafra Potato

4

MINISTRY OF FOOD AND AGRICULTURE

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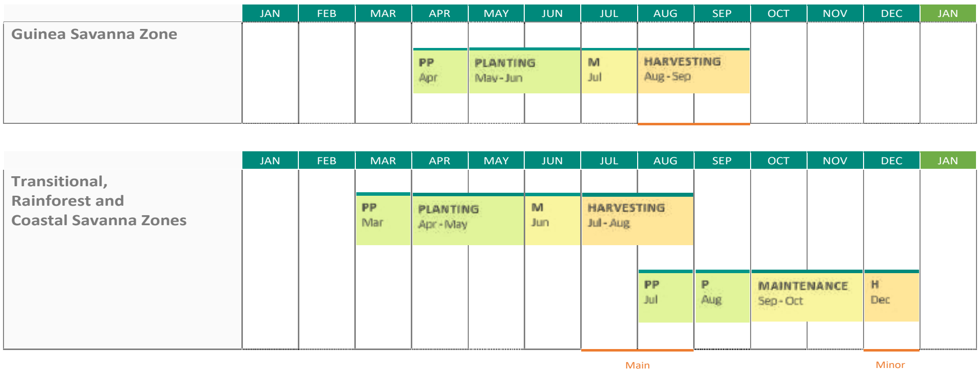
Introduction Con't

A typical crop cycle in Ghana

MAIZE CROP CYCLE

Annual Crop
Harvested 4 months after planting



ACTIVITIES

PP - Pre-planting: Land preparation
P - Planting
M - Maintenance: Weed control, Pest & disease control, Fertilizer application
H - Harvesting

NOTES

MINISTRY OF FOOD AND AGRICULTURE

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Developing the appropriate strategies 1

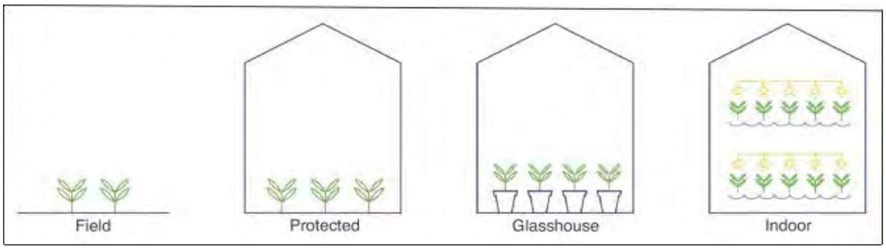
The adaptation of agriculture or making agriculture resilient to climate change requires the implementation of a myriad of complementary strategies:

- moving agriculture to new locations to follow environmental change
- adopting protected agriculture by partially or completely controlling the environment.
- Utilizing environments hitherto classified as not useful for agriculture to mitigate climate change effects
- Developing new agronomic packages for crops to mitigate climate change effects

6

Developing the appropriate strategies 2

Manipulating production/agronomic systems



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Source: Current Opinion in Plant Biology, 2020

Developing the appropriate strategies 3

- Utilization of underutilized crop species to be able to contribute to climate adaptation and mitigation
- Domestication of new species and the improvement of existing ones to adapt to climate change effects
- Extensive use of wild relatives of crops capturing much more of the available climate smart plant biodiversity into elite genotypes.
- Strengthening gene banks to preserve important genotypes for future utilization
- Accessing UPOV PLUTO database to support breeding

MINISTRY OF FOOD AND AGRICULTURE

Using the appropriate Genetic Tools to mitigate climate Change

Genetic improvement of crops as a key strategy to adapt to mitigate climate change effects:

- *Genomic tools for plant genome analysis have continued to improve rapidly.*
- *Crop improvement needs to use genomic tools to design and then deliver the required genotypes to fit changing and hitherto difficult environments.*
- *Genomic tools can be used to incorporate new traits from wild relatives to elite genotypes*
- *Genomic tools such as* TALEN, CRISPR/Cas-technique or base editing can be used to improve wild relatives of crop species to make them usable

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Genetic improvement technology

Traditional Crop Modification

selective breeding and hybridization

Genetic Engineering

High yielding, pests and diseases control, manipulation of genome for improved varieties, including farmer preferred traits (PVS, PVB)

Genome Editing

Removal of genes responsible for deleterious traits affecting storage Nutrient uptake

10

MINISTRY OF FOOD AND AGRICULTURE

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Genetic technologies that have been applied in plant improvement in Ghana and elsewhere

Technology	Contribution to crop improvement
Phenotypic selection	Eco-geographical adaptation
Cross breeding/hybridization	High yield increases, agronomic improvement and adaptation to climatic fluctuations and mitigation
Genetic manipulation	Reduction of dependency on agrochemicals (e.g. Bt Cowpea, Bt cotton, etc.)
Molecular markers	Resistance breeding (e.g. fall armyworm, drought, salt tolerance, aflatoxin accumulation resistance, etc.)
Genomic Selection	Increased rate of genetic gain (e.g. Food crop , forest trees and animal breeding)
Gene editing	Novel products (e.g. Golden rice, Tomato, Maize, Wheat, etc.)

MINISTRY OF FOOD AND AGRICULTURE

Conclusions

- Future food production will rely on the continued development of new crop varieties
- Underutilized crop species will need research attention to be able to contribute to climate adaptation and mitigation
- Domestication of new species and the improvement of existing ones to adapt to climate change effects
- Extensive use of wild relatives of crops capturing much more of the available climate smart plant biodiversity.
- Strengthening gene banks/treaty on Convention on Biological Diversity (CBD)
- Accessing UPOV database to support breeding

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Thank You!
13
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QUESTIONS

CUI Yehan (Mr.), Vice-President of the Council, UPOV (moderator)

Does anyone have any questions regarding to the top five speakers, please raise your hands and please do so. No.

HUERTA Yolanda (Ms.), Legal Counsel and Director of Training and Assistance, UPOV

Professor Cui, there is a question from Argentina from Ms. Laura Villamayor from Argentina.

VILLAMAYOR María Laura (Sra.), Coordinadora de Relaciones Institucionales e Interjurisdiccionales, Instituto Nacional de Semillas (INASE), Secretaría de Agricultura, Ganadería, Pesca y Alimentación, Buenos Aires, Argentina

Thank you so much. Good morning for me, good afternoon for everyone, a good night. First of all, thank you for the presentations, interesting presentations. I would like to ask a question about the Brazilian Agricultural Research Corporation (EMBRAPA) presentation and about drought tolerance you were talking about, Mr. Alexandre from EMBRAPA. We have some kind of regulations between Argentina and Brazil dealing with these transgenic genes, and I want to know how did you deal with this problem that critics have sometimes against drought tolerance transgenics? I want to know how you deal with these kind of comments against transgenics. And the second question is, do you have some special regulations for genetic edition, or do you treat them as if they were transgenics or as normal varieties? So, these are the two questions I have for Alexandre. Thank you so much.

VALSTAR Marien (Mr.), President of the Council, UPOV (moderator)

Thank you, Laura. Who would you like to respond to the question?

LIMA NEPOMUCENO Alexandre (Mr.), Researcher, Brazilian Agricultural Research Corporation (EMBRAPA), Brazil (speaker)

Thank you very much for the questions. First, transgenics is a very, very important and interesting technology. Brazil have today 70% of its area using no tillage because of the herbicide-resistant genetically modified plants, unfortunately, because of all these polemics of using transgenics in agriculture. Because before the Roundup Ready soybean, we have transgenics in medicine industry. Nobody discussed about that. But that's not the point here. We got very interesting results from transgenic plants, like I showed. We introduced some of those over-expression genes from epidotes in soybean plants. Like I said, it's in our best materials, but it's so expensive, and we cannot -- we cannot do regrade by ourselves. You are trying to get this partnership with a private company, and we hope we can move forward, and then they're going to help us to deregulate in Brazil and Argentina and other countries.

But like I said, genome edition came, and there is this harmonization in terms of legislation among many countries when you have editions that simulate mutations that already happen in nature or could be introduced by classical breeding. Why you should consider a transgenic and have all that cost? First of all, the biosafety is preserved. In CONABIA in Argentina, in Brazil, it's passed by the Safety Commission. Paraguay, Colombia, Chile, United States, Canada also have their agencies that's in the same way. We know that Japan, Australia, China seems to go in the same direction. We still need to see what's going to happen with Europe. But this genome edition is a very interesting tool. Transgenics is still going to be very important because there are some things that we still cannot do using genome edition. But because of these polemics, only 4-5 companies can really put solutions in the market.

Another problem is that only the big commodities, because of the cost, those are cash crops, they have this technology being used. But genome edition, this more assertive legislation, I believe, is changing that. Brazil and Argentina are negotiating right now to have a kind of simultaneous deregulation of GMOs and also genome edited plants. It's under discussion right now. And I believe it could be a model also for America, maybe the Americas in terms of recognizing the analysis of the agencies of each country thus to have a more fast and more assertive use of those technologies in agriculture.

I don't know if I answered your question. But in Brazil, transgenics is doing seven years, seven years because polemics was prohibited until came the new Brazil biosafety law. But during seven years, we cannot use this very important technology in our agriculture. And we see that now if genomic edition legislations all over the world, it's changing, and I hope it's changed.

CUI Yehan (Mr.), Vice-President of the Council, UPOV (moderator)

Thank you, Mr. Alexandre's reply. Are there any other questions from participants?

HUERTA Yolanda (Ms.), Legal Counsel and Director of Training and Assistance, UPOV

Professor Cui, there is a comment from Mr. Ranner.

RANNER Herwig (Mr.), Team Leader – Climate change and agriculture, Unit for Sustainable Agriculture, Directorate General for Agriculture and Rural Development (DG AGRI), European Commission

Yes. Thank you. It was just because it was raised by my colleague from Brazil, but he doesn't know how things work in Europe. As I said, I can't speak for the whole of Europe. There's more than just the European Union.

In the European Union, we have rather strict rules in place concerning genetically modified organisms. I think there's also a colleague of mine from DG SANTE in the realm if there are specific questions on that. But, in general, we rather try to avoid using genetically modified organisms. And there's, as I said, strict rules and very strict procedures in place if you work with such plants. But there's also other means to use new plant varieties if they are not -- because we have some cases of invasive plants that we also try to avoid as we try to conserve our biodiversity. But I think there, we have the same issues as Brazil or in Argentina or other countries. Thank you.

HUERTA Yolanda (Ms.), Legal Counsel and Director of Training and Assistance, UPOV

Professor Cui, there is also a request for the floor from the EU Commission, Miss Päivi Mannerkorpi.

MANNERKORPI Päivi (Ms.), Team Leader - Plant Reproductive Material, Unit G1 Plant Health, Directorate General for Health and Food Safety (DG SANTE), European Commission, Brussels, Belgium

Thank you. The European Union was addressed in relation to new genomic techniques, and I would like to inform you that we are currently, on the request of Member States some years back, working on possible new legislation on new genomic techniques that would be different from the current GMO legislation that my colleague, Mr. Ranner, was referring to. So, this is an ongoing process, and we hope to see a proposal -- legislative proposal next year, and this will be then discussed with the Member States. So, just to let you know that it's an ongoing process in the European Union. Thank you.

CUI Yehan (Mr.), Vice-President of the Council, UPOV (moderator)

Thank you, Päivi, from European Union. I can see Mr. Alexandre from Brazil would like to reply. floor is yours, Alexandre.

LIMA NEPOMUCENO Alexandre (Mr.), Researcher, Brazilian Agricultural Research Corporation (EMBRAPA), Brazil (speaker)

Just to compliment. I don't know how the discussions in the European Union are going. I have been participating. Brazil have been participating, invited by the Organisation for Economic Co-operation and Development (OECD) meetings, and it's really clear the scientific community in Europe know the importance of those new brilliant technologies, mainly genome edition. And like the person that spoke before me, yes, there has been a discussion in Europe, as I know, and probably there is -- there will be new legislation. And we hope this is going to be in the same direction that is going in those countries in yellow and in blue that I show in my presentation. Thank you.

VALSTAR Marien (Mr.), President of the Council, UPOV (moderator)

Thank you, Päivi, from European Union. I can see Mr. Alexandre from Brazil would like to reply. floor is yours, Alexandre.

LIMA NEPOMUCENO Alexandre (Mr.), Researcher, Brazilian Agricultural Research Corporation (EMBRAPA), Brazil (speaker)

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THEMATIC SESSION 3:

Plant breeding for climate change adaptation and mitigation in agriculture: crop perspectives

Moderator: Mr. Patrick Ngwediagi, Chair of the Administrative and Legal Committee, UPOV

Breeding targets to improve wheat performance in drying climates: adapting wheat cropping systems to current and future climate change
Mr. Greg Rebetzke, Research Genetist, Canberra, Australia

New plant variety protection system and the cultivation of water-saving and drought-resistant rice
Mr. Yu Zhang, Research associate,Shanghai Academy of Agricultural Sciences, China

Using crop genome dynamics for stress adaptation
Mr. Etienne Bucher, Research group leader «Crop Genome Dynamics", Agroscope, Switzerland

SmartRice: a rice product grown using more sustainable methods to reduce the use of agricultural resources and provide more rice to meet the growing worldwide appetite
Mr. José Ré, Vice President, Global New Products Development – Rice Tech USA, United States of America

Questions

Characterization of the flowering phenology of the varieties of the world olive tree collection in Morocco for the selection of genotypes adapted to climate change
Ms. Hayat Zaher, Researcher, Marrakech Regional Agricultural Research Centre (CRRA), National Institute for Agricultural Research (INRA), Morocco

Climate change in the ornamental sector – A breeder's perspective
Mr. Robert Boehm, Head of Biotechnology, Selecta One, Germany

Adapting cereal varieties to climate change in the Nordic countries – which traits can plant breeding work with and which ones are much more difficult?
Ms. Tina Henriksson, Group Manager Breeding, Cereals & Pulses & Senior winter wheat breeder, Swedish Company Lantmännen, Sweden

Hot climate program: an apple breeding program for hot climate
Ms. Lidia Lozano, Researcher, Institute of Agrifood Research and Technology (IRTA), Spain

Grassroots breeding of future smart crops, better adapted to climate change: Learnings from Nepal's experience
Mr. Pitambar Shrestha, Programme Advisor, Local Initiatives for Biodiversity, Research and Development (LI-BIRD), Nepal

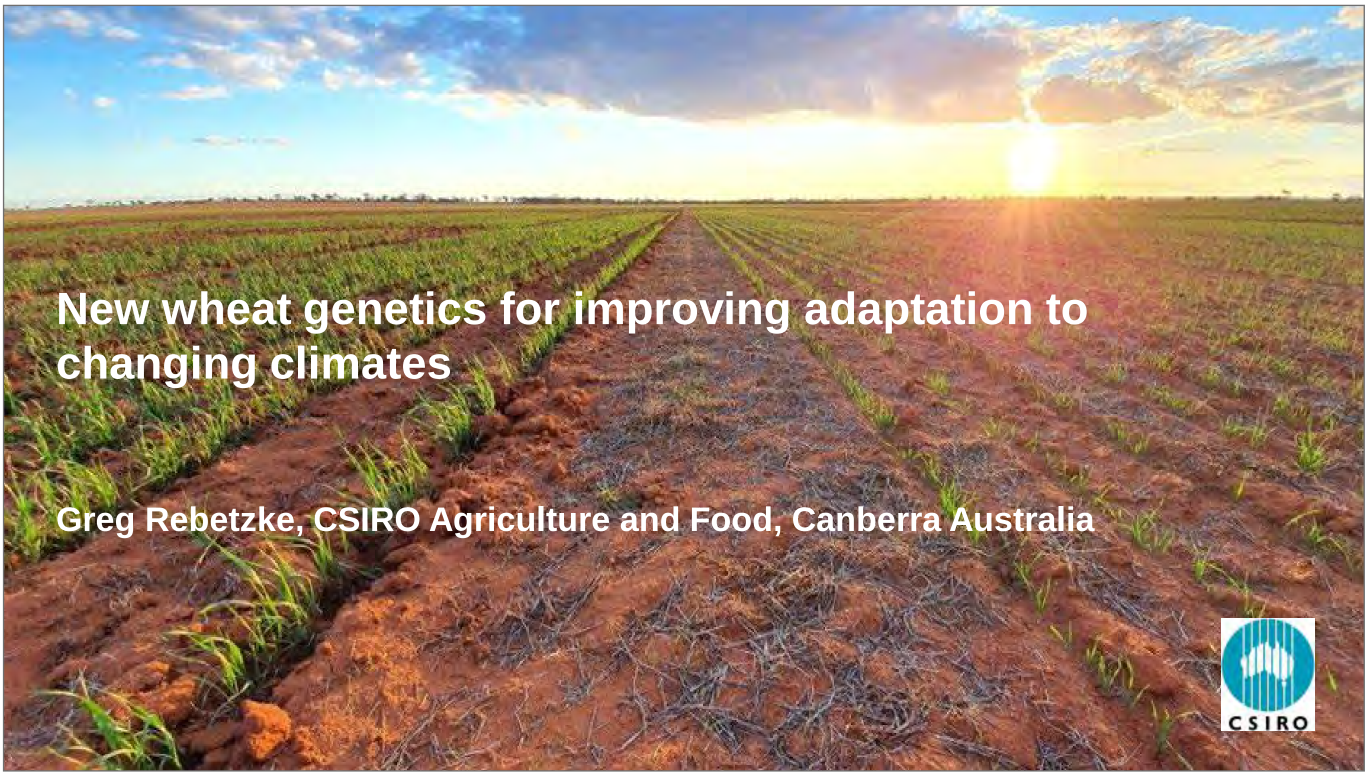
Vegetable company strategies to address the challenge of producing more food under increasingly harsh conditions and how the PBR system can help breeders to cope with such challenges
Ms. Astrid Schenkeveld, Specialist Plant Breeder's Rights & Variety Registration, Rijk Zwaan, Netherlands

Questions

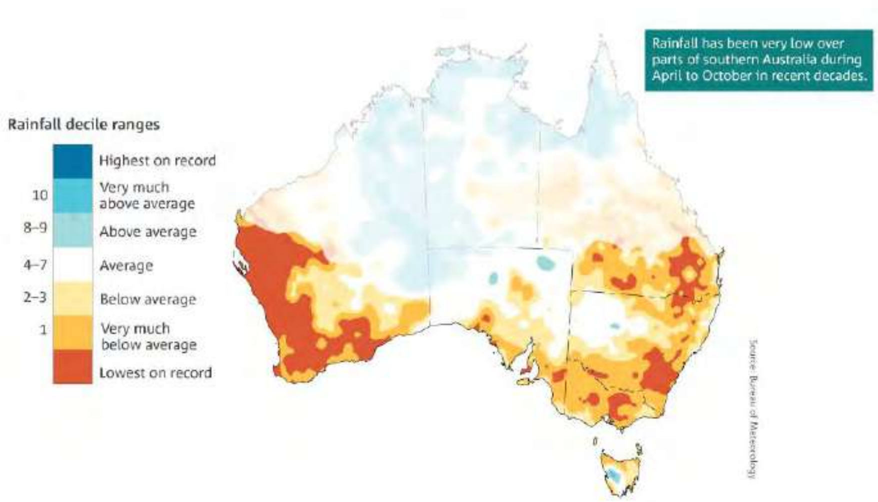
BREEDING TARGETS TO IMPROVE WHEAT PERFORMANCE IN DRYING CLIMATES: ADAPTING WHEAT CROPPING SYSTEMS TO CURRENT AND FUTURE CLIMATE CHANGE

Mr. Greg Rebetzke
Research Genetist, Canberra, Australia

Presentation made at the Seminar



Changes in April-October rainfall



Above average, average or below average winter cropping rainfall for the period 1998 to 2018, in comparison with the entire rainfall record from 1900.

…..and the future

"There is a high degree of confidence that southern Australia will spend more time in drought in future years, consistent with projected declines in rainfall"

(Source: BOM, 2020)

April to October rainfall deciles for the last 20 years (1999–2018). A decile map shows where rainfall is above average, average or below average for the recent period, in comparison with the entire rainfall record from 1900. Areas across northern and central Australia that receive less than 40 per cent of their annual rainfall during April to October have been faded.

Current focus on breeding ‘resistance’ to climate change

In Australia, future climates are predicted to be characterized by:

- greater atmospheric concentrations of CO_2
- warmer air and soil temperatures (throughout growth and particularly at sowing and through grain-filling)
- earlier and more intense frost events
- prolonged drought (reflecting more frequent but smaller rainfall events)

Solutions to breeding for climate change in the literature include:

- Small breeding cycles to rapidly select adaptation genes in keeping with climate changes (Atlin et al. 2017)
- Evolutionary breeding using on-farm participatory engagement (Ceccarelli et al. 2010)
- Target ‘stress alleles’ from wild relatives to meet challenging environmental changes (Dempewolf et al. 2014)
- Trait-based focus to improve tolerance/resistance to heat and drought (Hunt et al. 2018)

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- Evolutionary breeding using on-farm participatory engagement (Ceccarelli et al. 2010)
- **‘Stress alleles’ from wild relatives to meet challenging environmental changes (Dempewolf et al. 2014)**
- **Trait-based focus to improve tolerance/resistance to heat and drought (Hunt et al. 2018)**

Climate change and the challenge with 'resistance-based', trait-breeding

Climate constraint	Trait(s)	Value proposition?	Genetic control?	Genetic variability available?	Ease of selection
Frost/heat	Grain number (fertility), grain size	Unknown – High?	Complex	No	Difficult
Heat	Leaf architecture/ orientation	Unknown – Small?	Largely simple	Yes	Largely simple
Heat	Photosynthesis	Unknown – High?	Complex	Some	Difficult
Heat	Respiration	Unknown – Small?	Complex	No	Difficult
Heat	Development	Unknown – High?	Simple	Yes	Simple
Heat	Tillering/biomass	Unknown – High?	Complex	Some	Difficult
Drought	Many (e.g. WUE, WSC, VPD-responsiveness)	Unknown – High?	Complex	Yes	Difficult
CO_2	Grain yield/protein	Unknown – High?	Complex	Some	Difficult

+ potential for high temperatures to challenge existing disease-breeding targets and duration/effectiveness

A need to focus on breeding now for adaptation to future changing climates

Future climate impacts on crop growth appear complex (interactions in temperature extent and duration, VPD, rainfall, and CO_2)(Mark Howden pers. comm.)

A need to focus on breeding <u>now</u> for adaptation to future changing climates

Future climate impacts on crop growth appear complex (interactions in temperature extent and duration, VPD, rainfall, and CO_2)(Mark Howden pers. comm.)

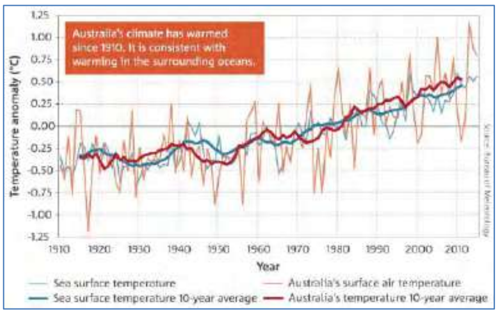
Trait-based breeding only works when there is a long-term, reliable signal for selection (genetic correlation for selection environment with TPE is high) (Rosielle and Hamblin 1980; Atlin and Frey 1989)

A need to focus on breeding <u>now</u> for adaptation to future changing climates

Future climate impacts on crop growth appear complex (interactions in temperature extent and duration, VPD, rainfall, and CO_2)(Mark Howden pers. comm.)

Trait-based breeding only works when there is a long-term, reliable signal for selection (genetic correlation for selection environment with TPE is high) (Rosielle and Hamblin 1980; Atlin and Frey 1989)

Future climate = 'reliably predictable' + significant climate variability



(source: www.climatechangeinaustralia.gov.au)

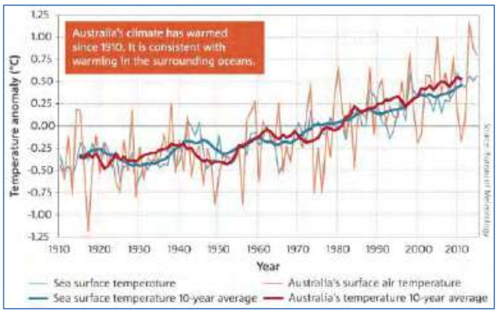
A need to focus on breeding now for adaptation to future changing climates

Future climate impacts on crop growth appear complex (interactions in temperature extent and duration, VPD, rainfall, and CO_2)(Mark Howden pers. comm.)

Trait-based breeding only works when there is a long-term, reliable signal for selection (genetic correlation for selection environment with TPE is high) (Rosielle and Hamblin 1980; Atlin and Frey 1989)

Future climate = 'reliably predictable' + significant climate variability

So, the question in breeding remains 'how much of this forecast change is predictable across long breeding cycle timespans?' Can we be confident that genes under selection with breeding now will be retained when needed in future climates?



(source: www.climatechangeinaustralia.gov.au)

A need to focus on breeding now for adaptation to future changing climates

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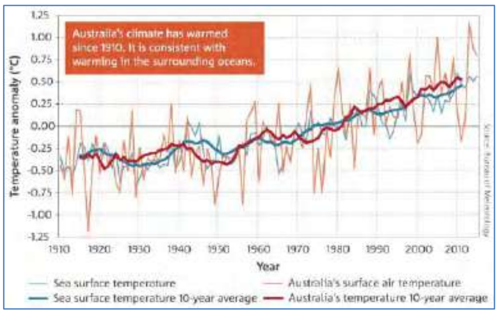
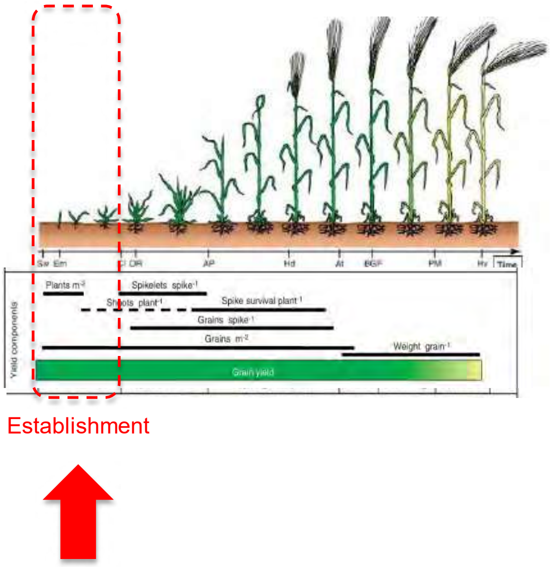
So, the question in breeding remains 'how much of this forecast change is predictable across long breeding cycle timespans?'

Do we need to change our thinking away from 100+ years of farming in reliable albeit rainfed systems? Is there need and is there opportunity to breed and develop cropping systems containing crop varieties that are more *opportunistic* than *resist* against climate change?

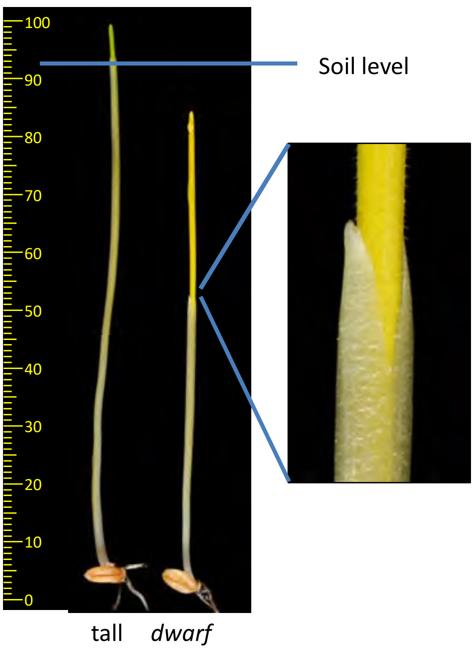


(source: www.climatechangeinaustralia.gov.au)

Opportunity breeding - Optimising crop establishment



The coleoptile: genetics to better link seed to soil surface



Coleoptile length determines how deep seed can be sown

Challenges in successful wheat establishment with changing climates

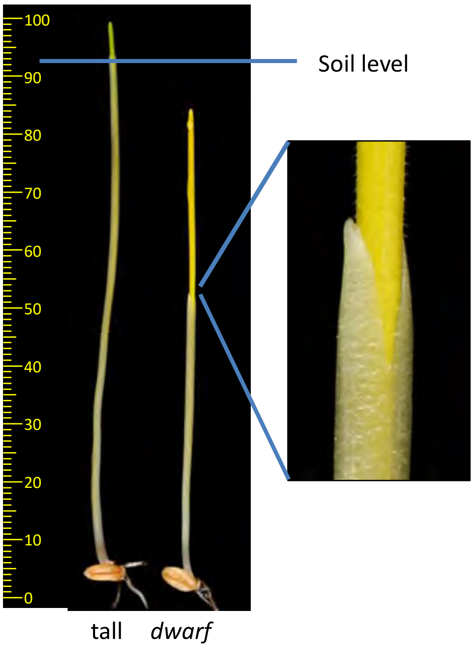
Declining autumn rainfall (April-May)
- later germination and risks with dry sowing
- greater reliance on stored moisture (deep sowing)

Early sowing of longer season varieties
- soil temperature can increase by 10-15°C
- high soil temperatures reduce coleoptile length

Soil factors
- furrow in-fill with wind and rain

Key trait: long coleoptiles that ensure timely emergence and assured crop establishment

The coleoptile: genetics to better link seed to soil surface



Coleoptile length determines how deep seed can be sown

Dwarfing 'height' genes affect coleoptile length:

Since the early 1960s, coleoptile length was known to be shortened and establishment reduced with Green Revolution dwarfing genes and particularly in warmer soils (Allan et al. 1962)

Replacing green Revolution with new dwarfing genes to increase coleoptile length – here sowing at 12cm depth

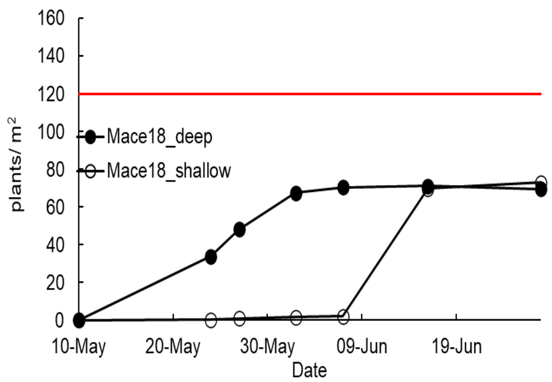
Green revolution *Rht2* dwarf

***New Rht18* dwarf**

Mike Lamond (SLR)

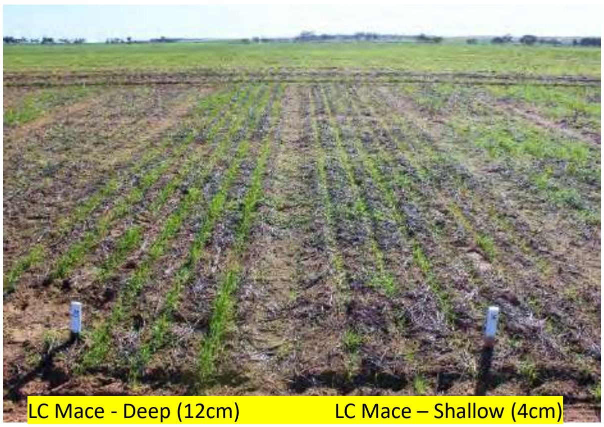
Accessing subsoil moisture for early germination and growth

Sowing Date: 10 May (seasonal break 31 May)



Source: Dr Bonnie Flohr, CSIRO

Summer fallow rainfall (Nov-Mar): 77 mm



Earlier shoot and root growth with sowing into deep moisture
(<u>note</u> increased weed numbers with late emergence of shallow depth)

Accessing subsoil moisture for early germination and growth

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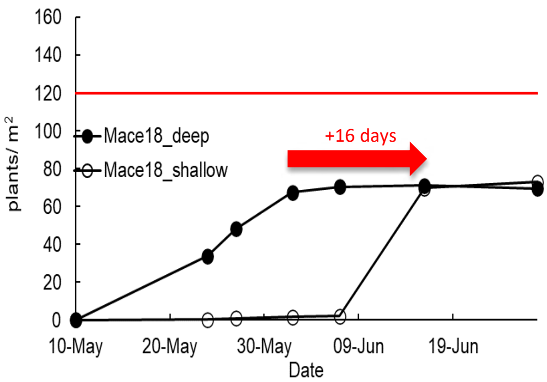
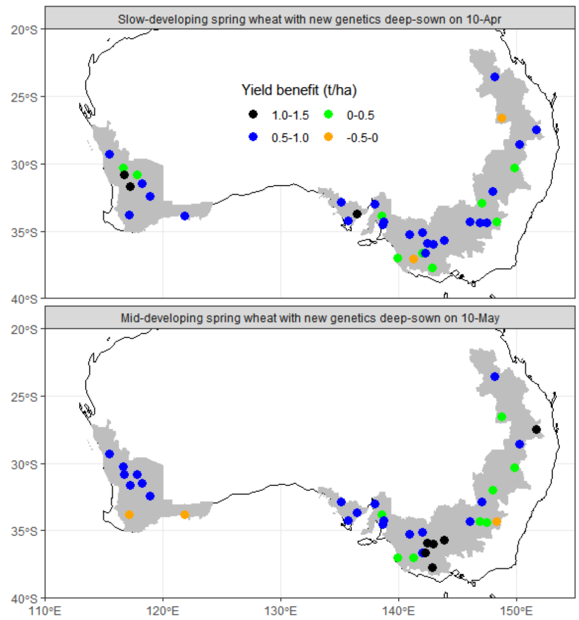


Source: Dr Bonnie Flohr, CSIRO

Earlier shoot and root growth with sowing into deep moisture
(note increased weed numbers with late emergence of shallow depth)

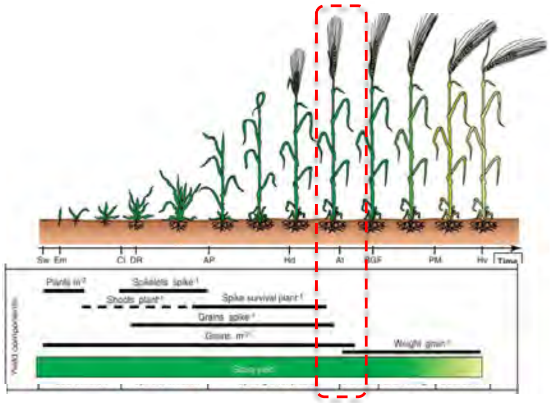
Modelled Yield Benefit of Long Coleoptiles Across Australia for Future Climates



18-20% mean annual yield benefit (1901-2020) of wheat with new genetics (long coleoptiles and greater early vigour) sown at 120mm depth compared to baseline wheat sown at 45mm depth at 37 sites

(Zhao et al. 2022; *Nature Climate Change*)

Opportunity breeding - Awnless wheats for changing climates



Removing awns for frost-, heat- and drought-prone wheat regions

Awns damage animals mouths to reduce the value of frost-, heat- and drought-affected crops for animal feed

Grower returns can be high for awnless, high soluble-sugar hay

Frost-damaged wheat crop

Wheat bailed as hay for feed

Reducing financial risk – delivery of new CSIRO-bred, awnless wheat varieties ‘LRPB Bale’ and ‘LRPB Dual’ for grain or hay/grazing

Key messages

Breeding for climate change (**and changing climates**) must be in train now but will be challenging:

- Target environments will be climatically complex
- With adequate genetic variation, breeding cycles still take time
- Selection relies on an established environment types (‘TPE’) - progress will be slower in breeding for variable climates than where change is unpredictable and less directed
- Risk potential loss in key climate adaptation alleles in absence of a reliable stress (and particularly if there is a performance cost in its absence!)

Clear evidence of climate change (and variability) now:

- Genetic variation exists that provides and prepares for climate adaptation now and into the future (e.g. long coleoptiles for deep sowing, development genes for targeted sowing dates, greater early vigour for late sowing opportunities, awnless wheats for grazing/hay etc.)
- Provide farmers with genetic options that best fits their farming system and allows them to ‘play the season’ while reducing financial and environmental risk

Acknowledgements

- SLR Agriculture (WA): *Michael Lamond and team*
- CSIRO: *Therese McBeath, Belinda Stummer, Andrew Fletcher, Bonnie Flohr, Sarah Rich, John Kirkegaard, Zhigan Zhao, Enli Wang, and team*
- EPAG Research (SA): *Andrew Ware, Rhaquelle Meiklejohn, and team*
- AgGrow Agronomy and Research (NSW): *Barry Haskins, Rachael Whitworth, and team*
- Dept Agric. and Fisheries (QLD): *Darren Aisthorpe and team*
- DPIRD (WA): *Steven Davies and team*
- LongReach Plant Breeders: *Colin Edmondson and Bertus Jacobs*

- GRDC projects SLR2103-001RTX, DAQ2104-005RTX, UCS2105-002RSX, CSP00183; CSIRO Drought Resilience Mission; DAWE

CLIMATE CHANGE: AN OPPORTUNITY FOR INNOVATION IN AGRICULTURE

Mr. Yu Zhang
Institute For Agri-Food Standards And Testing Technology, Shanghai Academy Of Agricultural Sciences, Shanghai, China

Rice is an important crop plant, accounting for about one third of grain crops. With the development of urbanization, the area of agricultural land use is gradually reduced and the extensive management mode has reduced the yield of rice. Moreover, in recent years, extreme climate such as drought and high temperature have occurred frequently, leading to severe challenges for rice yield.

In addition, we must acknowledge that global warming increases the greenhouse gas emissions from rice paddies, while greenhouse gas emissions promote global warming, ultimately causing rice-yield losses and greatly threatening global food security. Therefore, greenhouse gas emissions from rice paddies are an unprecedented major concern in the context of food security, which is drawing global attention. A major challenge in the development of sustainable rice is how to break the vicious cycle of greenhouse gas emissions and global warming in rice production. In China, the goal of carbon neutrality in rice production, which means zero net CO_2 emission from rice field, has been proposed. Therefore, the need to cultivate water-saving, drought-resistant, environment-friendly and artificial rice varieties is urgent.

Professor Lijun Luo has classified inherited complex drought resistance into three types:

- Dehydration avoidance (DA) refers to the plant's capacity to sustain high water status by water uptake or a reduction of water loss in dry conditions.
- Dehydration tolerance (DT) is defined as the relative capacity of plants to maintain function under low leaf water status. The measure of this capacity includes several physiological traits such as osmotic adjustment, abscisic acid (ABA) content, proline content, soluble sugar content, antioxidase etc.
- Drought recovery (DR) refers to the recovery capability of the plant after a period of severe drought which causes the complete cessation of growth, a complete loss of turgor and leaf desiccation.

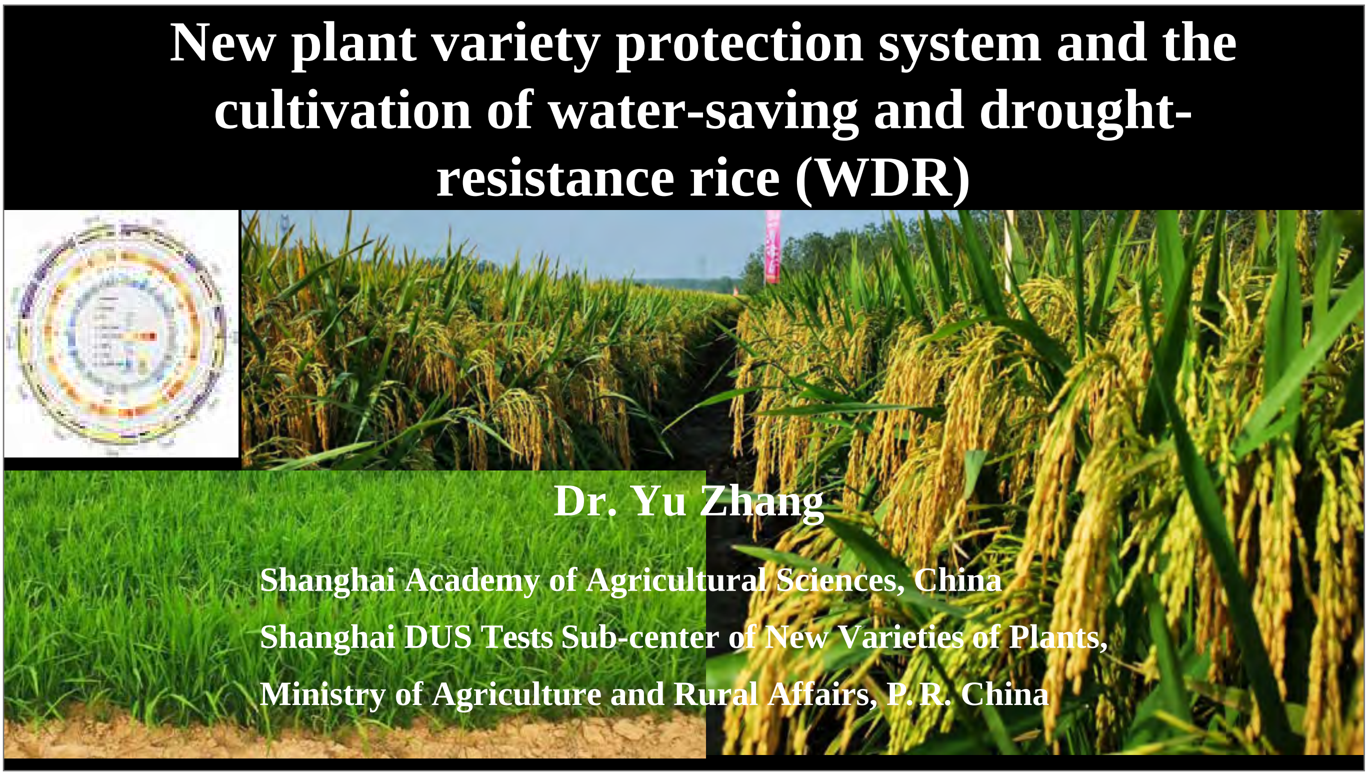
Hanyou73 is an important water saving and drought resistence rice (WDR) variety, authorized in 2016. The grouth cultivation of Hanyou73 in aerobic cultivation reduced about 97.2% of CH4 emissions compared with common rice varieties with flooding cultivation. Given the rapid development and commercialization of WDR, we can optimize a planting area of 670,000 hectares in China over the next five years, which has been projected in a current program for the high-quality development of seed industry in Shanghai. This means an annual reduction of 156,100 tons of CH4 emissions from rice paddies by replacement with WDR in total. Once the reduced carbon dioxide equivalent by WDR cultivation can be exchanged in the market, it can provide an extra benefit for farmers annually.

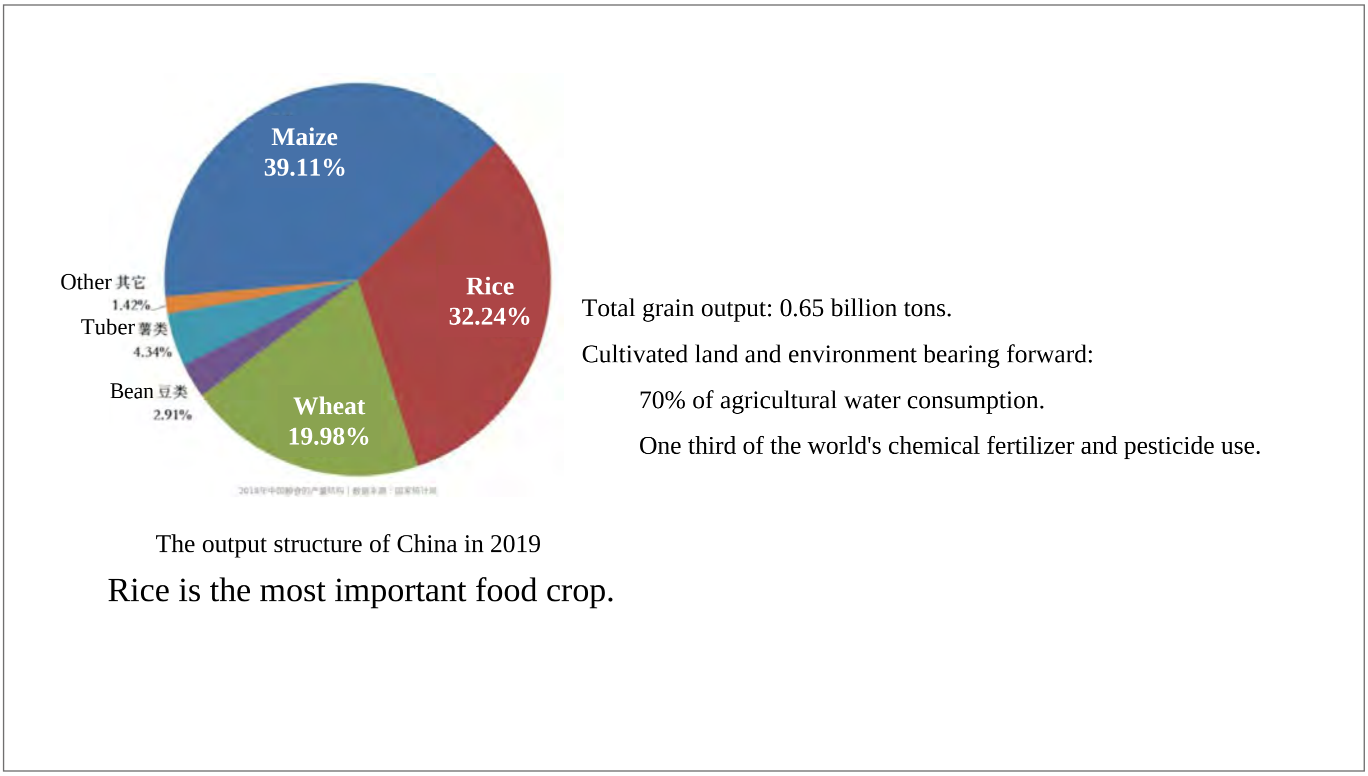
Advantages of breeding water-saving and drought-resistant rice:

- For paddy fields: change cropping methods.
- Changing the traditional way of growing rice, environment friendly and realizes resource savings.
- For dry land: adjust planting structure.
- Adjust crop planting structure, realizing value-added farmland to increase farmers' incomes.
- For new land: expand rice production area.
- WDR variety will be used in abandoned farmlands and hillslopes.

We believe that the WDR variety will achieve water- and labor-saving results, and emission reduction.

Presentation made at the Seminar





1、The increase in the national average rice yield is limited

2. Rice production relay on much labor force, while the economic benefit is low

lowland rice are poor in drought resistance and not leaving water.
It is not suitable for large scale mechanization because of poorly direct seeding character.
It's getting more expensive to plant.

3. Rice accounts for 50% of the total water consumption

Water resources per capita are declining in a water short country

2002 2200 m³
2030 1800 m³

Irrigation water shortage exceeds 120 billion m³ every year

4. Traditional rice production caused serious environmental pollution

With the increase of pesticide and fertilizer application, the environmental pollution becomes more and more serious.

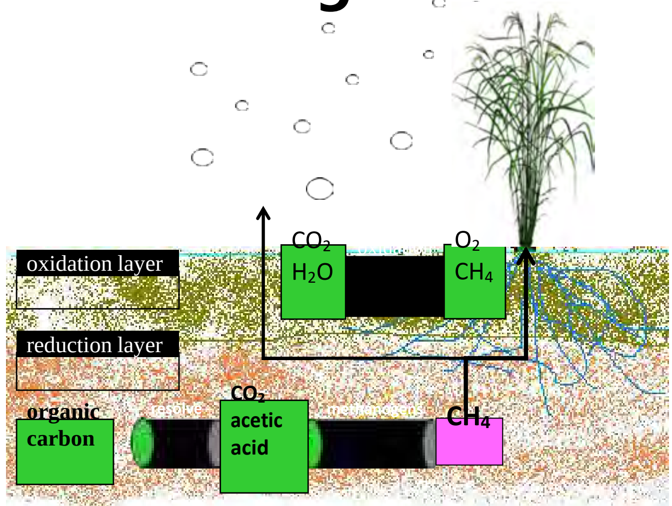
Low fertilizer utilization
Nitrogen fertilizer 35%
Phosphate fertilizer 25%

A lot of pesticides were used, whlie utilization rate is only 30%

5. Rice production produces a lot of greenhouse gases

《Climate Change Assessment report》

Year	Tm increased
2020	1.1 - 2.1 ^0C
2030	1.5 - 2.8 ^0C
2050	2.3 - 3.3 ^0C



Methane emission from paddy fields in China accounted for 19.73%

Slides from Yan X Y(2014)


nature COMMUNICATIONS

North China Plain threatened by deadly heatwaves due to climate change and irrigation

Global temperature to exceed 35 degrees Celsius several times in 2070-2100

Troubles: 1. Rice varieties are greatly affected by extreme environment.

2. Fresh water resources are very limited.

Solution: To cultivate **drought-resistance** and **ecologically friendly** rice varieties.

Evolution and differentiation between lowland and upland rice

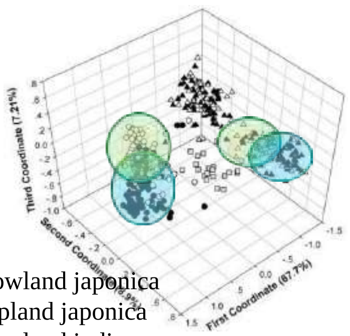
Oryza rufipogon Grif

From dry la to paddy fields

Upland is easy to planting.
The environmental pollution was lower compared to traditional rice variety produced.

Water demand increased
Drought resistance and direct seeding decreased

There was significant genetic differentiation between lowland and upland rice



- ○ lowland japonica
- ● upland japonica
- △ lowland indica
- ▲ upland indica
- □ Oryza rufipogon Grif

Table 6. Gene symbol, gene ID, and the annotated functions of the decisive selective loci detected in this study.

Locus	Gene symbol	Gene ID	Names	Predicted function
E647	Os01g0607400	4324222	hypothetical protein	Similar to STYLOSA protein
E359	Os06g0702600	4341978	hypothetical protein	Similar to Auxin response factor 7a
E1899	Os12g0563600	4352535	hypothetical protein	Protein of unknown function, DUF538 family protein
E3735	Os07g0260000	4342870	hypothetical protein	Protein prenyltransferase domain containing protein
E1238	Os10g0554200	4349339	hypothetical protein	TGF-beta receptor, type I/II extracellular region family protein
E1177	Os06g0633300	4341588	hypothetical protein	Phytosulfokines 1 precursor [Contains: Phyto sulfokine-alpha (PSK- alpha) (Phytosulfokine-a); Phytosulfokine-beta (PSK-beta) (Phytosulfokine-b)]
E4208	Os07g0546500	4343527	hypothetical protein	Conserved hypothetical protein

doi:10.1371/journal.pone.0106352.t006

Several selective Loci of drought-responding ESTs were identified to associated with the drought resistance of rice

Xia et al. 2014,Plos One

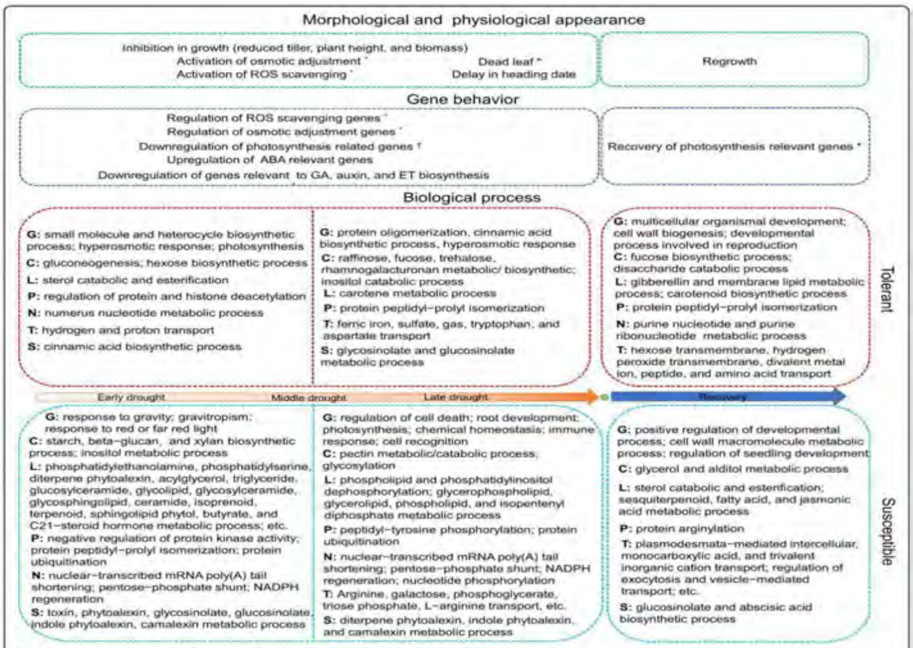
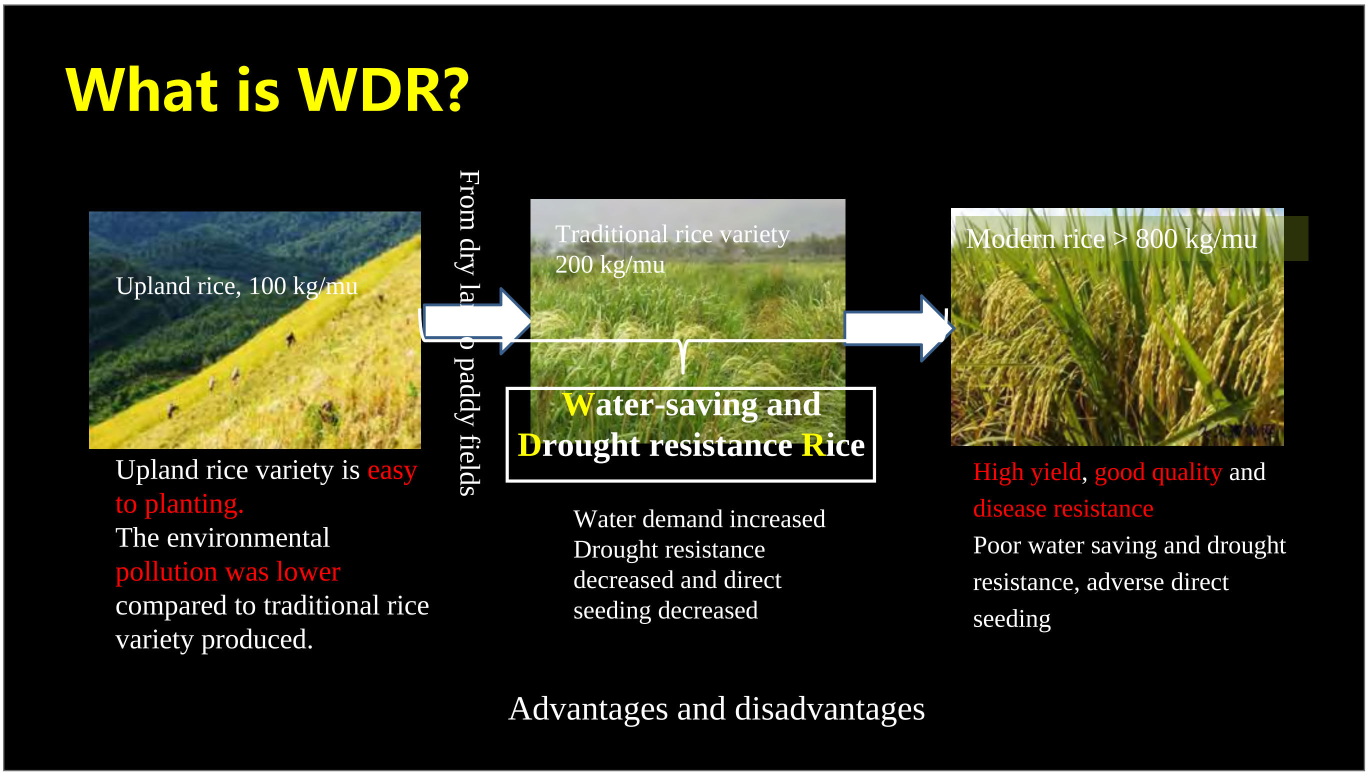


Fig. 4 Description of drought tolerance- and susceptibility- featured morphological responses, transcriptomic dynamics, and biological processes during drought and at the recovery stage. * indicates significant difference between tolerant and susceptible genotypes; † indicates different temporal patterns between tolerant and susceptible genotypes. C: carbohydrate metabolic process; G: general biological process; L: lipid metabolic process; N: nucleic acid metabolic process; P: protein metabolic process, S: secondary metabolic process; T: transport

The morphological, physiological responses, gene behaviors and biological mechanisms were different between drought-tolerant and susceptible cultivars in response to drought stress.

Xia et al. 2020 BMC Genomics



The development of WDR varierty: from concept to practice and theory

《Journal of Experimental botany》 Published concept and cultivate strategies

- •Paddy field direct seeding with drought management, water saving 50%, reduce pesticide fertilizer, stable rice yield
- •Dry land direct seeding with drought management, expand rice planting area.
- •Save labour and plant easily, and greatly reduce diffuse pollution and greenhouse gas emission.

2013

Second Prize of National Science and Technology Invention

2016

The Ministry of Agriculture promulgates industry standards related WDR

2020

First Prize of National Scientific and technological progress

Drought resistance of crops

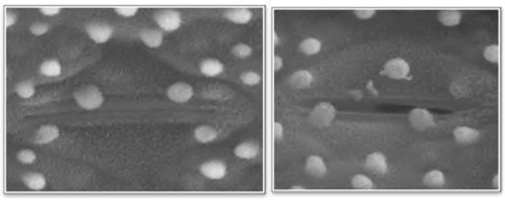
1.Drought Avoidance, DA

2.Drought Tolerance, DT

3.Drought Recovery, DR

Luo Lijun. 2010 JXB

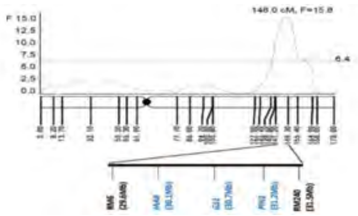
Drought avoidance



Deep root ratio (RDR) is an important index to measure drought resistance

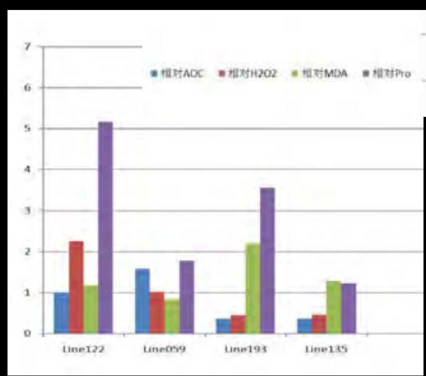
IRAT 109, a upland rice cultivar from Africa, was found with higher RDR and DA, was widely used in both gene identification and WDR breeding program

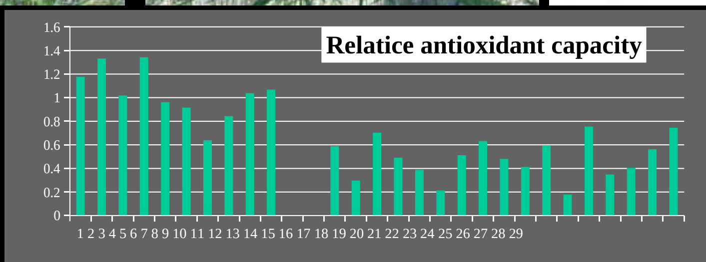
Fig. 1. Root architectures of the parents of the RILs.



Lou et al. 2015 JXB

Drought tolerance





Drought recovery

Stop water for 22 days

Recovery 3 h

Recovery 6.5 h

Achievements

There are 27 certified varieties, including 5 Chinese certified varieties and 22 provincial certified varieties. The research has been published in many journals such as in Cleaner Production, Molecular Plant, Plant Biotechnology Journal, Journal of Environmental Botany, Sciticific Report, Frontiers in Plant Science and so on.

HanYou73: Application for plant variety rights

综合查询

植物种类	水稻 Oryza sativa L.
品种名称	旱优73号
申请号	20110870.0
申请日	2011年11月11日
申请人	上海市农业生物基因中心
共同申请人	上海天谷生物科技股份有限公司
目前状态	授权
申请公告日	2012年3月1日
授权日	2016年3月1日
品种权人	上海市农业生物基因中心
共同品种权人	上海天谷生物科技股份有限公司

植物种类：	水稻
品种名称：	旱优73号
申请号：	20110870.0
申请日：	2011-11-11
申请人：	上海市农业生物基因中心
审查状态：	授权
申请公告日：	2012-03-01
授权号：	CNA20110870.0
授权日：	2016-03-01
公告号：	CNA007031G
品种权人：	上海市农业生物基因中心
品种权地址：	上海市北翟路2901号(201106)

HanYou73: was certification in Anhui, Hubei and Guangxi provience

High yield and quality

Water-saving drought-resistant

high temperature tolerance

and direct seeding

The character of WDR variety

Easy cultivation

Resistance to direct seeding

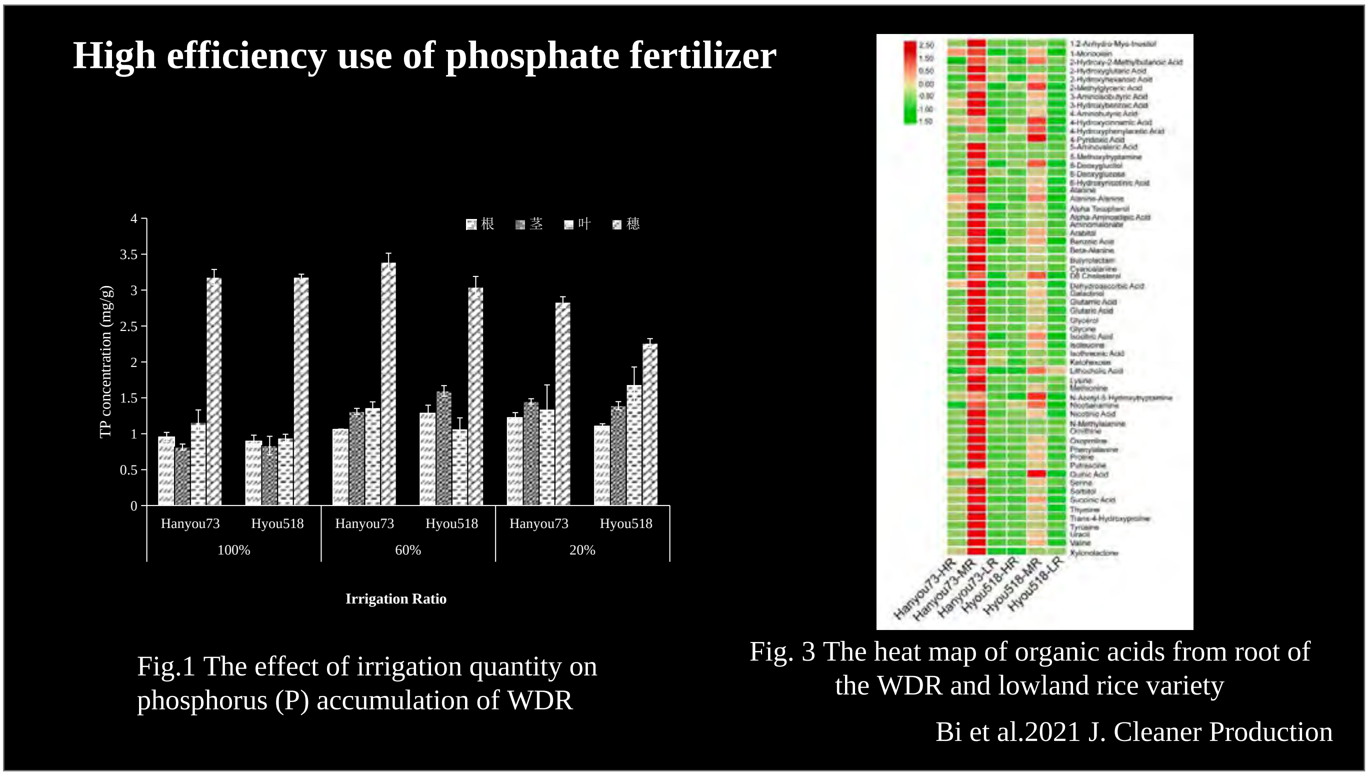
Rooting capacity, flooding tolerance, weeds (rice)

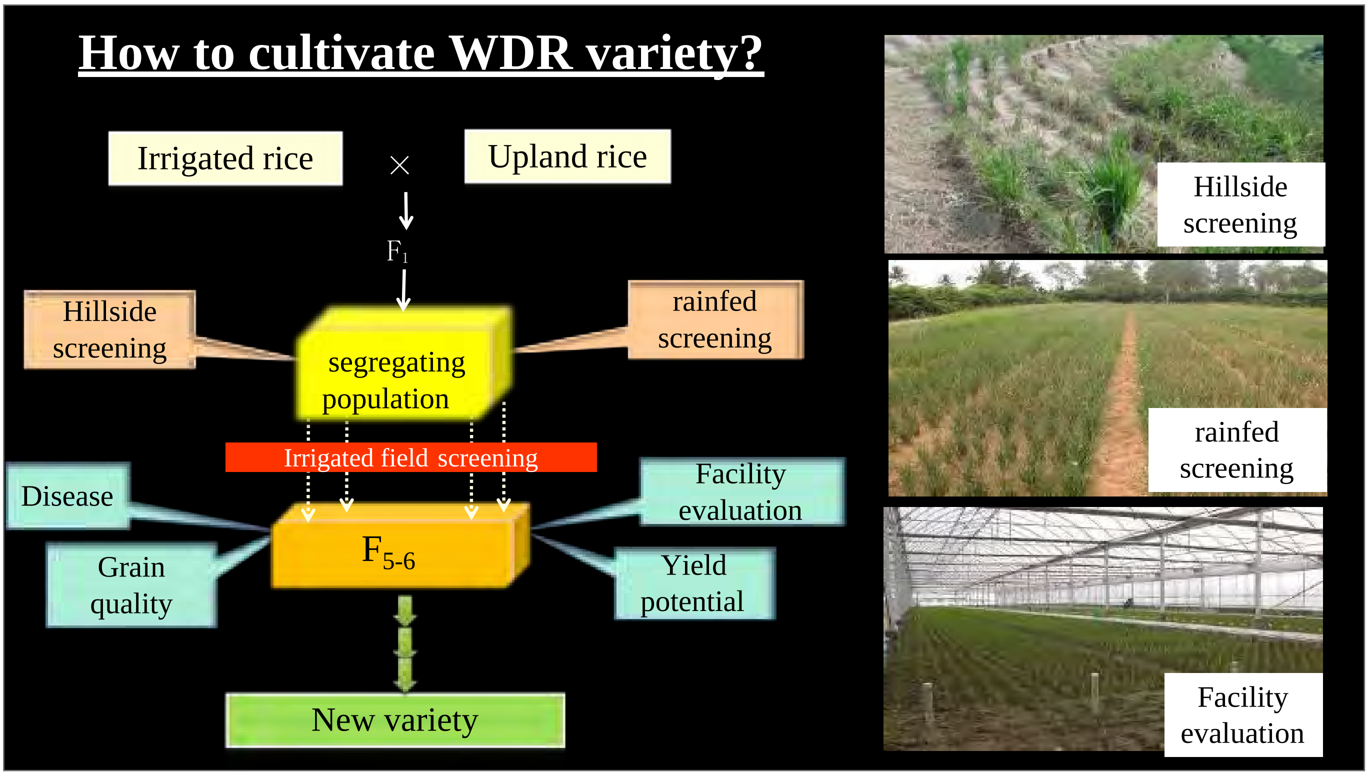
Efficient use of fertilizer

Environment friendly.....

Resistance to direct seeding

HanHui3 **HanYou73**


High efficiency use of phosphate fertilizer
TP concentration (mg/g)
根 茎 叶 穗
Hanyou73
Hyou518
Hanyou73
Hyou518
Hanyou73
Hyou518
100%
60%
20%
Irrigation Ratio
Hanyou73-HR
Hanyou73-MR
Hanyou73-LR
Hyou518-HR
Hyou518-MR
Hyou518-LR
Fig.1 The effect of irrigation quantity on phosphorus (P) accumulation of WDR
Fig. 3 The heat map of organic acids from root of the WDR and lowland rice variety
Bi et al.2021 J. Cleaner Production


How to cultivate WDR variety?
Irrigated rice
×
Upland rice
F_1
Hillside screening
segregating population
rainfed screening
Irrigated field screening
Disease
Facility evaluation
Grain quality
F_{5-6}
Yield potential
New variety
Hillside screening
rainfed screening
Facility evaluation

The goal of developing WDR variety

1. For paddy fields: Change cropping methods
2. For dry land: adjust planting structure
3. For new land: expand rice production area

Areas for developing WDR variety

I. Paddy field: water (drought) direct seeding and drought management

Changing the traditional way of growing rice
Realize resource saving and environment friendly!

Areas for developing WDR variety

II. Upland cropping (prone to waterlogging)

Adjust crop planting structure

Realizing value-added farmland to increase farmers' incomes

Target areas for WDR variety

III farmlands abandoned

Basic farmland will go up the mountain

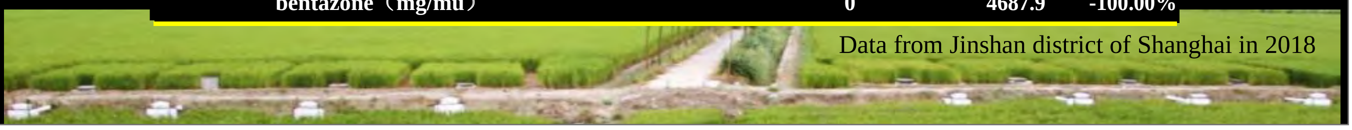
hillslope

The performence of WDR variety Hanyou3 in Guangxi provence in 2021

Reduction emission demonstration of WDR variety direct seeding in lowland field

		Huhan61（WDR）	Xiushui134（CK）	（%）
Input	Water（m^3/mu）	210	450	-53.30%
	Urea（kg/mu）	6	25	-76.00%
Output	yield（kg/mu）	717.9	679.1	5.40%
	grain quality	excellent quality	general	
Emission	nitrogen（g/mu）	19.63	68.05	-71.20%
	phosphorus（g/mu）	7.2	11.68	-38.40%
	CH_4（mg/mu）	100	500	-80.00%
	2methyl4chlorodicarbonamide（mg/mu）	0	27.24	-100.00%
	orthene（mg/mu）	0	4613.1	-100.00%
	avilamycin（mg/mu）	0	172.9	-100.00%
	indoxacarb（mg/mu）	1.14	9.92	-88.50%
	nitenpyram（mg/mu）	124.82	1004.94	-87.60%
	bentazone（mg/mu）	0	4687.9	-100.00%

Data from Jinshan district of Shanghai in 2018



WDR are going international

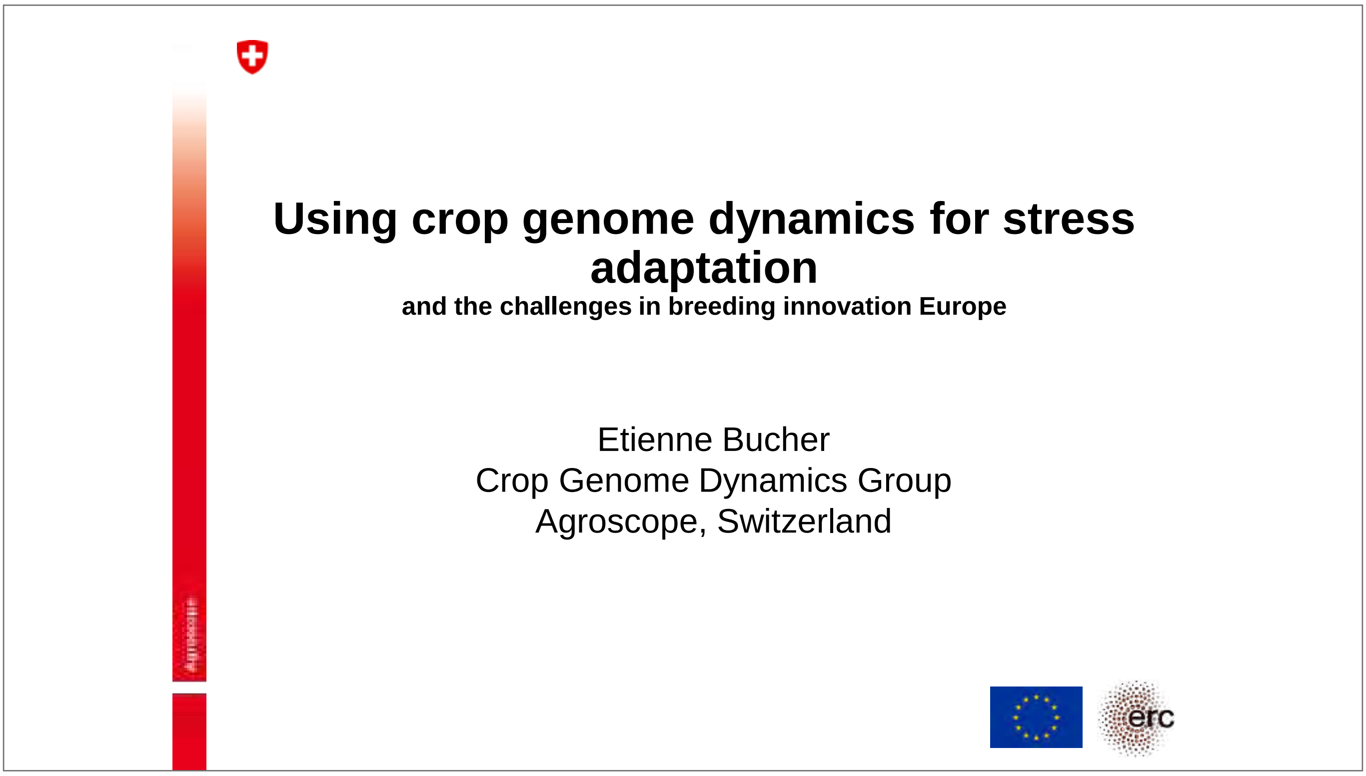
Consideration

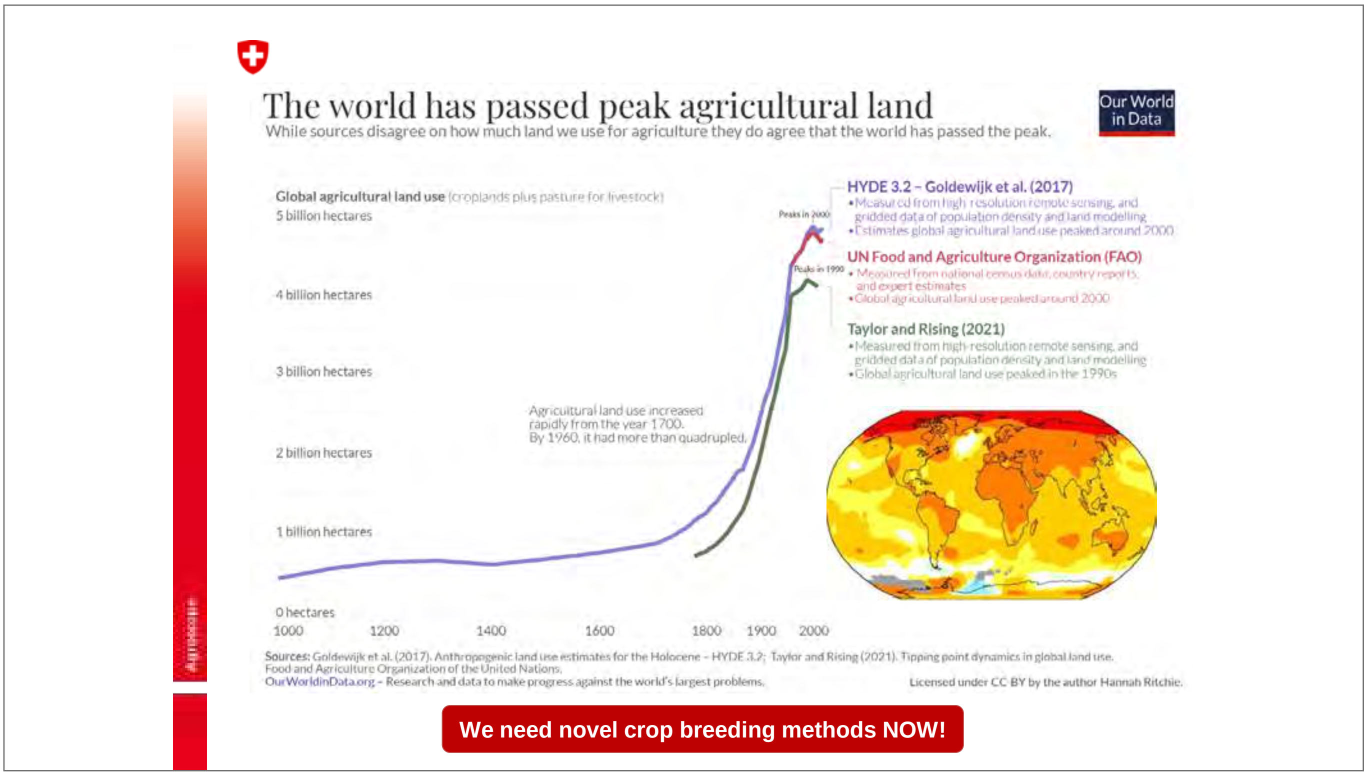
Environmental factors, such as drought, direct seeding, high temperature and flooding resistance, make it more and more urgent for agriculture to breed superior varieties. In the process of DUS testing, it is necessary to evalute the drought resistance of plants to cope with the climate change. Whether these stress-related traits can be selected for testing which needs further discussion in the future.

USING CROP GENOME DYNAMICS FOR STRESS ADAPTATION

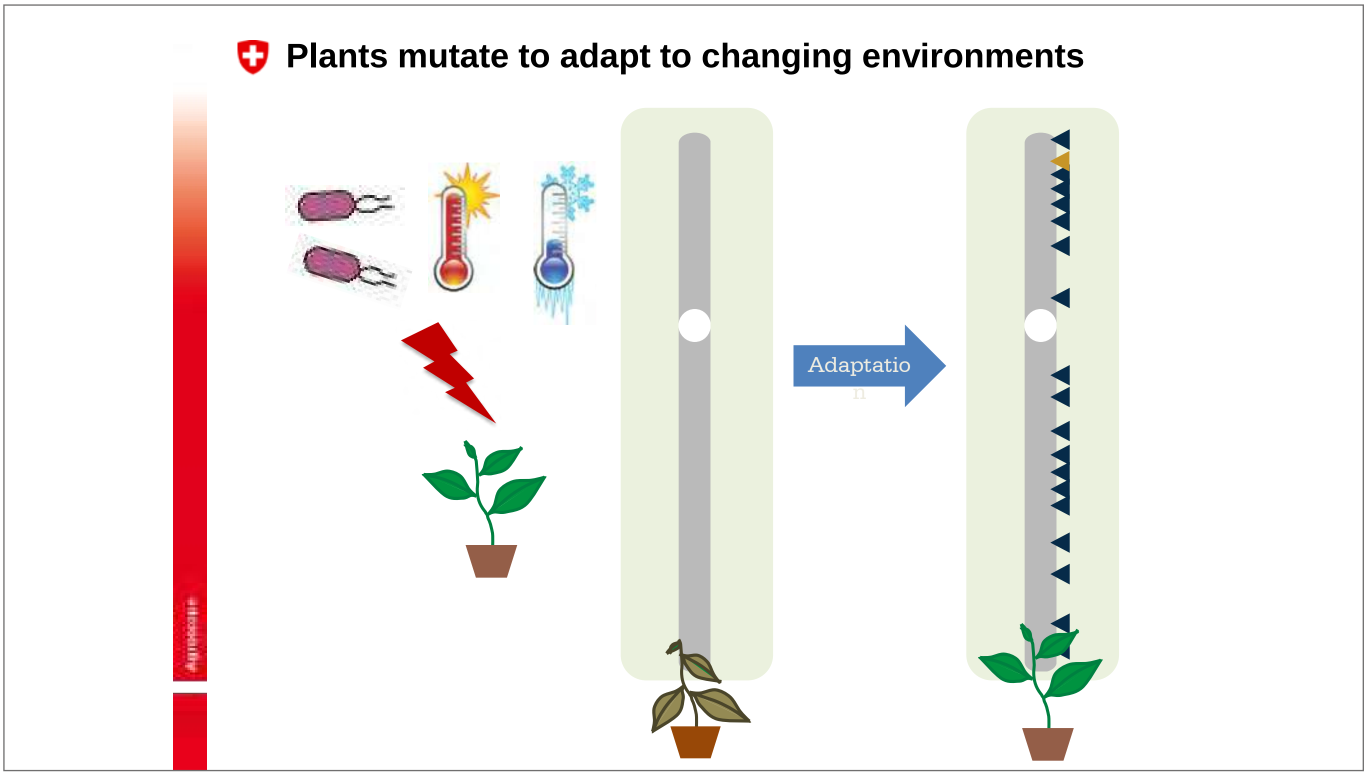
Mr. Etienne Bucher
Research group leader «Crop Genome Dynamics", Agroscope, Switzerland

Presentation made at the Seminar

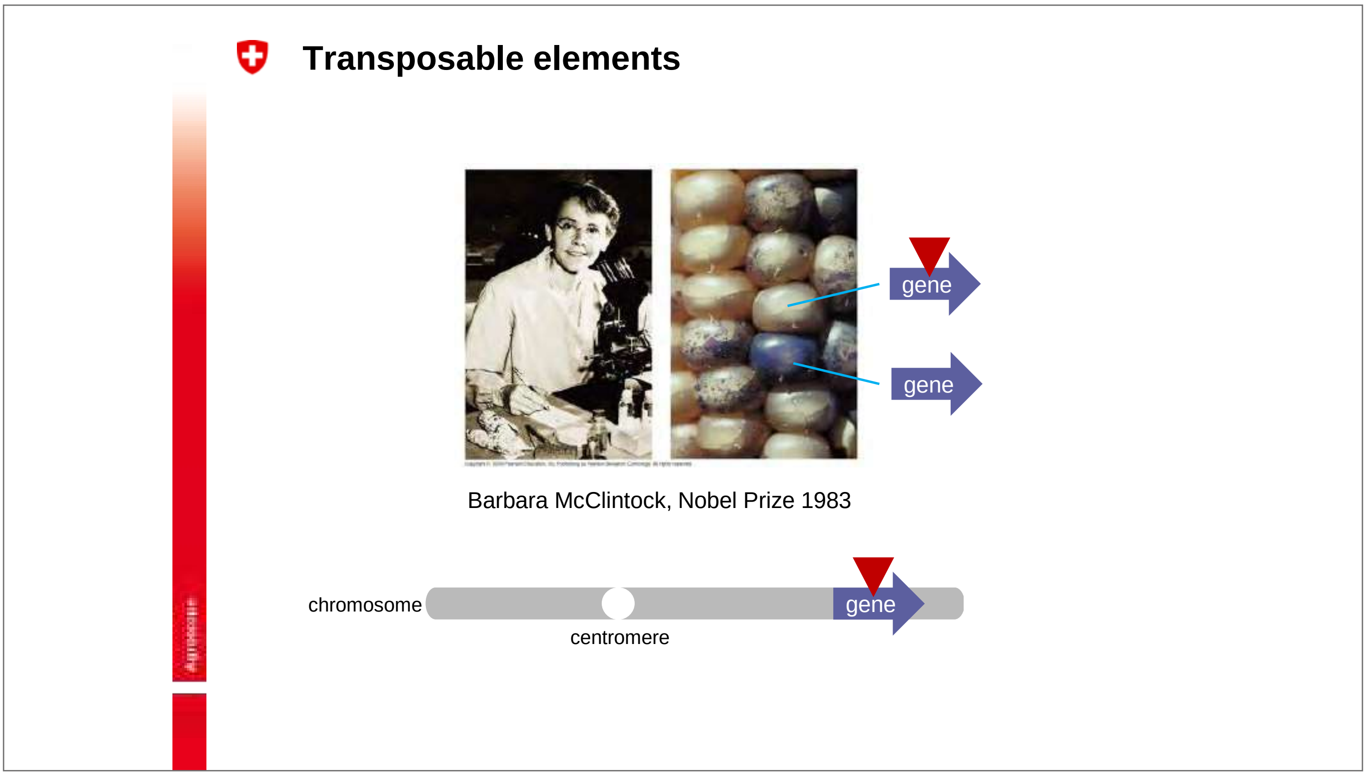


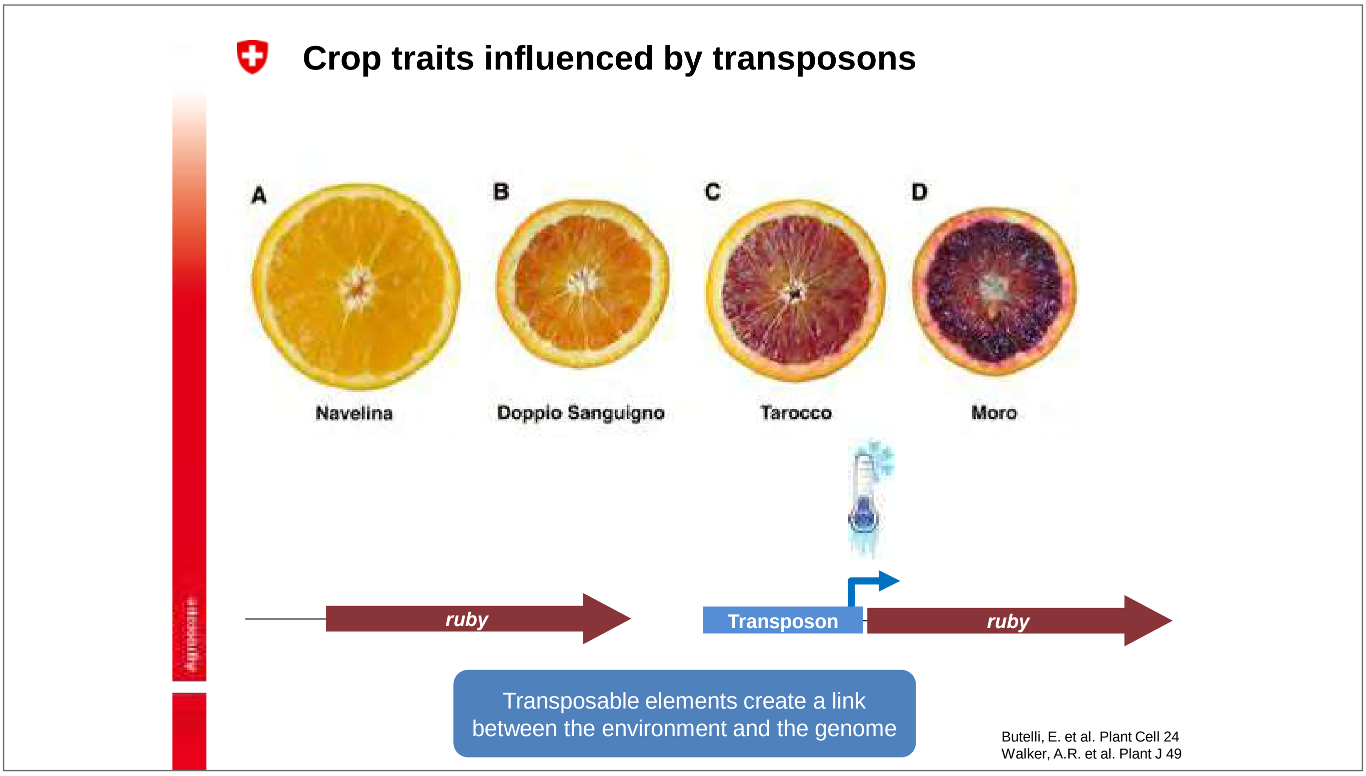


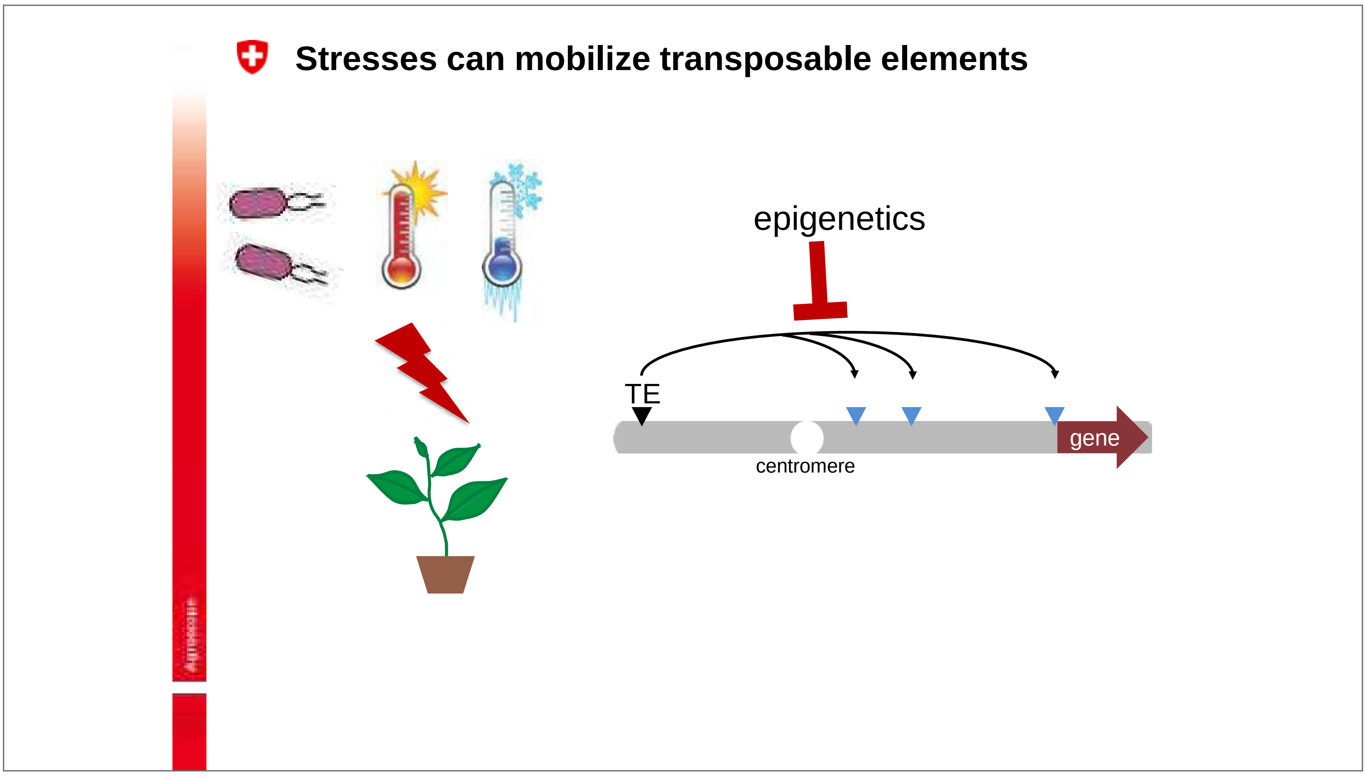
The world has passed peak agricultural land
While sources disagree on how much land we use for agriculture they do agree that the world has passed the peak.
Our World in Data
Global agricultural land use (croplands plus pasture for livestock)
5 billion hectares
4 billion hectares
3 billion hectares
2 billion hectares
1 billion hectares
0 hectares
1000
1200
1400
1600
1800
1900
2000
Agricultural land use increased rapidly from the year 1700. By 1960, it had more than quadrupled.
HYDE 3.2 – Goldewijk et al. (2017)
•Measured from high resolution remote sensing, and gridded data of population density and land modelling
•Estimates global agricultural land use peaked around 2000
UN Food and Agriculture Organization (FAO)
• Measured from national census data, country reports, and expert estimates
•Global agricultural land use peaked around 2000
Taylor and Rising (2021)
•Measured from high-resolution remote sensing, and gridded data of population density and land modelling
•Global agricultural land use peaked in the 1990s
Sources: Goldewijk et al. (2017). Anthropogenic land use estimates for the Holocene – HYDE 3.2; Taylor and Rising (2021). Tipping point dynamics in global land use. Food and Agriculture Organization of the United Nations.
OurWorldinData.org – Research and data to make progress against the world's largest problems.
Licensed under CC BY by the author Hannah Ritchie.
We need novel crop breeding methods NOW!

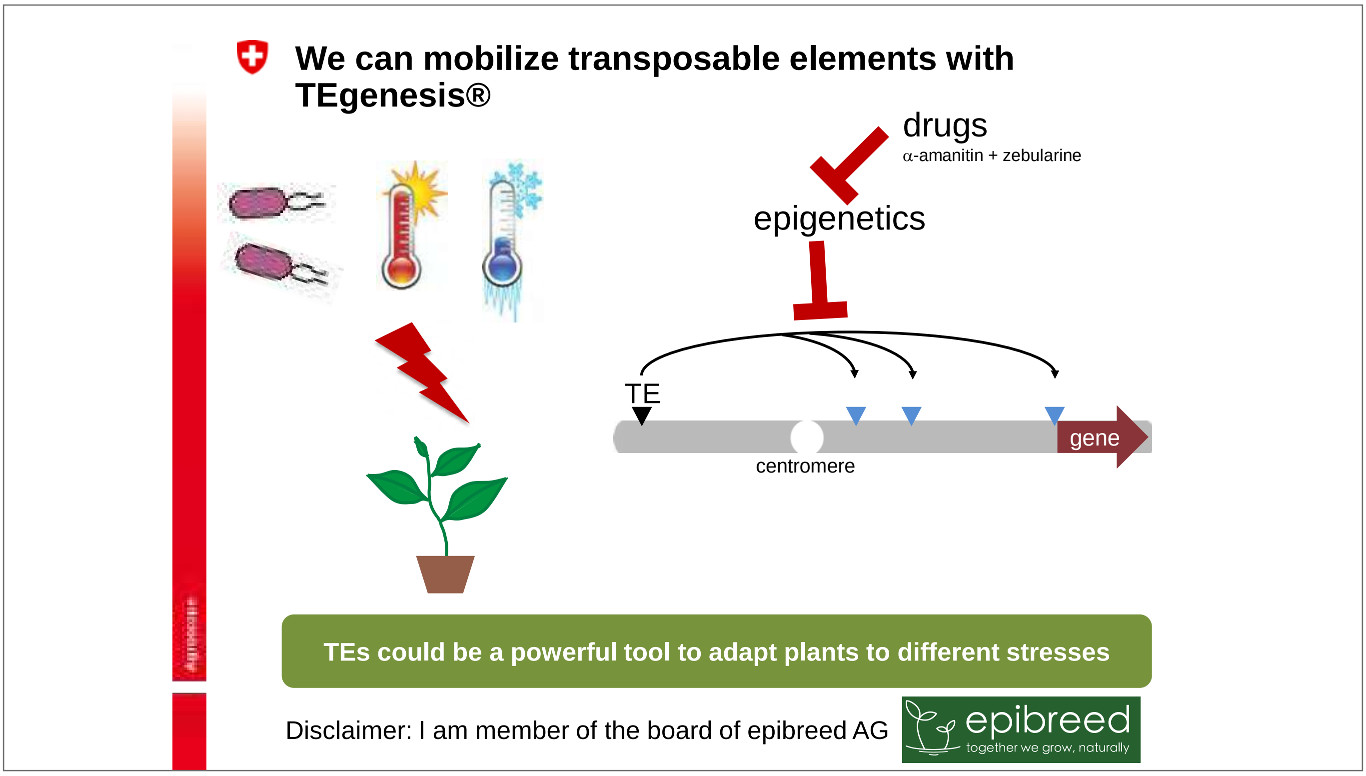


Plants mutate to adapt to changing environments
Adaptatio


Transposable elements
gene
gene
Barbara McClintock, Nobel Prize 1983
chromosome
gene
centromere


Crop traits influenced by transposons
A
B
C
D
Navelina
Doppio Sanguigno
Tarocco
Moro
ruby
Transposon
ruby
Transposable elements create a link between the environment and the genome
Butelli, E. et al. Plant Cell 24
Walker, A.R. et al. Plant J 49

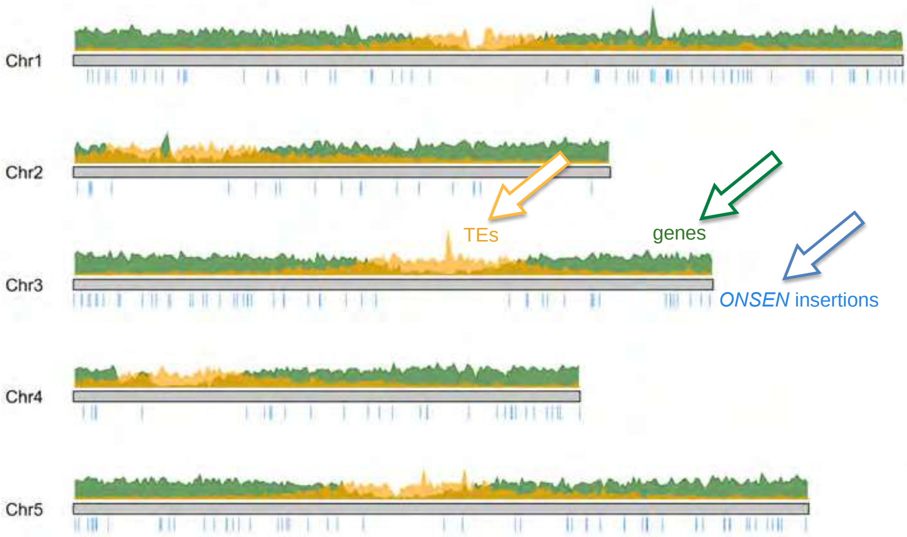

Stresses can mobilize transposable elements
epigenetics
TE
centromere
gene


We can mobilize transposable elements with TEgenesis®
drugs
α-amanitin + zebularine
epigenetics
TE
centromere
gene
TEs could be a powerful tool to adapt plants to different stresses
Disclaimer: I am member of the board of epibreed AG
epibreed
together we grow, naturally

Novel *ONSEN* transposable element insertions cause diverse phenotypes

Thieme, M. et al Genome Biol; 2017;18: 134.

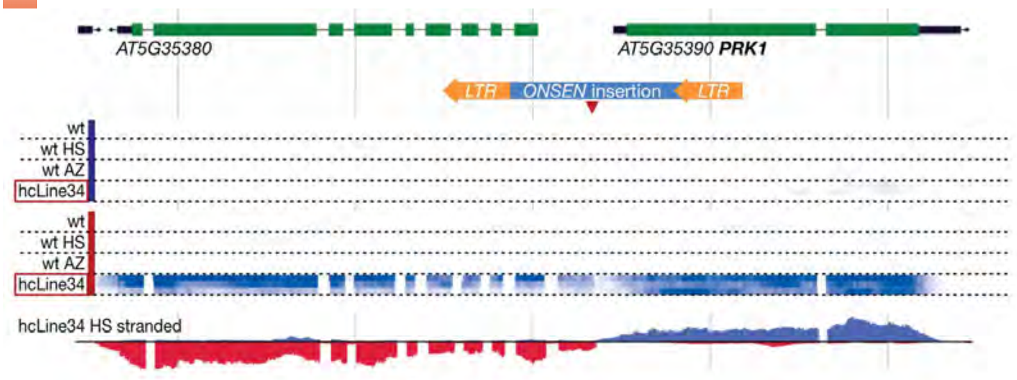
ONSEN integrates in gene-rich regions



278 novel *ONSEN* insertions identified

Roquis, D. et al., (2021). Nucleic Acids Res 49

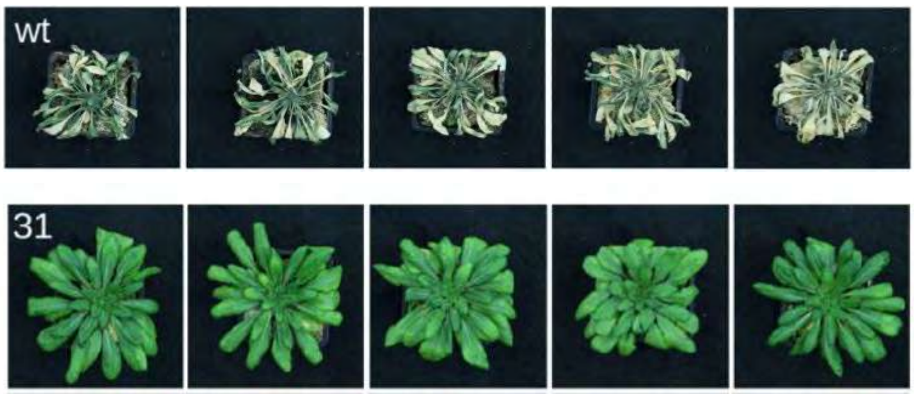
Gain of heat stress responsiveness by *ONSEN*



Gain of function mutation!

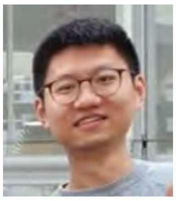
Roquis, D. et al., (2021). Nucleic Acids Res 49

Gain of drought tolerance thanks to *ONSEN*



Thieme, M. et al., (2022). New Phytologist

TE mobilization in rice and wheat



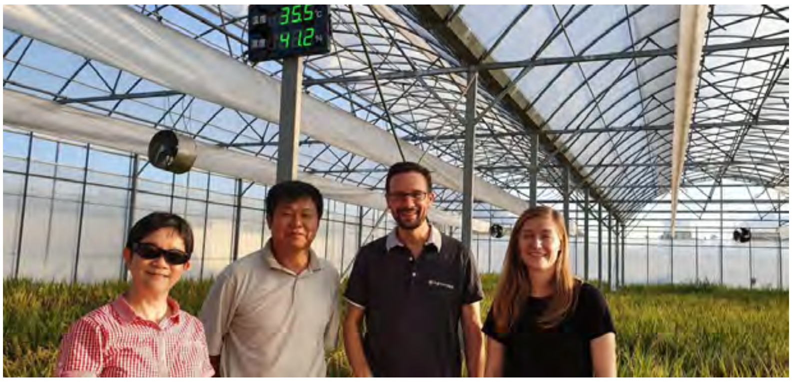
Haoran Peng

Marta Robertson

Mahnaz Katouzi

TE mobilization in rice: Going to the fields

TE mobilization in rice: heat stress

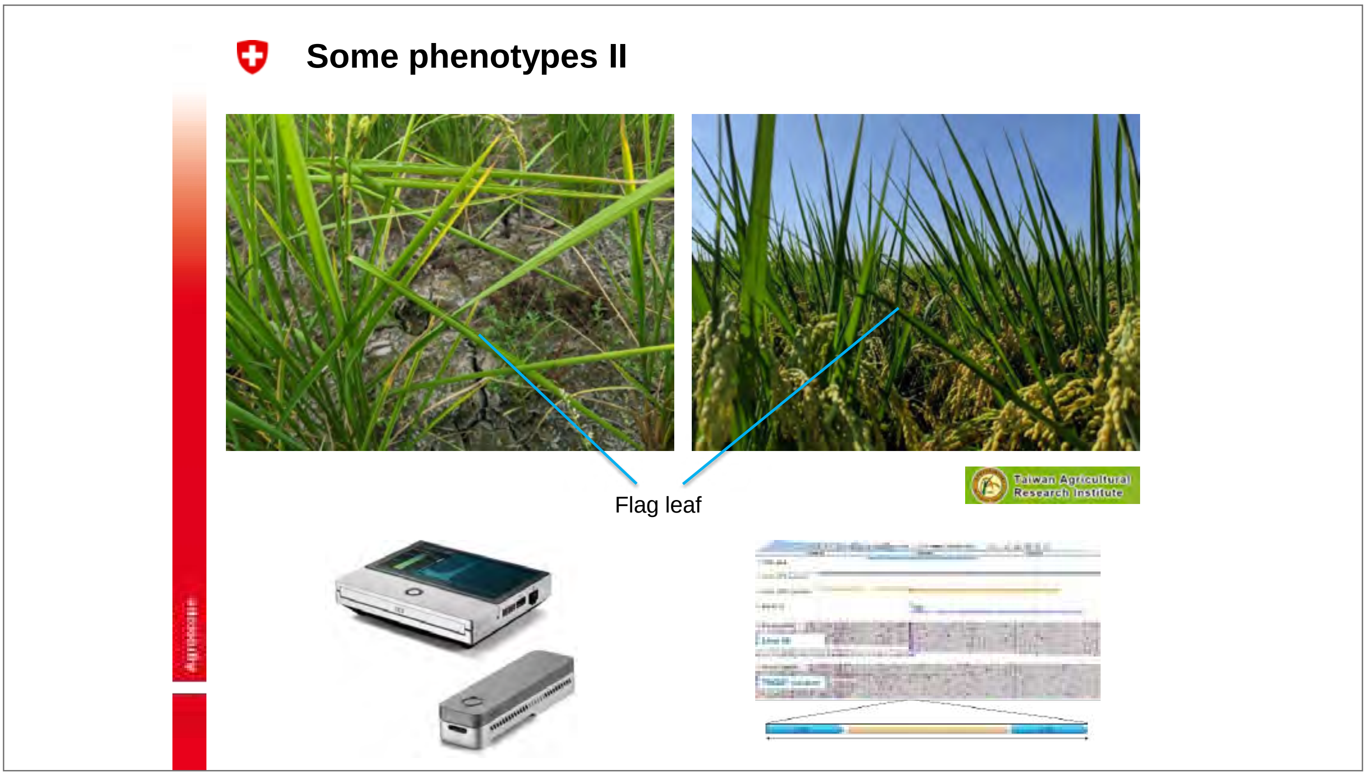


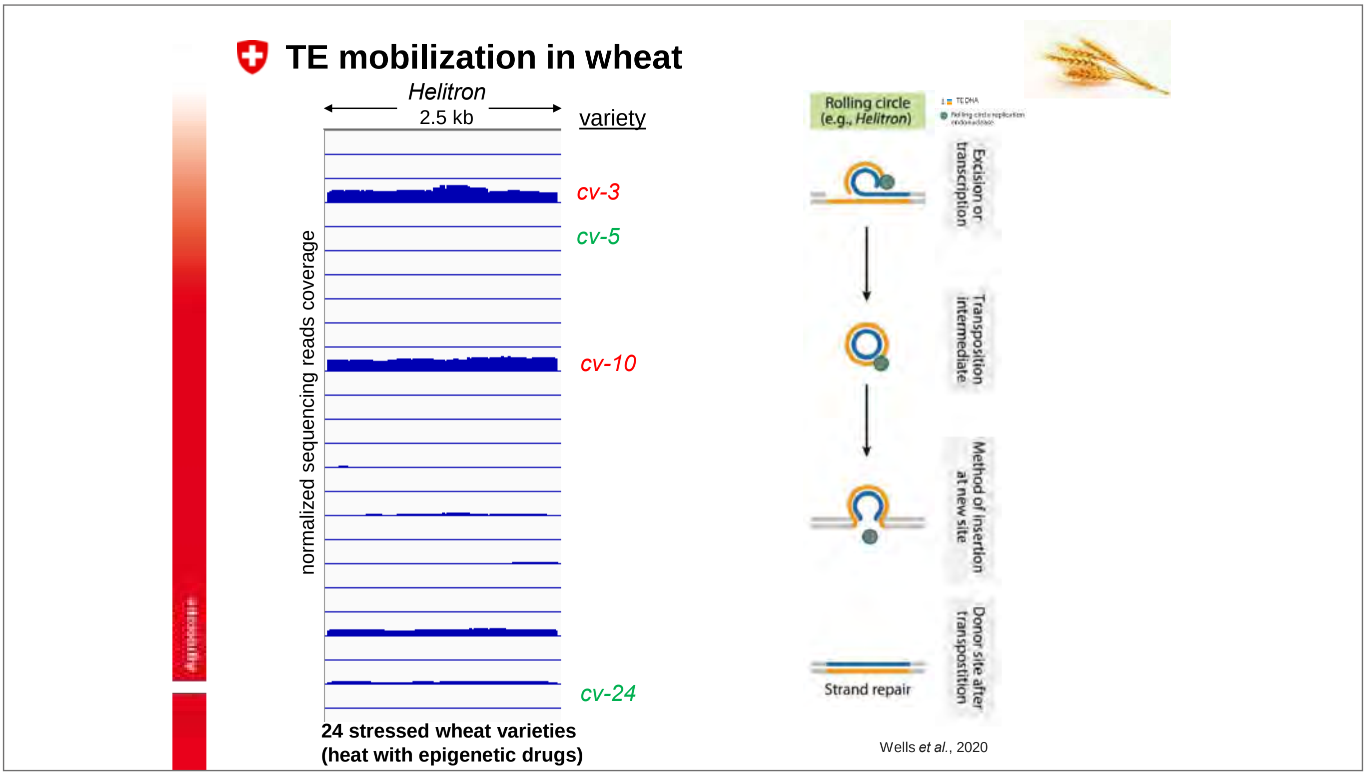
Thousands of transposon lines grown under heat stress, drought and control conditions

Taiwan Agricultural Research Institute

Some phenotypes I

Taiwan Agricultural Research Institute


Some phenotypes II
Flag leaf
Taiwan Agricultural Research Institute


TE mobilization in wheat
Helitron
2.5 kb
variety
cv-3
cv-5
cv-10
cv-24
normalized sequencing reads coverage
24 stressed wheat varieties
(heat with epigenetic drugs)
Rolling circle
(e.g., Helitron)
Excision or transcription
Transposition intermediate
Method of insertion at new site
Donor site after transposition
Strand repair
Wells et al., 2020

TE-induced phenotypic diversity in wheat

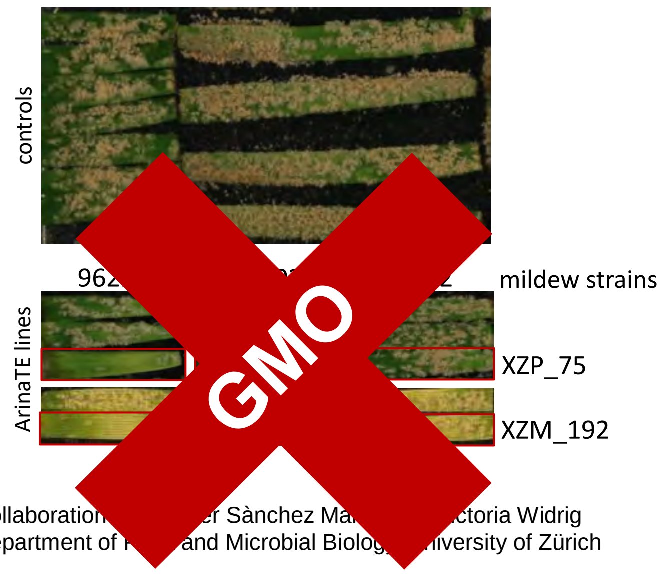
Ar_XZH_25

Ar_XZM_54

Induced pathogen resistance in wheat?

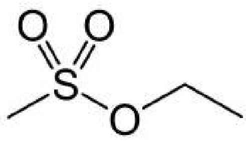
powdery mildew infection tests

Arina Kanzler



Collaboration ... er Sànchez Ma... ctoria Widrig
Department of P... and Microbial Biolog... niversity of Zürich

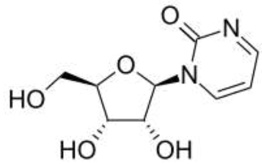
Innovation in crop breeding is forbidden in CH and EU



Ethyl methanesulfonate

strong mutagen

✓ safe!



epigenetic drugs

weak mutagen

X dangerous!

"no history of safe use"

=GMO

The weaker the mutagen, the tougher the regulation

Summary and outlook

Epigenetic drug treatments induce phenotypic diversity

We have detected novel TE insertions in rice

We have mobilized a TE in wheat

In Europe: Innovations cannot reach the farmers


Schweizerische Eidgenossenschaft
Confédération suisse
Confederazione Svizzera
Confederaziun svizra
Département fédéral de l'économie,
de la formation et de la recherche DEFR
Agroscope
Collaborations
Marie Mirouze
IRD
Institut de recherche pour le développement
Yue-ie Caroline Hsing
Roman Ulm
UNIVERSITÉ DE GENÈVE
Magdalena Julkowska
BTI BOYCE THOMPSON INSTITUTE
Javier Sanchez
University of Zurich
Jean Masson
INRAE
Haoran Peng
David Roquis
Anahita Nezhad Hadad
Nataliya Hrunyk
Maria Estefania Lopez
Esteban Alfonso
Mahnaz Katouzi
Agroscope
Dario Fossati
Former Members:
Marta Robertson
Michael Thieme
Funding:
erc
MARIE CURIE ACTIONS
EpiDiverse
European Training Network
Schweizerischer Nationalfonds
Fonds national suisse
Fondo nazionale svizzero
Swiss National Science Foundation

SMARTRICE®: A RICE PRODUCT GROWN USING MORE SUSTAINABLE METHODS TO REDUCE THE USE OF AGRICULTURAL RESOURCES AND PROVIDE MORE RICE TO MEET THE GROWING WORLDWIDE APPETITE

Dr. José Ré
Vice President, Global New Products Development – Rice Tech, United States of America

Rice breeding efforts were started by RiceTec more than 30 years ago. Hybrid rice technology, just being developed in China at that time, was licensed and introduced to the USA to initiate a rice hybrid breeding program. Genetics developed in China for hybrids adapted to transplant and manual cultivation needed to be adapted to mechanized rice cultivation utilized in the USA. Focused improvement programs were initiated with the goal of increasing root biomass, which is important to prevent lodging under direct seeding practices. Additional benefits of larger root masses include better soil profile exploration, increasing efficiency in accessing soil nutrients and water. Disease resistance and higher grain yield were also strengthened during successive breeding generations. Improvements in plant architecture, selection for materials more adapted to water-saving irrigation practices and the identification of improved hybrids that emit less greenhouse gases (GHG) per unit of output led to the design of SmartRice®, a more sustainable system to grow rice. The third party-verified system has strong environmental claims, such as a reduction of more than 50% in irrigation water utilization, a reduction of more than 50% in GHG emission and the potential to feed 20% more people per land unit. This sustainability-enhanced rice production system also favorably impacts environmental aspects such as wildlife, birds and pollinators' refuges, water quality and soil health. The system yields a traceable rice product that is available through online vendors and will soon be available in supermarkets throughout the USA. In India, the SmartRice® concept was coupled with FullPage®, an herbicide tolerance (HT) rice cropping solution, to create a powerful system ready to drive a revolutionary transformation in the way rice is grown in India. This HT direct seeding system benefits growers by saving from transplanting and irrigation cost, by increasing grain yield and by providing a reliable weed management tool. Additional benefits, such as lowering GHG emissions, are achieved by adopting the SmartRice®+FullPage® system in comparison with transplanted rice (TPR); lowering GHG emissions could lead to additional revenue for farmers through the generation of carbon credits.

For small and medium-sized breeding companies like RiceTec, the continued virtuous circle of research investment and innovation generation is only possible when strong IP policies are in place. The 30+ years we have invested in developing the products society can enjoy today, products that are contributing to mitigate and adapt to climate change, should not be allowed to be taken away from us, the developers of the initial varieties and technologies, by those that take advantage of misinterpretations of fundamental IP protection concepts like essentially derived varieties (EDV). Through the ongoing revision of the Explanatory Notes on Essentially Derived Varieties under the 1991 Act of the UPOV Convention, UPOV has the opportunity to continue promoting IP systems that are fair and that promote investment in innovation for the benefit of society and the planet.

Presentation made at the Seminar

Seminar on the role of plant breeding and plant variety protection in enabling agriculture to mitigate and adapt to climate change

UPOV

International Union for the Protection of New Varieties of Plants

SmartRice®: a rice product grown using more sustainable methods to reduce the use of agricultural resources and provide more rice to meet the growing worldwide appetite

Dr. José Ré, Vice President, Global New Products Development
RiceTec USA, United States of America

Wednesday, October 12, 2022

RiceTec

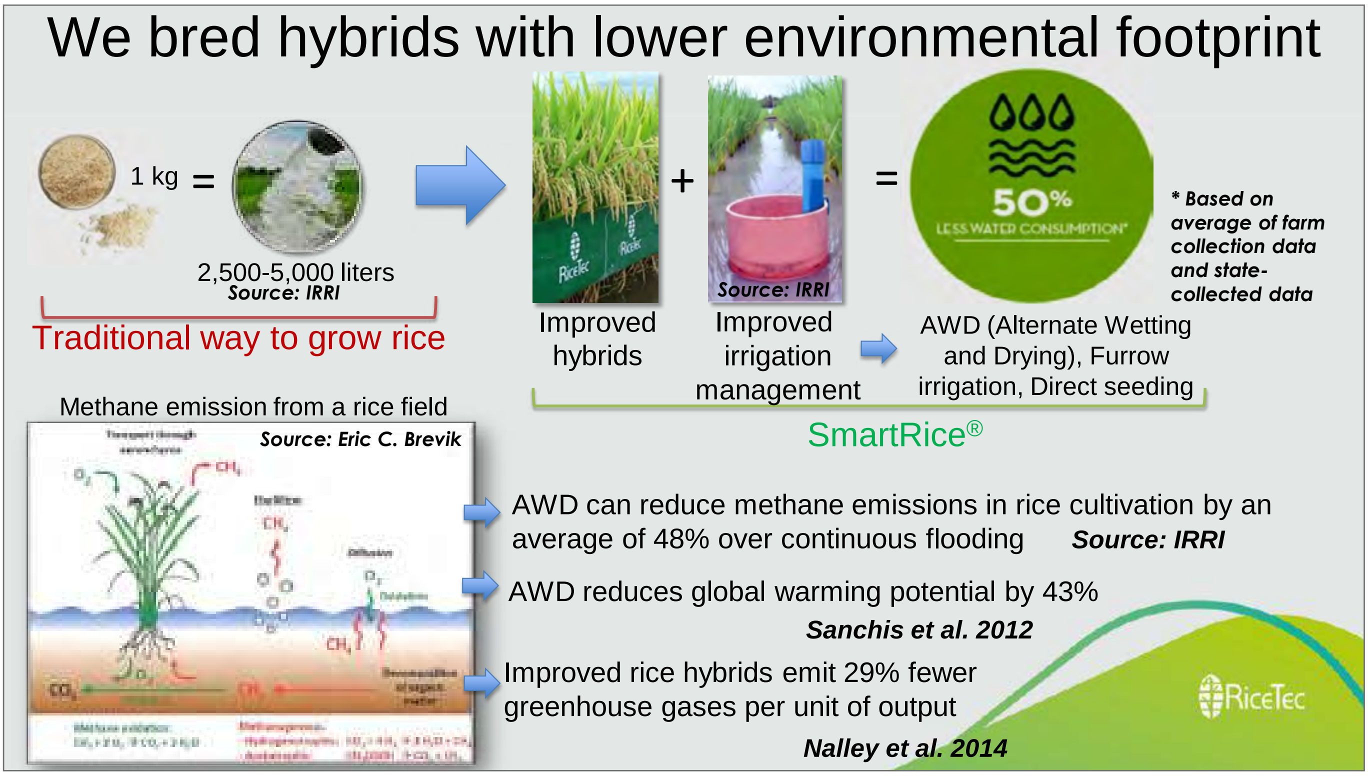
Our rice breeding journey started about 30 years ago

Transplanted Hybrid Rice → **Direct Seeding Hybrid Rice**

RiceTec

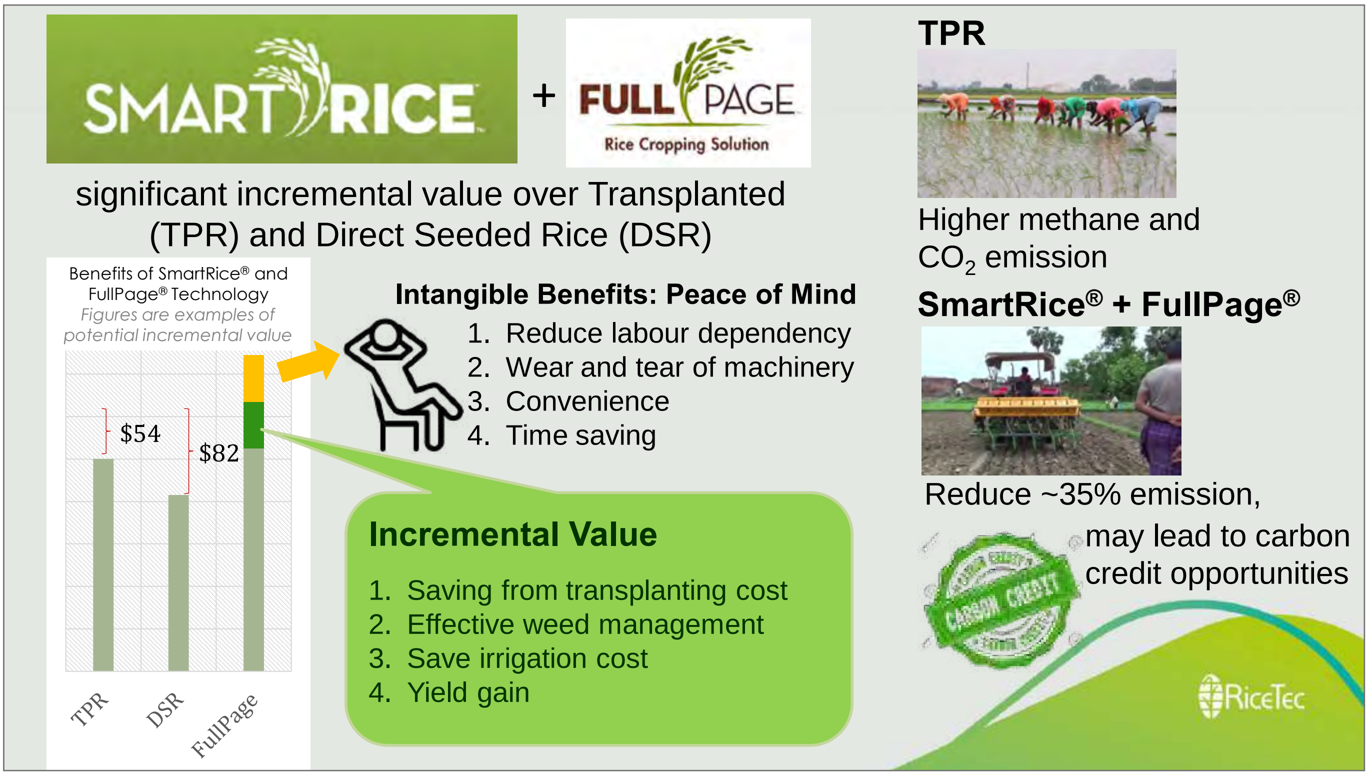

We focused breeding to increase root biomass
unimproved hybrid rice
improved hybrid rice adapted to direct seeding and water-saving management practices
RiceTec


We bred disease resistance traits and high grain yield
RiceTec


We bred hybrids with lower environmental footprint
1 kg =
2,500-5,000 liters
Source: IRRI
Traditional way to grow rice
+
=
Source: IRRI
50% LESS WATER CONSUMPTION*
* Based on average of farm collection data and state-collected data
Improved hybrids
Improved irrigation management
AWD (Alternate Wetting and Drying), Furrow irrigation, Direct seeding
SmartRice®
Methane emission from a rice field
Source: Eric C. Brevik
AWD can reduce methane emissions in rice cultivation by an average of 48% over continuous flooding Source: IRRI
AWD reduces global warming potential by 43%
Sanchis et al. 2012
Improved rice hybrids emit 29% fewer greenhouse gases per unit of output
Nalley et al. 2014
RiceTec


SMART RICE
GOOD FOR YOU.
GOOD FOR THE EARTH.
• The first sustainable rice with strong environmental claims
o >50% water use reduction
o >50% GHG reduction
o 20% more people potential to feed per land unit
o Third-party verification (SCS)
• Whole farm approach to conservation
o Wildlife-bird-pollinator refuges; water quality, soil health
• Complete transparency and traceability
o Consumers can follow from field to store
SCSglobal SERVICES
Setting the standard for sustainability
RiceTec


SMART RICE
+
FULL PAGE
Rice Cropping Solution
Smart Farmer - Convenience and higher profitability
Profitability
Higher Productivity & Cost Reduction
Convenience
Reduce Labor Dependence
Sustainable
Reduction Water, Fuel Usage & GHG
RiceTec


SMART RICE
+
FULL PAGE
Rice Cropping Solution
significant incremental value over Transplanted (TPR) and Direct Seeded Rice (DSR)
Benefits of SmartRice® and FullPage® Technology
Figures are examples of potential incremental value
$54
$82
TPR
DSR
FullPage
Intangible Benefits: Peace of Mind
1. Reduce labour dependency
2. Wear and tear of machinery
3. Convenience
4. Time saving
Incremental Value
1. Saving from transplanting cost
2. Effective weed management
3. Save irrigation cost
4. Yield gain
TPR
Higher methane and CO_2 emission
SmartRice® + FullPage®
Reduce ~35% emission,
may lead to carbon credit opportunities
CARBON CREDIT
RiceTec

We are a medium-size, privately own, rice breeding company

- We reinvest about 15% of revenue on research, development, innovation, and genetic improvement of rice and we rely 100% on our earnings to continue innovating. ***SOCIAL RESPONSIBILITY***

- Our investors, plant breeders, and product developers must have the opportunity to earn competitive returns on the investments in new seed products which benefit our planet, our health, and our food. ***FAIRNESS***

- Strong IP policies makes this possible. ***ENABLING ENVIRONMENT***

- Currently, there are attempts to weaken UPOV 91 Act by weakening the fundamental EDV concept, that if successful will deeply affect the ability of companies like us to continue bringing innovations to market.

QUESTIONS

NGWEDIAGI Patrick (Mr.), Chair of the Administrative and Legal Committee, UPOV (moderator)

So, participants, you are welcome. If you have questions, raise your hand using the facility there and we will allow you to ask a question.

HUERTA Yolanda (Ms.), Legal Counsel and Director of Training and Assistance, UPOV

Patrick, there is a question from Päivi from the European Commission, Ms. Päivi Mannerkorpi.

NGWEDIAGI Patrick (Mr.), Chair of the Administrative and Legal Committee, UPOV (moderator)

Okay. You are welcome, please. Go ahead.

MANNERKORPI Päivi (Ms.), Team Leader - Plant Reproductive Material, Unit G1 Plant Health, Directorate General for Health and Food Safety (DG SANTE), European Commission, Brussels, Belgium

Thank you. Just shortly to comment because the European Commission was mentioned by Mr. Etienne Bucher from Switzerland. So, it is clear that the current legislation in the EU is not fit for purpose for new genomic techniques, and that's why the commission and the member states are enrolled in a project to look for a more proportionate and fit for purpose legislation for new genomic techniques.

You mentioned that it was not possible to carry out field trials under the current GMO legislation, but there are rules for release in the environment and you just need to get the authorization under the so-called Annex B approval of the Directive 2001/18/EC: The national authority is responsible for making a decision on the release based on an environmental risk assessment and an assessment of the health risks according to the rules in Part B of Directive 2001/18/ECEN••• - Deliberate release of GMOs for any other purpose than for placing on the market. So, it is possible to carry out field trials for research purposes. Thank you.

NGWEDIAGI Patrick (Mr.), Chair of the Administrative and Legal Committee, UPOV (moderator)

Thank you, Päivi. Please, if you have any comments about what Päivi has just commented? That was directed to Etienne.

BUCHER Etienne (Mr.), Research group leader "Crop Genome Dynamics", Agroscope, Switzerland (speaker)

Yes. Thank you very much for this comment. You are right. In principle, we are allowed to do field trials, but the rules actually changed during my European Union (EU) project, so suddenly it was not allowed – we were not allowed anymore to immediately go to the field with them, and then to apply for field trials for a year. And so then, the project at that time was already finished. So, it was really a blocking thing. So, it also impacts basic research. I think that was my important message here, that it slows down research also.

It's true, in principle, we can do field trials, but it's a very heavy procedure. Thank you.

CHARACTERIZATION OF THE FLOWERING PHENOLOGY OF THE VARIETIES OF THE WORLD OLIVE TREE COLLECTION IN MOROCCO FOR THE SELECTION OF GENOTYPES ADAPTED TO CLIMATE CHANGE

Ms. Hayat Zaher
Researcher, Marrakech Regional Agricultural Research Centre (Crra),
National Institute For Agricultural Research (Inra), Morocco [1]

ABSTRACT

A total of 331 olive cultivars from the world olive collection of Marrakech (WOGBM) were characterized according to the Biologische Bundesanstalt, Bundessortenamt, Chemische Industrie (BBCH) scale. Phenological stages related to olive inflorescence emergence and flowering were recorded over six years, 2014–2019, throughout the WOGBM. The objective of this study is to evaluate inter-annual variation on flowering time and flowering period. We used phenological data over six years of 331 cultivars to classify Mediterranean olive cultivars into three groups according to their corresponding Julian days, starting from January 1st of each year (DOY: Day of the Year). A significant positive correlation was detected between all flowering stages. Variance analysis showed cultivar and year effects on all flowering stages. A hierarchical cluster analysis of cultivars according to method showed three groups: the early, intermediate and late flowering groups. Stage 51 is a key stage of the olive tree's flowering phenology, its early observation is correlated with a long flowering period. We noted a correlation between a short flowering period and the increase of temperature expressed by the sum of degree days. In southern Mediterranean countries, we recommend the selection of varieties with low chilling requirements (early stage 51 for better adaptation to xeric conditions during the summer period). As the selection of adapted cultivars is based on global warming, our classification of olive Mediterranean genetic resources should be validated by further investigations, validating the statistical approach by the experimental one.

KEYWORDS: olive, flowering, phenology, BBCH scale, worldwide collection, Marrakech, chilling requirement, selection

Co-authors : **Omar Abou-Saaid,[1,2,3,] Adnane El Yaacoubi,[4], Abdelmajid Moukhli,[1], Ahmed El Bakkali,[5], Sara Oulbi,[1], Cherkaoui El Modafar[3] and Bouchaib Khadari[2,7]**

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[3] Université Cadi Ayyad, Laboratoire Biotechnologie et Bio-ingénierie Moléculaire, FST Guéliz, Marrakech, Morocco
[4] Université Sultan Moulay Slimane, École supérieur de technologie, Khenifra, Morocco
[5] INRA, UR Amélioration des Plantes et Conservation des Ressources Phytogénétiques, Meknès, Morocco
[6] CBNMed, AGAP Institute, Montpellier, France

INTRODUCTION

The olive tree (*Olea europaea* L.) is one of the oldest cultivated fruit trees in the Mediterranean basin. Evidence of cultivation practices by morphometry from the Neolithic and the Bronze periods was advanced in the Western as well as the Eastern Mediterranean basin especially (Terral and al. 2004). The world production of olive fruit in 2013 was about 22,039 million tones, with 67.31% in the European Union (FAOSTAT 2016).

Olive tree flowering is a highly complex process, depending on several factors (chilling, photoperiod, temperature, hormone variations, fertilizer elements and carbohydrate compounds, amounts in tissues, etc.) and it is characterized by two distinct physiological phases: (a) bud initiation and (b) floral bud development (Bernier 1988). Lavee (1996) and Fabbri and Benelli (2000) argued in favor of the model with two successive biological processes: flower bud induction and differentiation in olive. In the first step, during spring–summer, likely flower buds are simulated to prevent their differentiation into leaf buds. In the second step, during autumn–winter, and under further favorable conditions, the candidate buds are simulated again to form the flower structure. Flower induction occurs in February and March, approximately two months before flowering (Hartmann 1951; Monselise and Goldschmidt 1982; Fab¬bri and Alerci 1999).

Climate studies show good evidence of warm winters and reducing winter chilling accumulation. Olive flower buds need chilling in winter to open properly, but the chilling influence on flower bud induction and differentiation is still in question. Chilling need time was considered differently by authors (Hartman 1951; Lavee 1996; Fabbri and Benelli 2000). Bud dormancy break requires a certain amount of cold, but once dormancy has been broken, mild temperatures accelerate bud break. Despite the complex action of chilling and day temperature, flowering time including the date of full blooming and the duration of flowering had been proven to be reliable bio-indicators of climatic variations (Garcia-Mozo *et al.* 2009).

During the period of flowering and fruit set water and fertilizer needs are higher. Olive flowering intensity is likely influenced by the availability of N, P and K (Nitrogen, Phosphorus, Potassium) (Erel and al. 2008). Concentrations of carbohydrate compound variations of different tissues of the tree during the flowering and fruit set period was shown by Bustan *et al.* (2011): starch, mannitol and sucrose concentrations increased from December to March in all tissues, and then decreased along with flowering and fruit set development.

The times of flower bud induction and flowering are important for (I) fruit set and productivity; (II) alternate bearing (Ben Sadok and al. 2013; Mert *et al.* 2013); (III) mating probabilities for two olive trees (Weis and Kossler 2004); (IV) drought adaptation; (V) evolution and population genetic structure such as gene flow between individuals (Hendry and Day 2005).

Evolutionary flowering time change studies have gained considerable attention in view of current global climate change (Van Dijk 2009). Ongoing climate variation can affect olive flowering time and ecological dynamics. Indeed, flowering time is a key adaptive trait in plants and is conditioned by the interaction of genes and environmental factors including photoperiod, temperature and chilling requirement (Nelson *et al.* 2014). Droughts and other anticipated changes in precipitation and winter temperature may particularly be important factors in arid regions (Franks *et al.* 2007). In arid Mediterranean areas, early flowering is likely linked to varieties with low chilling requirements. Such varieties could be adapted for drought conditions because they are able to escape drought at a sensible stage of flowering period.

In the present work, we have investigated flowering time over six years (2014–2019) of 331 olive cultivars in the WOGBM using BBCH scale (Meier 1997; Sanz-Cortés *et al.* 2002) in order to i) classify varieties of the WOGBM collection depending on flowering time in order to select adapted cultivars to climate change, and ii) to evaluate inter-annual variation on flowering time.

MATERIAL AND METHODS

Location and plant material

The study was carried out on olive trees from 331 olive cultivars of the WOGBM in the Tassaout experimental station of the National Institute of Agronomic Research, Marrakech, about 65 km far from Marrakech (latitude 32° 03 N, longitude 7° 24 O et 465 m of altitude). The olive trees were grown in similar pedoclimatic conditions and received the same crop management practices.

Flowering observations

Phenological observations in the field were performed in order to determine the time of the main flowering stages. Observations were recorded using the international standardized BBCH scale for olive flowering data (Meier 1997; Sans-Cortés *et al.* 2002) of 331 cultivated Olea europaea (L.) cultivars of the WOGB collection. Each cultivar is represented by at least three trees. Data were recorded over six years, 2014–2019, throughout the WOGBM. Observations were carried out every two or three days from February 1st to the end of the flowering period to determine the date of inflorescence emergence stages (stages 51 to 59) and flowering stages (stages 61, 65 and 69) according to the BBCH scale for olive tree (Meier 2001). Phenological data have been converted according to their corresponding Julian days in terms of the 'day of the year' (DOY), starting from January 1st of each year.

Statistical analysis

Descriptive statistics analysis (minimum, maximum and average values) and coefficient of variation were performed for all observed flowering stages over the six years from 2014 to 2019. Analysis of variance (ANOVA) and Turkey's test was performed for all flowering stages in order to test the significance of variance among genotypes and between the six years. All statistical data analyses were run in the R programming environment (R Development Core and Team 2021; version R 3.6.3).

RESULTS

Analysis of variance (ANOVA) of WOGBM

The variance analysis showed an important significant year effect, followed by cultivar, as well as the interaction effect on full flowering date. Full flowering dates for olive cultivars ranged over the years between 91 DOY (April 1st) in 2019 to 150 DOY (May 30th) in 2016.

Correlations between phenological stages

Correlations between phenological stages recorded (as Julian days for all trees per cultivar) from bud burst (stage 51) to the end of flowering (stage 69) and the flowering duration for the 331 cultivars of the worldwide collection Marrakech from 2014 to 2019 were investigated by Pearson correlation analysis (Figure 1). A significant correlation was observed within inflorescence emergence stages (stages 51, 54 and 55), and flowering stages (stages 60, 61, 65 and 69), with values ranging for emergence stages between 0.81 and 0.93 respectively, and for flowering stages between 0.90 and 0.98 respectively. Nevertheless, the budburst stage 51 is significantly negatively correlated to the flowering duration measured as the DOY difference between the beginning of flowering (stage 61) to the end of flowering (stage 69). A significant negative correlation was observed between the flowering duration and the inflorescence emergence stages (correlation value ranged between -0.42 and -0.58). A low correlation between stage 51 and flowering stages was observed (Pearson correlation ranged between 0.11 to 0.49). Interestingly, blooming time (stage 65) is significantly correlated to all phenological stages, including those related to the inflorescence emergence.

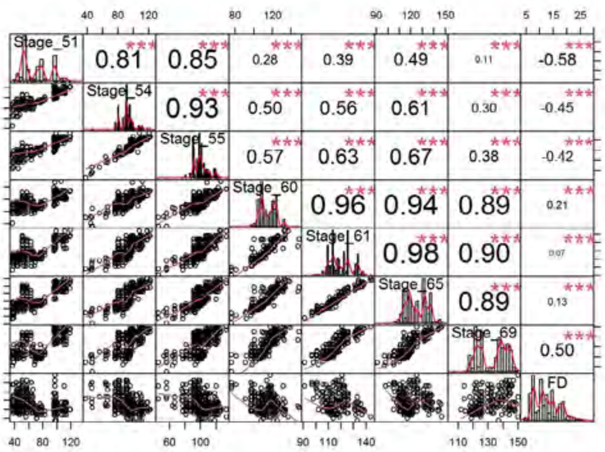

Figure 1. *Correlation between phenological stages from bud burst (stage 51) to the end of flowering (stage 69) and the flowering duration for the 331 cultivars of the worldwide collection in Marrakech during six years, 2014–2019.*

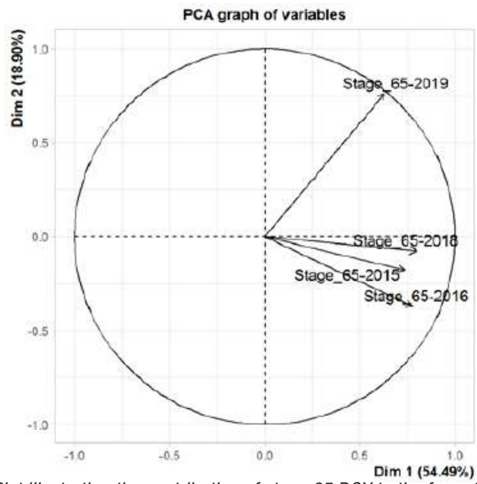

Figure 2 *Plot illustrating the contribution of stage 65 DOY to the formation of PCA axes. Principal components Analysis (PCA) of the phenotypic variability observed within the OWGBM collection*

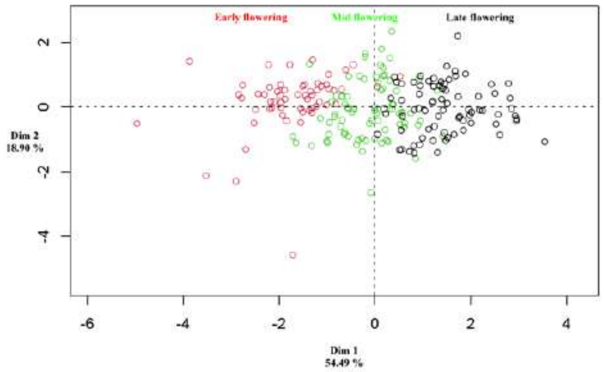

Figure 3. *Principal components analysis of the stage 65 DOY of the different cultivars on the plan determined by the first two principal components.*

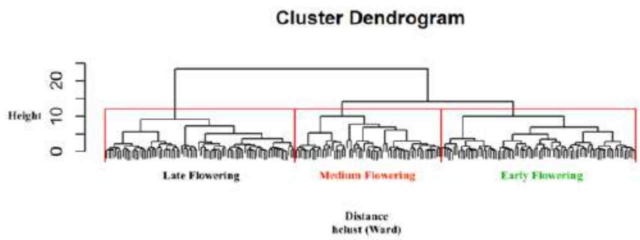

Figure 4. *Dendrogram based on flowering date of the WOGB collection.*

Hierarchical cluster analysis

Clustering of cultivars according to Ward's method (Figure 4) showed three major groups of flowering date: the early, mid and late flowering groups, with average of Julian dates corresponding to flowering dates of 119 (April 29th), 123 (May 3rd), 125 (May 5th) respectively.

Following the first classification of the 331 studied cultivars according to their full flowering dates, the three groups are represented by:

- early flowering: Arbequina, Bouteillan, Coratina, Bouchouika, Lucques, Meslala;
- medium flowering: Picholine marocaine, Picholine de Languedoc, Picual, Frantoio, Gordal Sevillana, Chemchali;
- late flowering: Leccino, Ottobratica, Maurino, Chetoui, Bosana, Ascolana tenera.

DISCUSSION

The olive reproductive cycle is characterized by bud formation during the previous summer, dormancy during the cold period, bud burst in late winter and flower structure development from bud burst to flowering in spring. Temperature and precipitation have an important impact on vegetative development and especially on flowering (Cenci *et al.* 1997; Aguilera and Ruiz Valenzuela, 2009). The flowering induction of the buds is a noteworthy phase, because it can express a great part of future flower production variability, taking into consideration the fact that it is directly involved in the reproductive process (Rallo and Martín 1991). Olive flower induction may occur in January–February, approximately two months before full flowering period, or earlier in summer and winter, depending on chilling accumulation (Hartmann 1951; Monselise and Goldschmidt 1982; Fab¬bri and Alerci 1999). Hence, the induction period is still not known.

The influence of the climate on plant phenology represents a field of research that is in continuous evolution. This is being increasingly studied from the point of view of climate change, for consideration of the potential adaptation measures of plant species. Indeed, this interest is greater in areas where climate conditions might force more rapid adaptation, such as in the Mediterranean area, which is expected to suffer stronger effects in terms of climate change (Giorgi and Lionello 2008).

Climate change can already modify the phenology of numerous plant species (Menzel *et al.* 2006). Olive phenology has been reported as a good indicator of future climatic change due to its dependence on temperature (chilling and heat requirements) and its geographical distribution over the high-risk warming area of the Mediterranean basin (Osborne *et al.* 2000).

Olives require chilling during winter months for flowering induction, ending with bud burst in spring (Lavee 1996). These chilling requirements are frequently met in a Mediterranean climate areas. But today, studies on climate change effect on olive flower induction, flower intensity and flower phenology show that olive chilling requirements cannot be satisfied for some varieties, especially in south Mediterranean areas.

Low temperature and high precipitation during the months previous to the flowering period are the meteorological variables that affect the flower and pollen production of olive trees. Temperature is recognized to be the main determinant of budburst timing in temperate trees (Schwartz 2003). In the case of the olive (*Olea europaea L.*) different phenological models described in the literature have revealed the temperature as the best external variable to predict flowering time (Alcalá and Barranco 1992; Recio *et al.* 1997; Fornaciari *et al.* 1998; Osborne *et al.* 2000; Galán *et al.* 2005). Varietal differences in response to climatic variation are observed. Unpublished data on the Menara 40 varieties collection from 1971 to 1976 showed variation in average length of flowering period between 21 days and 50 days. Regarding the varieties, those with short flowering cycles have flowering periods between 8 and 26 days (such as Cucco (13 days), Frontoio (14 days), Picholine Marocaine (16 days)). Varieties with long flowering cycle have flowering period between 17 and 21 days (such as Picholine du Languedoc (23 days), Arbequina (19 days) and Blanqueta (18 days)). Our observations over the years 2014–2019 showed that budburst stage 51 is significantly negatively correlated to the flowering duration measured as the difference between the beginning of flowering (stage 61) to the end of flowering (stage 69). We also showed year effect, followed by cultivar, as well as the interaction effect, on full flowering date of the WOGBM.

Climate studies show good evidence of warm winters and reducing winter chill accumulation on olive flowering intensity. Olive flower buds need chilling in winter to open properly. Despite the complex action of chilling and degree day temperature on olive tree phenology, olive tree flowering periods and the duration of flowering have been proven to be reliable bio-indicators of climatic variations (Garcia-Mozo *et al.* 2009).

CONCLUSION

A wide range of variation was found in the WOGBM for all phenological stages and the flowering period. Stage 51 can be considered as a key stage of olive tree flowering phenology. Its early observation is correlated with a long flowering period. Cultivars with late stage 51 need more time to satisfy their minimum chilling requirements and cumulate more degree days before reaching that stage. In southern Mediterranean countries, we recommend a selection of varieties with low chilling requirements (early stage 51 for better adaptation to xeric conditions in the summer period). Indeed, drought and other anticipated changes in precipitation and winter temperature may be particularly important factors in arid regions (Franks *et al.* 2007). In the arid Mediterranean area, early flowering olive varieties (with low chilling requirement) can be adapted for drought conditions because they can ovoid the drought at the flowering stage. During the olive tree flowering and fruit set periods, the demand of olive tree on water, fertilizers and carbohydrates is higher (Erel and al. 2008; Bustan *et al.* 2011). Regarding the selection basis of adapted cultivars to global warming, our classification of olive Mediterranean genetic resources should be followed by further investigations, validating the statistical approach by the experimental one.

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Presentation made at the Seminar

Characterization of the flowering phenology of the world olive collection varieties in Morocco: towards selection of adapted varieties to global

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1

INTRODUCTION

The olive tree constitutes a remarkable species by its biological and ecological characteristics widely cultivated in many regions of the world, particularly in the Mediterranean area

However, this crop is faced to climatic constraints in the current context of global warming, perturbing its biological, physiological and phenological development

2

INTRODUCTION

Air temperature, uncontrolled, is the most important abiotic factor affecting olive development

It mainly involved in the dormancy and flowering process during winter and spring respectively

In fact, the bud dormancy onset and its breaking date phase are strongly influenced by winter chill; while the flowering achievement is highly correlated to spring heat

3

INTRODUCTION

In addition to the biennial bearing of olive, the annual temperature variations during these two periods seem to have significant negative consequence on the development cycle of tree production resulting in economic repercussions

At phenological level, it was reported that increase of temperature during winter and spring induced flowering advance of olive cultivars in some Mediterranean areas such as Morocco, France, Spain, Italy and Tunisia

4

INTRODUCTION

Evolutionary flowering time change studies Gained considerable attention in view of the current global climate change

=

Ongoing climate variation can affect olive flowering time and ecological dynamics

5

OBJECTIVES

Flowering time is a key adaptive trait

We investigated Flowering time of **331 olive cultivars** in the **OWGB-M** Marrakech using BBCH scale

- Evaluate inter annual variation on flowering time and flowering period of **OWGB – Marrakech**
- Classify varieties of the **OWGB – Marrakech** collection depending on **Flowering time** and **Flowering duration**.

6

Materials & Methods

- Phenological observations were conducted out on 331 cultivated Olea europaea (L.) cultivars identified based on 554 accessions and originating from 14 Mediterranean countries. Each cultivar is represented by at least 3 trees.

Origine	Nombre d'accessions	Années de plantation
Italie	146	2003/2004
Espagne	89	2003/2004
Chypre	20	2004
Grèce	17	2003
Portugal	15	2003
France	13	2003
Tunisie	25	2005/2008/2011/2012
Maroc	38	2007/2008
Algérie	43	2008
Croatie	16	2008
Egypte	19	2008
Slovénie	9	2008
Syrie	65	2009
Liban	6	2009

7

Materials & Methods

- According to the BBCH scale, phenological stages related to the olive inflorescence emergence and flowering were recorded over six years 2014-2019 overall the WOGBM.
- Observations were carried out every two or three days from the first February to the end of the flowering period to determine the date of inflorescence emergence stages (stage 51 to Stage 59) and flowering stages (stage 61, 65 and 69) according to the BBCH scale for olive tree (Meier, 2001).
- Phenological data have been converted according to their corresponding Julian days, starting from the first of January of each year (DOY: Day of the Year).
- All statistical data analyses were run in the R programming environment (R Development Core and Team, 2021; version R 3.6.3)

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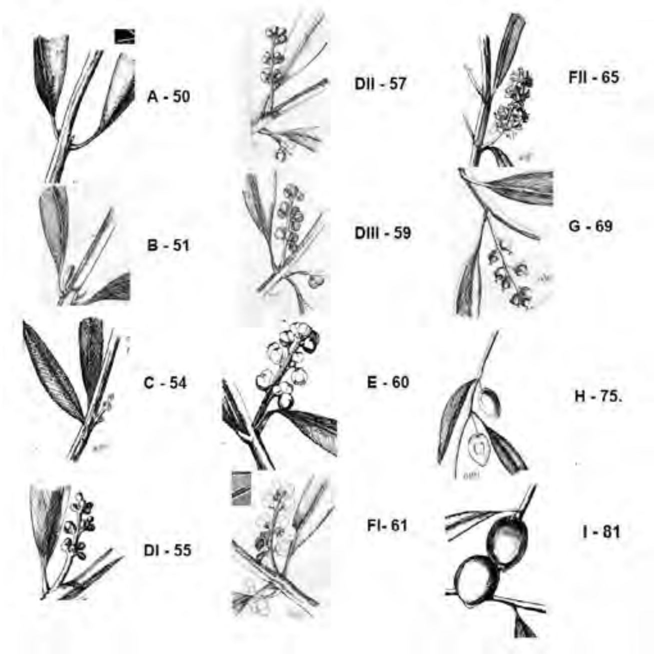
Phenological stages



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Flowering stages

Stage 51

Stage 54

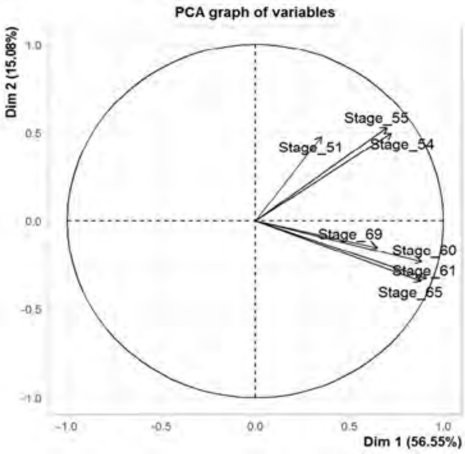
Stage 55

10

Flowering stages

11

Results

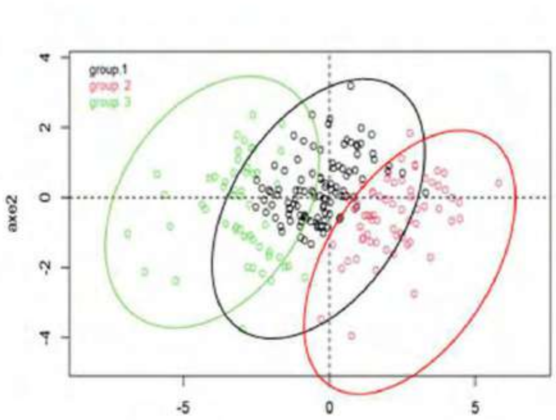


High correlation between flowering stages

12

Results

Principal components Analysis (PCA) of the phenotypic variability observed within the OWGB Marrakech collection



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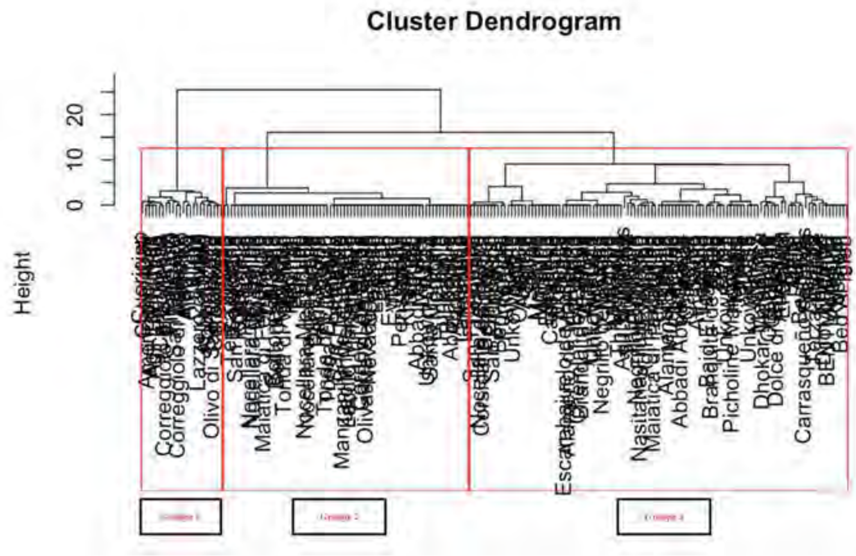
Results



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Results

Three groups :

- Early flowering : Arbequine, Karolia, Lechin de Sevilla, Manzanilla de Sevilla, Hojiblanca…
- Intermediate flowering : Picholine marocaine, Picholine de Languedoc, Sigoise, Lucques; Koroneiki; Chemlal de Kabilye
- Late flowering : Picual, Leccino, Mastoidis Haouzia, Ottobratica, Chetoui …

Results

- Significant differences among cultivars were observed for all the evaluated flowering stage
- Higher values of flowering stage 51 phenological data were obtained for cultivars with supposed low Chilling requirement
- The budburst stage 51 is significantly negatively correlated to the flowering duration measured as the DOY (day of the year) difference between the beginning of flowering (stage 61) to the end of flowering (69).

Conclusion & Perspectives

- A wide range of variation was found in the WOGB Marrakech collection for all Phenological data
- Our results concerning flowering dates of the WOGBM cultivars showed an important significant year effect, followed by cultivar
- Flowering date for olive cultivars ranged over years between 91 DOY (April 1st) in the year 2019 to 150 DOY (May 30th) in the year 2016.
- Clustering of cultivars according to ward's method showed 3 groups : the early, intermediate and late flowering groups

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Conclusion & Perspectives

- Stage 51 is a key stage of olive's trees flowering phenology, its early observation is correlated with long flowering period. Flowering period observations show correlation between a short flowering period and the increase of temperature expressed by the sum of degree-days.

Stage 51

- As the selection basis of adapted cultivars to global warming, our classification of olive Mediterranean genetic resources should be validated by further investigations, validating the statistical approach by the experimental one.

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Thank you
Dr. Hayat ZAHER
Researcher at INRA, UR Amélioration des Plantes, Marrakech, Morocco

CLIMATE CHANGE IN THE ORNAMENTAL SECTOR – A BREEDER'S PERSPECTIVE

Mr. Robert Boehm
Head of Biotechnology, Selecta One, Germany

The paper gives a short impression about climate change adaptation in the ornamental sector. This sector of horticulture is much smaller than the agricultural sector, though it is also affected by climate change consequences.

The Selecta One Group is globally leading in breeding, growing and marketing of vegetatively propagated ornamental plants. By selling approximately 600 million young plants per year all over the world, Selecta One serves all relevant markets, especially US, Europe and Asia. The product portfolio encompasses bed and bedding plant species, but also perennials and pot plants. The assortment is quite wide, and the breeding department is currently working on over 60 different genera and species.

Climate change is threatening the way these ornamentals are cultivated, especially considering extended periods of drought and heat stress caused by sun irradiation. This is what we have to face in the future.

Ornamental plants, including loans, are intensively maintained by gardeners and end consumers; this includes appropriate watering and care to keep the ornamental value over the summer and drought periods. To do this, a lot of water is wasted. Residual drought stress and additional heat stress damage nevertheless result in a decreased ornamental value, which also leads to increased susceptibility to pests and diseases as well as frustrated consumers who are no longer willing to invest further in ornamentals. Thus, there is a high demand of drought and heat stress tolerant plants also in the ornamental sector.

There are numerous different adaptations that plants have evolved to tolerate or to escape drought and heat stress, encompassing morphological as well as physiological adaptations, which genetically are quite complex.
In contrast to agriculture, the ornamental sector is characterized by high genetic variability between species and within species. The different varieties on the market are highly heterozygous, which makes breeding difficult and the transferability of breeding knowledge from one species to another, or even from one variety to another, is low.

To improve drought and heat stress tolerance in ornamentals, single specific adaptations can be targeted to improve the plants by breeding, like an increased acidic acid biosynthesis, reduced leaf surface, juxtaposition on the leaf or whatever. But if you look at the genetic background, you find highly quantitative traits, with many mechanisms involved, resulting in a complex inheritance.

To follow a traditional breeding approach, we first developed phenotyping protocols to characterize drought stress tolerance in greenhouse trials. For this, we measured many different parameters in big 4 l-pots (baskets). By this, we could identify genetic variation in the existing assortment regarding overall drought stress tolerance, without concentrating on single mechanisms.

However, when you are trying to increase drought stress tolerance by deliberate crossing of tolerant lines, the progeny splits up again with regard to this trait because of the heterozygous nature of the genetic material. It is not possible to pyramidize the necessary genes and thereby greatly increase the drought stress tolerance.

Biotechnological approaches here may serve as alternative. Fifteen years ago, Selecta tried such biotechnological approach to increase drought stress tolerance in collaboration with Mendel Biotechnology in the US, providing transcription factor genes from Arabidopsis thaliana which are related to drought stress tolerance. We introduced and overexpressed different transcription factor genes in different ornamental species, mostly petunias, and we regenerated a lot of transgenic lines, overexpressing these transcription factors. We tested them extensively in the greenhouse and also in field trials in the US. At the end, we came to transgenic candidate lines with reduced water needs of 30% at the beginning of the season, but this effect decreased more and more over the summer. Overall, we did not get a clear increase in drought stress tolerance and water saving. The effect was not high enough and not really predictable, because the overexpressed transcription factor genes activate highly complex and specific biosynthetic pathways which seem to be differently regulated in the different plant species.

But the elaborated phenotyping protocols allowed us to identify drought stress tolerant varieties in our existing assortment. This enabled a third strategy to be assessed for drought stress tolerant products, the selection. This relies on the identification of existing cultivars which are naturally more adapted to drought stress tolerance. Moreover, identification and development of new species with naturally evolved abiotic stress tolerance like grasses, Crassulaceae plants or other xerophytes can contribute to existing bed and bedding species and varieties.

These new selections led to our first commercial drought stress tolerant variety series called the Planta Morgana series. Here, we provide to our clients proven drought and heat stress tolerant varieties from the traditional bed and bedding species, supplemented by new species which fit within this series due to their ornamental value.

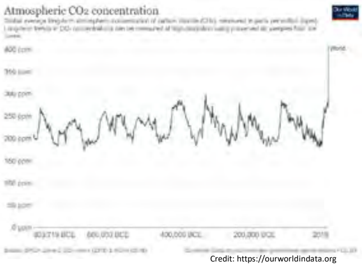
As a take home message, the presentation showed examples of different breeding and selection approaches to improve drought and heat stress tolerance in ornamental plants. In the first approach, the traditional breeding strategy was employed but the results show that it is quite hard to increase drought and heat stress tolerance in traditional pot plant varieties. They are genetically highly heterozygous, which hampers to efficiently pyramidize important genes in a deliberate way.

The second approach was based on the overexpression of regulating transcription factor genes. This biotechnological strategy was not successful because there is too little basic knowledge about detailed molecular pathways and gene regulation in the ornamental varieties and the transferability of gene functions between species or varieties are low. The best strategy may be selection strategy. Here, you make use of the given genetic variability in a breeder's gene pool and select for drought stress tolerant varieties, or even select and develop new species with naturally evolved high drought and heat stress tolerance for the market.

Presentation made at the Seminar

Climate change is a reality

selecta
we love to grow



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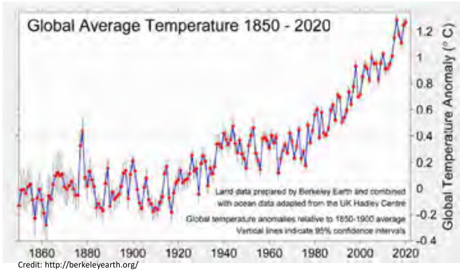

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4

Impact for ornamental culture

selecta
we love to grow

- Extended care and water supply
- Heat stress damages
- Reduced ornamental value
- Increased Susceptability for pests & diseases
- Dissapointed consumer

Credit: https://www.nature-and-garden.com/gardening/

Urban gardening

Credit: https://arborhilllandscaping.com/

Landscaping

Credit: https://www.park-der-gaerten.de/

Woody plant Arrangements

5

Impact for ornamental culture

selecta

- Extended care and water supply
- Heat stress damages
- ...mental value
- ...for pests & diseases

High demand for drought and heat stress tolerant plants


Credit: https://www.nature-and-garden.com/gardening/

Urban gardening


Credit: https://arborhilllandscaping.com/

Landscaping


...gaerten.de/

Woody plant Arrangements

6

Natural drought stress adaptations

selecta

Morphological :
- Compact, delayed growth
- Elongated root system
- Stoma density and distribution
- Hairy or waxy leaf surfaces

Physiological :
- Altered stoma management (ABA metabolism)
- Osmoregulation capacity

Complex :
- Tolerance to high leaf temperatures
- High recovery rate after wilt
- High water use efficiency


Credit : https://pflanzen-fuer-dich.de/


Credit: iStock.com/barbol88

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Breeding strategies for drought stress tolerance

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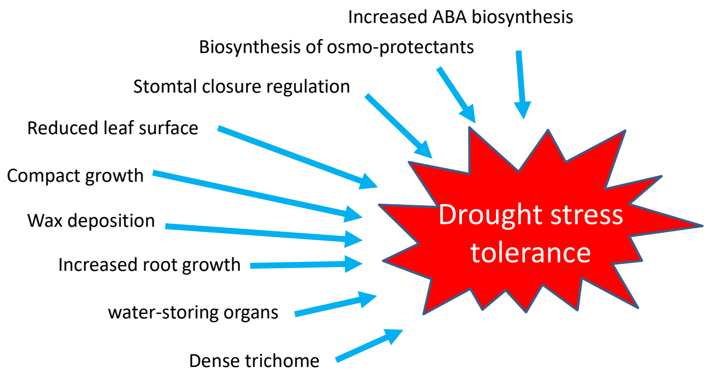

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Genetic background of abiotic stress tolerances

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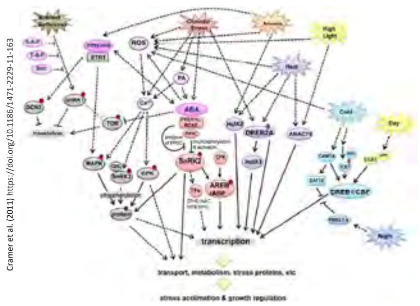
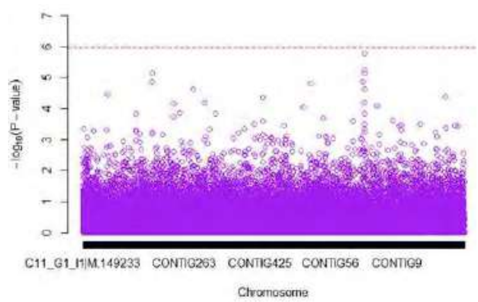
- Highly quanitative traits
- Many mechanisms involved
- Polygenic, multilocus molecular base
- Complex inheritance
- Hard to deliberately pyramidize by crossing





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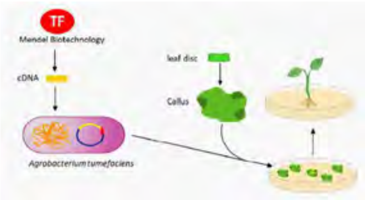
Biotechnological approach at Selecta



Transcription-factor	Protein family	trait
CBF1	AP2 TF	Frost
CBF2	AP2 TF	Frost
CBF3	AP2 TF	Frost
CBF4	AP2 TF	Frost, Drought
G1073	AT-hook TF	Drought
G481	NF-YB	Cold, Drought
G1274	WRKY TF	Cold, Drought
G47	AP2/ERF	Drought
G682	MYB TF	Cold, Drought, Heat
G1792	ERF TF	Pathogene, Drought, Cold
G28	ERF TF	Pathogene
G913	AP2 TF	Cold, Drought
G2133	AP2/ERF	Drought
G664	R2R3 MYB TF	Cold
G634		Drought
G1705	ERF TF	Pathogene, Drought

10

Breeding strategies for drought stress tolerance

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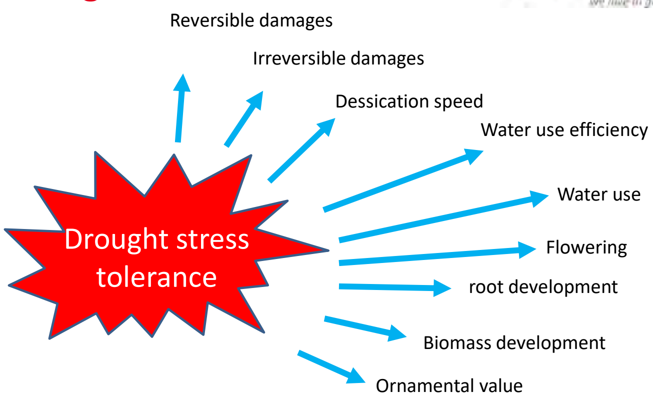

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Phenotyping Drought Stress in Baskets

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- Variants: well-watered, watering weekly and 2-weekly
- Repeated visual evaluation over 4 weeks

- Water use (WU) : ml/d
- Water use efficiency (WUE) : g fg/g water
- Reversible threshold water content (TWC_{rev}) : mbar
- Irreversible threshold water content (TWC_{irr}) : mbar
- Desiccation speed (DS) : dOV/dt
- Biomass 10 weeks after cutting
- Biomass ratio fw/dw
- Flower canopy (FCC)
- overall ornamental value (OV

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Selection for tolerant genotypes/varieties

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PH 2011 2954 | PH 2011 2977 | PH 2011 2860 | PH 2011 2929

PH 2011 2961 | PH 2011 2918 | PH 2011 2840 | Lilac Dark Vein (Reference line)

Pictures taken after 14 days water withdraw, before watering

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Substitution by new cultures

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- Species with naturally evolved plant stress tolance mechanisms
- C4/CAM-metabolism, drought-adapted morphology
  - Grasses
  - Crassulaceae (Sedum, Echeveria)
  - Xerophytes (Helichrysum, Calocephalus)
  - Others (Portulak, Brachyscome, Felicia)

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Marketing tolerant Varieties/Cultures

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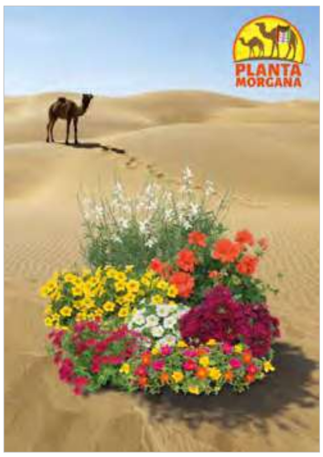
- Recommendation of more drought stress tolerant plant series
- Marketing with POS-material (pots, banner, label)



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Take-home message

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Strategy	Prerequisite	
Biotechnological strategy	Detailed molecular knowledge of pathways, genes and regulation network	
Breeding strategy	Successful pyramidization of different pathways. Acceptance of compact plants	
Selection strategy	Characterization tools for drought stress tolerance	

18

The Future ?

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Thank You!
20

ADAPTING CEREAL VARIETIES TO CLIMATE CHANGE IN THE NORDIC COUNTRIES – WHICH TRAITS CAN PLANT BREEDING WORK WITH AND WHICH ONES ARE MUCH MORE DIFFICULT?

Ms. Tina Henriksson
Goup manager breeding, Cereals & pulses & senior winter wheat breeder, Swedish company lantmännen, Sweden

Lantmännen is a coop owned by Swedish farmers; about 90% of Swedish farmers own a share in the coop.

Lantmännen invests about 100 million Swedish krona in plant breeding each year, and although this is a very small part of Lantmännen, we have ten breeding programs, three breeding stations and a rather large investment in new facilities. We have recently invested in climate chambers and genotyping facilities to take our variety development further.

Why do we need to have Swedish plant breeding? The answer is that we are a small country in the north and we need to have crops that are adapted to Swedish agriculture and agricultural practices. We need adaptation in some of the crops to our day length, which is very different over the year – in the northern part of our growing area, we actually have no night at all during the summer months. We also need to work towards lowering our environmental impact. This is a political choice as well as a climate change choice. We aim towards increasing on farm value for the Swedish farmers which are our owners. We want to try to expand our export market. And, as we are a small country in the north, we need to do it ourselves.

Lantmännen is a fairly large company. We own the whole chain of production, from plant breeding to grain to mills to industries like bakeries, and we produce consumer products.

We work with almost all the crops that are grown in the country. We work with winter wheat, winter triticale, spring barley, spring oats, faba beans and peas, and we work with all different forage grasses and forage legumes grown in our environment. Forages are actually the largest crop in Sweden. We also work with potatoes and salix.

We have breeding stations in different parts of the county. The main station is in the south of Sweden, but we also have a breeding station fairly far north and two stations in between, in the most important growing areas. We also have a breeding station in Emmeloord in the Netherlands.

Climate change has different perspectives depending on whether you consider the short or the long term. Plant breeding is a powerful tool in creating value, and plant breeding is capable of adapting varieties in an efficient way, if we just follow the climate change. But there are components in climate change that are a real challenge to work with. Plant breeding creates robust varieties and it is very important for farm security for the farmers.

In the short run we need to manage this change by adding more locations – and maybe locations in the south so we can be prepared. We need to use new markers for stress tolerance and develop more markers. We need to use new methods for selecting for stress tolerance. And we need to use more selection for root traits and develop methods to measure root traits.

What we do a lot of now is use new image analysis methods in the evaluation and selection process to be able to see things that we cannot see with our own eyes, but that we can see with drones and/or specialist cameras. This area of work will be expanded in the near future.

We also have started to use genomic selection together with speed breeding and marker selection to speed up the development of new parents in the breeding programs.

In the long run we need for us, up here in the north, to look at new crops, maybe to look at new characters that we are not used to working with, and to look for new resistances for traits that we have not had to look for before – for example, different diseases and also different insects.

Plant breeding 3.0, precision phenotyping. Image analysis is an example of what we do to try and keep up with climate change and be more and more efficient. We try to use as much as we can of drone images to evaluate and make decisions, to obtain more information from each yield plot than we have before. The genomic selection we are working on is in combination with speed breeding to try and make sure that we can evaluate as much material as possible, as quickly as possible.

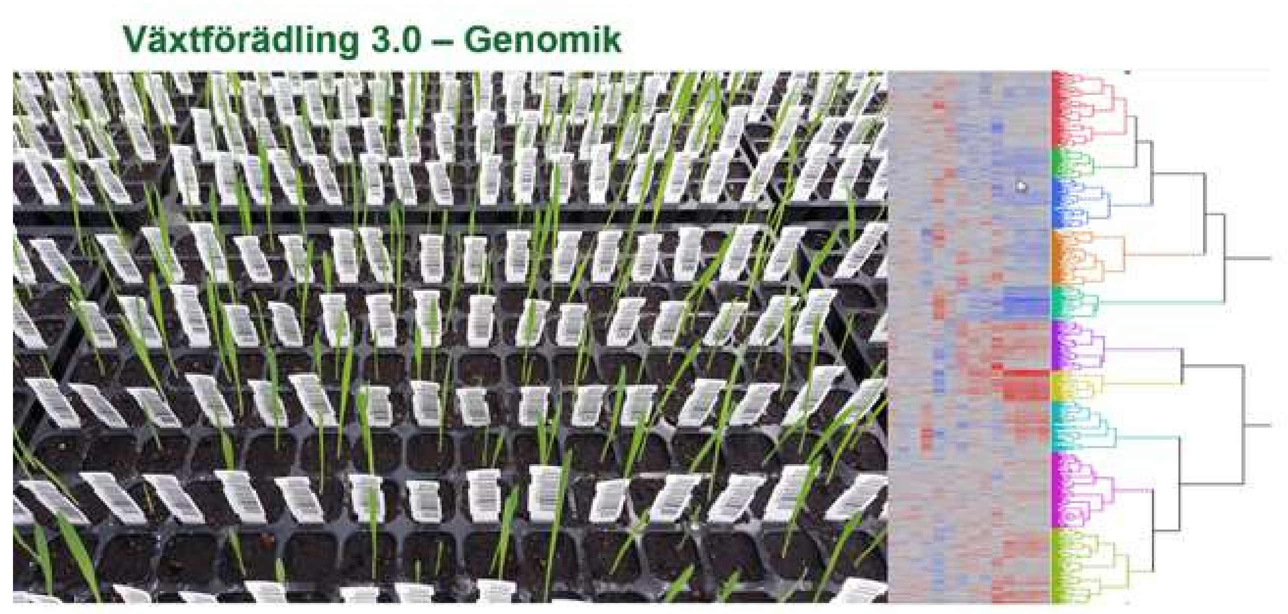


Figure 1: *Individual plants are genotyped and one way of presenting the result is a dendrogram over to what extent they are related to each other.*

Presentation made at the Seminar

Why Swedish plant breeding?

- Adaptation to Swedish agricultural practices
- Adaptation to day length
- Lowering environmental impact
- Increased value for Swedish farmers
- Increased export
- We are a small country and nobodyelse will do it….

3

Lantmännen has the whole value chain

- Plant breeding
- Grain
- Mills
- Industry
- Consumer products

We work with a large number of crops

Cereals
- **Winter wheat**
- **Winter triticale**
- **Spring barley**
- **Spring oats**

Pulses
- **Faba beans**
- **Peas**

Forages
- **Forage grasses**
- **Forage legumes**

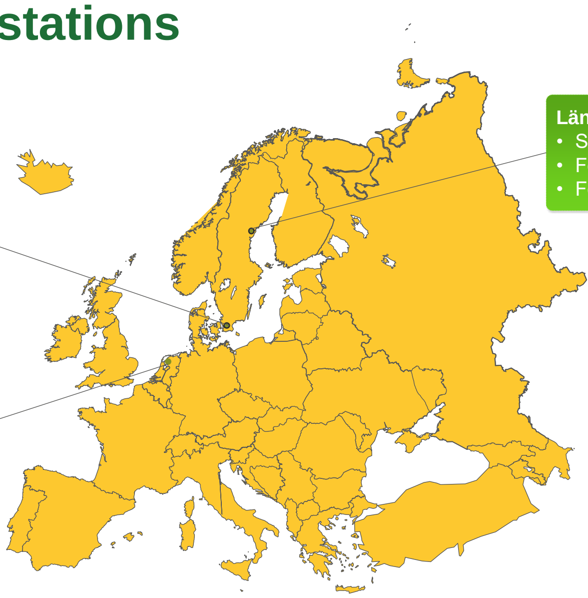
Potatoes

Salix

Our plantbreeding stations

Svalöv
- Winter wheat
- Winter triticale
- Spring barley
- Spring oat
- Peas
- Field beans
- Forage grass
- Forage legumes
- Salix

Emmeloord
- Triticale
- Potatoes



Lännäs
- Spring barley
- Forage legumes
- Forage grass

Climate change in short and the long run - can plant breeding meet the challenges?

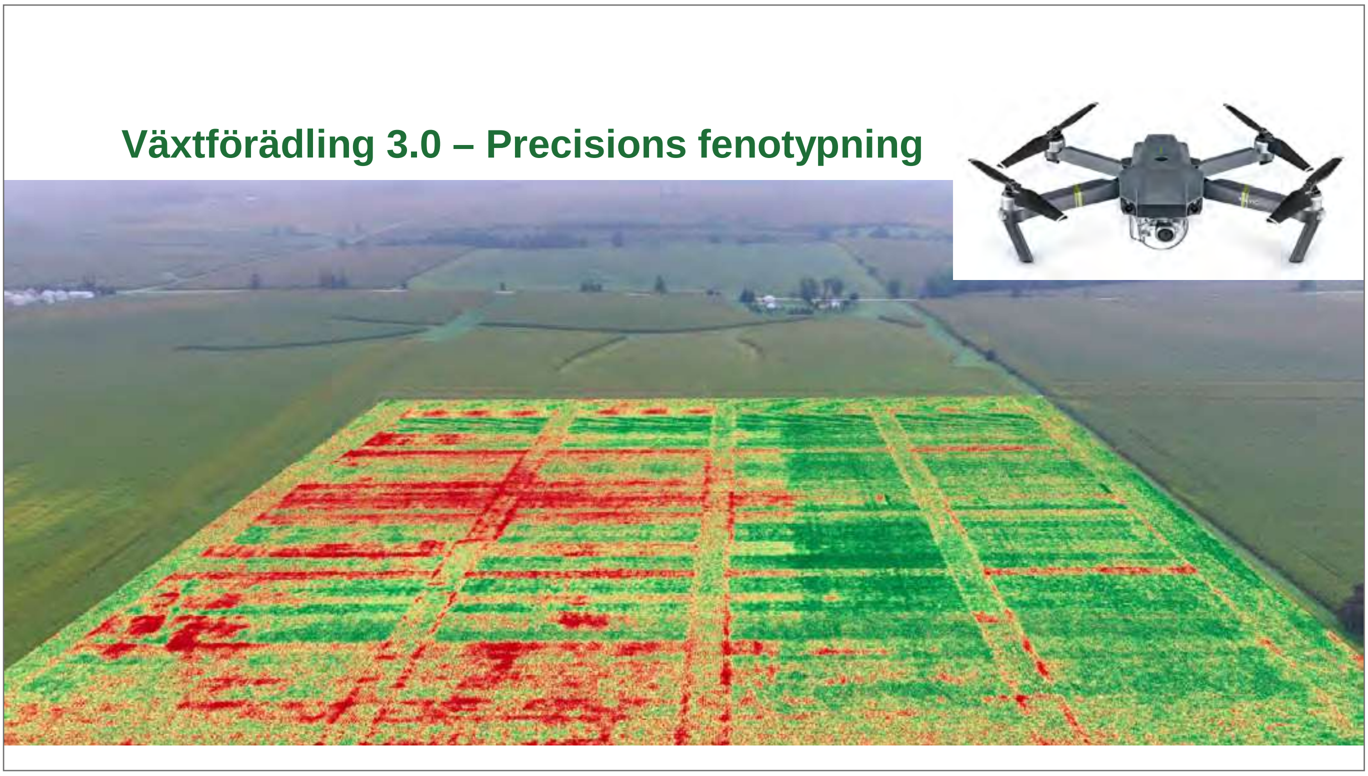
- Plant breeding is a powerful tool to create value
- Plant breeding slowly but surely follows climate change and adapts the varieties
- Plant breeding creates robust varieties and on farm security for farmers

In the short run

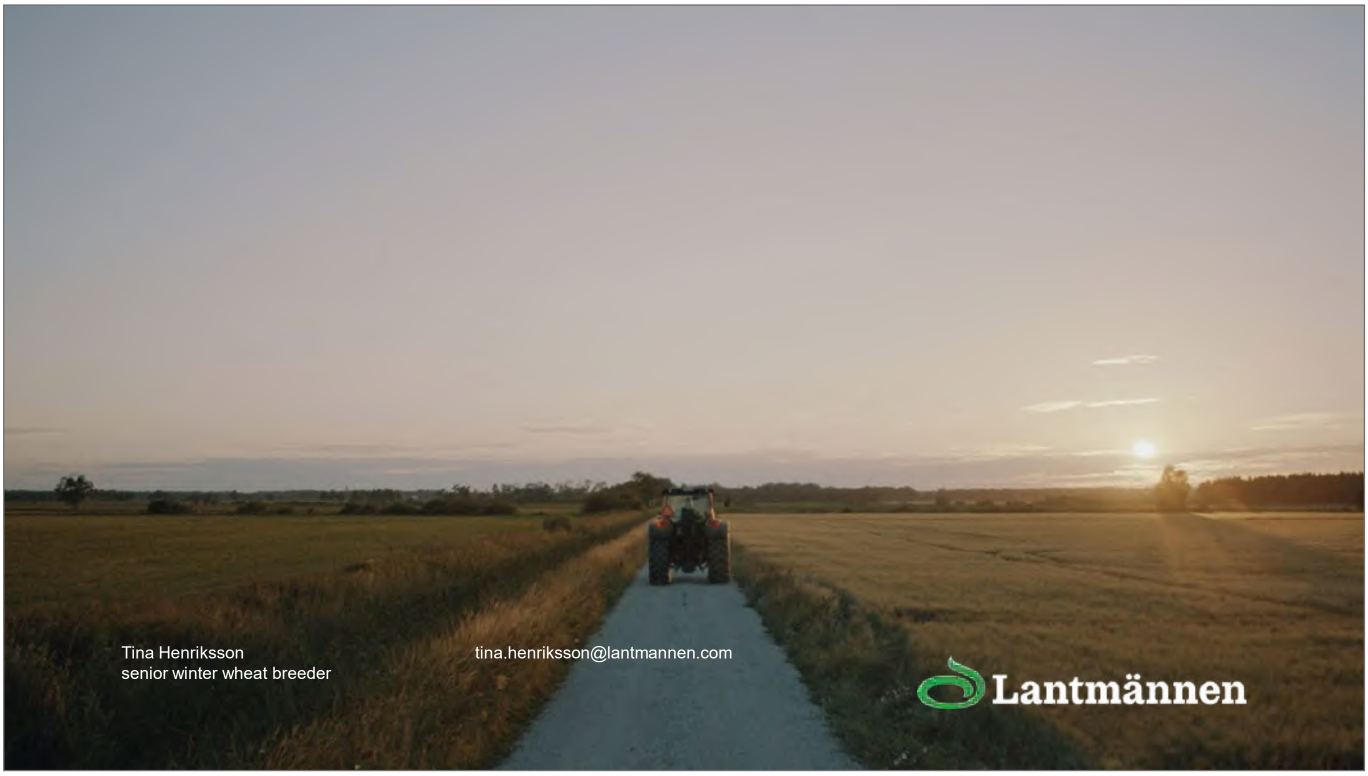
- adding of more locations with different environmental challenges,
- use of more selection for root traits and development of methods for this
- Use of new methods for selecting for stress tolerance,
- Use of new markers for stress tolerance-development of these
- Use of new image analysis methods in the evaluaton and selection process
- Use of genomic selection together with speed breeding and marker selection to speed up the development
- In the long run,

8


In the long run
• New crops
• New characters
• New resistances
9


Växtförädling 3.0 – Precisions fenotypning

Växtförädling 3.0 – Genomik



GRASSROOTS BREEDING OF FUTURE SMART CROPS, BETTER ADAPTED TO CLIMATE CHANGE: LEARNINGS FROM NEPAL'S EXPERIENCE

Mr. Pitambar Shrestha and Mr. Nirangjan Pudasaini
Local Initiatives For Biodiversity, Research And Development, Nepal

BACKGROUND AND INTRODUCTION

The impact of climate change on agriculture is as severe as in other sectors. Thus, agricultural research institutes have started focusing their work on developing new varieties and technologies that are adapted to changing climates. In the case of Nepal, the National Rice Research Institute (NRRP) has released some rice varieties that are tolerant to drought while some are suitable to water-logging conditions. While reviewing the literature, we can also find similar research being carried out on other cereal crops, such as wheat and maize, through crossing and other plant breeding methods. However, the research institutes have not placed much emphasis on exploring, evaluating and utilizing the traditional crop varieties of several crop species available in the farmers' field in the breeding program through selection from the existing diversity, also known as grassroots plant breeding.

Nepal is known as a pioneer country in participatory plant breeding (PPB), and researchers have developed different methods of PPB, including grassroots plant breeding. Grassroots plant breeding is a simple, effective and efficient method of plant breeding that strengthens farmers' skills in seed selection, production and marketing (Sthapit and Rao 2009; Sthapit *et al.* 2013). In this method, the selection of seed samples of desired traits from the existing diversity of traditional varieties is selected by farmers and researchers in the farmers' field. The breeding process involves need assessment, diversity assessment, selection of preferred traits, registration of the selected line in the National Seed Board (NSB) and making seed available through community seed banks (CSB) or community-based seed production (CBSP) approach. This is also a process of bringing farmers' varieties into the formal system.

The grassroots plant breeding method is highly relevant in the countries like Nepal, where rich diversity exists in the farmers' fields. And in the countries like Nepal, the formal plant breeding program has paid little or no attention to crops such as finger millet, foxtail millet, proso-millet and amaranths, as these are considered minor crops. However, considering the nutritional properties and other traits such as drought and early maturity, these crops are known as climate resilient and future smart crops. In the highlands of northwestern Nepal, these crops are key for food security (Parajuli *et al.* 2016) as the geography and climatic conditions are not favorable for crops like rice. This means farming communities have no option but to cultivate traditional varieties that they have been growing for many years.

In 2015, with the financial assistance of the United Nations Environment Programme Environment (UNEP)/Global Environment Facility (GEF), Bioversity International collaborated with Local Initiatives for Biodiversity, Research and Development (LI-BIRD) and Nepal Agricultural Research Council (NARC) for implementing the Local Crop Project (LCP). The LCP was implemented in four mountain districts of Nepal, namely Dolakha, Lamjung, Jumla and Humla, and had considered eight mountain crops – foxtail millet, finger millet, proso-millet, amaranth, beans, high altitude rice, buckwheat and naked barley – as mandate crops for research and development activities[1]. And the grassroots plant breeding method was applied to foxtail millet, finger millet, proso-millet and beans. This chapter presents the methodology and findings of grassroots plant breeding on the aforementioned first four crops.

Case example 1: foxtail millet

Foxtail millet *(Setaria italica)* was a major staple crop 30–40 years ago at the Ghanpokhara village of Lamjung District in Nepal. However, its cultivation started declining due to an expansion of the road network in the village as people started eating rice from the market. The household survey conducted in 2015 revealed that only 10% of households

1. http://himalayancrops.org

were found to be cultivating foxtail millet. The average area and production per household were 635 m2 and 89.4 kg respectively (Gurung *et al.* 2016). While sharing these findings and the nutritional properties of foxtail millet with the local community, they realized the importance of foxtail millet and agreed to improve this crop. Thus, 15 landraces of foxtail millet, including accessions from the National Genebank, collection from other project sites and six locally available varieties, were evaluated on farm. The local community preferred their variety, *Bariyo Kaguno*, as other varieties could not compete with it on yield, taste and grain size.

From this point onward, the research was focused on this variety; seed samples of the *Bariyo Kaguno* were collected from five custodian farmers from the same village, mixed to maintain diversity within the variety and planted in the farmers' field. Next year, true *Bariyo Kaguno* type panicles were selected jointly by farmers and researchers as a process of seed purification. The selected panicles were multiplied and distributed to many farmers as enhanced *Bariyao Kaguno*. At the same time, both qualitative and quantitative data were collected, and the variety was registered at the NSB as the first formally registered foxtail millet variety.

The LCP also facilitated the establishment of the Ghanapokhara Community Seed Bank to promote the conservation and utilization of local varieties. CSB members were trained both for institutional development and quality seed production of foxtail millet and other crops. Marketing of seed and grain was another issue with foxtail millet. Thus, the project also worked on these aspects. Today, the Ghanapokhara Community Seed Bank conducts seed production and collects foxtail millet grain for marketing. Though small in quantity, foxtail millet has been a source of income for farmers at Ghanpokhara, Lamjung.

Case example 2: finger millet

Jumla District is located in the high hills of western Nepal. The LCP focused its work on finger millet (*Setaria italica*) as one of the eight mandate crops. The grassroots plant breeding was applied to the finger millet variety *Rato Kodo*. As in the case of foxtail millet, 49 finger millet varieties were collected from various sources, including *Rato Kodo* from the Hanku village, and tested there. Among the test entries, *Rato Kodo* from the same locality performed well. Farmers preferred this variety compared to other tested varieties for higher grain yield, bold grain size and easy threshing ability. Therefore, seed samples of *Rato Kodo* were further collected from various farmers from the Hanku village to capture the heterogeneity within the variety. The seeds were mixed and planted as a single entry. Based on the farmers' selection criteria, the true type of *Rato Kodo* panicles was selected and the seed was bulked and multiplied. Next year, the seed was distributed to many farmers for testing as an enhanced *Rato Kodo*. At the same time, required data and information were collected and the variety was registered at the NSB. As a community institution, the LCP facilitated the establishment of Hanku Community Seed Bank. The CSB has taken responsibility for seed production and distribution of enhanced *Rato Kodo* and other local varieties in the locality.

Case example 3: amaranth

Amaranth (*Amaranthus spp.*) was another crop included under the grassroots plant breeding program at Hanku village in Jumla District. The household survey carried out in 2015 revealed that 30% of households were found to be cultivating amaranth. In Jumla, amaranth is planted as a border crop, whereas finger millet, beans or other crops were planted as the main crop. The LCP team collected several accessions from and around Hanku and Talium villages, including *Lal Marse*, literally the "red amaranth", from Talium village. While testing the collections at Talium, the community preferred *Lal Marse* from Talium, mainly for high yield and large grain size. Thus, panicle selection was performed, and the seed was multiplied and distributed to many farmers in Jumla District. At the same time, required data and information were collected and the variety was registered with the NSB. The Hanku Community Seed Bank established with the support of the LCP conducts seed production and distribution of the registered variety *Lal Marse* in the area.

Case example 4: proso-millet

Chhipra village (altitude ranges from 2,000–4,800 masl.) of Humla District was another LCP site where proso-millet (Panicum *miliaceum*) was found to be cultivated by 89% of households (Parajuli *et al.* 2016). In Humla, proso-millet is the second most common crop after finger millet. The district is known for its harsh climatic condition and rugged terrain, which makes agriculture even more difficult. Proso-millet is one of the crops that can be grown in marginal land as well as in rainfed conditions. As part of the grassroots plant breeding activity, 22 accessions of proso-millet were collected from various sources and tested at Chhipra village, including *Dudhe Chino*, literally the “milky proso-millet” from Chhipra. As mentioned in three other case examples, the *Dudhe Chino* from Chhipra village was preferred by the farmers for better taste and easy processing/de-husking compared to other test varieties. Therefore, panicle selection was performed, and seeds of the selected panicles were multiplied and distributed to many farmers for testing and dissemination. The necessary data and information were gathered and the variety was registered in the NSB under the leadership of Chhipra Community Seed Bank. The Chhipra Community Seed Bank produces and distributes seeds of the registered variety every year.

LESSONS LEARNED

Grassroots plant breeding is a simple process of plant breeding that empowers farmers and their institutions. Farmers’ participation and their views are considered key for the seed selection and enhancement process. Since community institutions such as community seed banks are established and involved in seed production, distribution and selling in the local community, they contribute to strengthening the local seed system and on-farm management of local varieties. The grassroots plant breeding process generates basic data about varietal characteristics and the farmer-preferred variety is selected, as it can be confidently used as a parent in the breeding activities for further development. Grassroots plant breeding is very simple and all activities are conducted in the farmers’ field; it does not require huge resources and time. In the case of Nepal, seed regulation has a special provision for the registration of local varieties which have excluded the Distinctness, Uniformity and Stability (DUS) requirement. It is also a process of recognizing the contribution of farmers, of enhancing access to quality seed by the local communities and realizing of farmers’ rights, as outlined in Article 9 of the International Treaty on Plant Genetic Resources for Food and Agriculture (ITPGRFA). The case examples presented in this chapter are related to the crops that are cultivated under marginal land and harsh growing conditions – these crops are climate resilient.

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Presentation made at the Seminar

LI-BIRD

Grassroots breeding of future smart crops, better adapted to climate change: Learnings from Nepal's experience

UPOV Seminar on the Role of Plant Breeding and Plant Variety Protection in Enabling Agriculture to Mitigate and Adapt to Climate Change

Pitambar Shrestha and Niranjan Pudasaini

12 October 2022, Virtual Seminar

Local Initiatives for Biodiversity, Research and Development (LI-BIRD)
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Outline

- **National context**
  - Geography, climate and climate change
  - Smallholder farmers and plant breeding
- **Concept of the grassroots breeding**
- **Grassroots breeding of future smart crops: case examples**
  - Foxtail Millet, Finger Millet, Proso-millet, Amaranth
- **Lessons learned**

National context

Geography, climate and climate change

- Geographically, Nepal's land has been divided as **High Mountains, Mid-hills, Siwalik and Terai** with climatic characteristics varying from **tropical to alpine condition** within a lateral span of 200 Km.
- The meteorological data indicate consistent warming and rise in the maximum temperature at an annual rate of **0.04 to 0.06 °C** (NAPA) where as the **annual precipitation is on the general decline**.
- The **impact of such changes in agriculture is tremendous**, so the future research and development should consider developing climate resilient crop varieties, breeds and technologies.

Smallholder farmers and plant breeding

- The crops such as **Foxtail Millet, Finger Millet, Proso-millet and Amaranth** are known as climate resilient and future smart crops as these crops are cultivated in harsh growing conditions, **has high level of nutritional properties,** and often cultivated by smallholder farmers.
- So far, the formal plant breeding programme in Nepal has paid **no attention on crops such as Foxtail Millet, Proso-millet and Amaranth** except on **Finger Millet**.
- Farmers have little or no option of cultivating these crops to feed the family in some areas. Hence interventions on these crops contribute to food security and income of the smallholder farmers.

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Concept of the grassroots breeding

- Grassroots breeding is a simple approach to plant breeding - **selection from existing diversity** of traditional varieties by farmers under the targeted environment.
- The breeding process involves **need assessment, diversity assessment, selection of preferred traits, registration of the selected line in the National Seed Board (NSB), seed multiplication** and distribution.
- It's a process of bringing farmers' variety under the formal domain

Finger Millet, Jumla

Amaranth, Jumla

Proso-millet, Humla

Foxtail Millet, Lamjung

Source: *Sthapit and Rao 2007*

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Grassroots breeding of future smart crops

Case example 1: *Bariyo* Foxtail Millet, Ghanpokhara, Lamjung District

Background

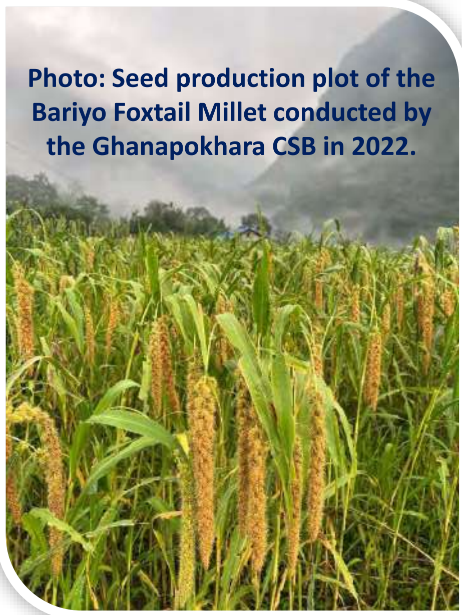
- Foxtail millet was a major **staple food crop 30-40 years ago** in the area
- But its cultivation started declining due to expansion of the road network in the village as people started eating rice from market. **Only 10% households found cultivated** it on an average area of 635 Sqm/household producing 89.4 kg/household (Household Survey Report 2016).
- Foxtail millet was **jointly identified** by the community and the Local Crop Project team **for seed selection and enhancement** in 2015.
- **15 landraces** including accession from the National Genebank and another project sites, and six locally available varieties were evaluated on farm.
- ***Bariyo Kaguno*** (from Ghanpokhara) was preferred by the local community due to high yielding, good taste and relatively larger grain size.

Grassroots breeding of future smart crops

Case example 1: *Bariyo Kaguno* (Bariyo Foxtail Millet), Ghanpokhara, Lamjung District (Contd.)

The Grassroots breeding process

- Seed samples of ***Bariyo Kaguno*** were collected from five custodian farmers, it was mixed and planted in the farmers field.
- True to ***Bariyo Kaguno*** type panicles were selected jointly by farmers and scientists.
- Seeds of the selected panicles were multiplied and distributed to many farmers. Market linkage was developed for grain.
- Data were collected and the variety was registered in the National Seed Board by Ghanpokhara Community Seed Bank.
- The Ghanpokhara Community Seed Bank produces and supplies quality seed in the locality and surrounding districts.



Grassroots breeding of future smart crops

Case example 2: *Rato Kodo* **(**Red Finger Millet), Hanku, Jumla District

Background and the grassroots breeding process

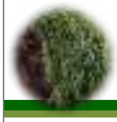
- **Finger Millet** was identified as a mandate crop for research by the Local Crop Project in 2015,
- **49 varieties were collected** from different sources and tested at Hanku, Jumla including *Rato Kodo* (Red Finger Millet) of the same locality.
- The *Rato Kodo* from Hanku, Jumla performed well compared to other varieties in terms of **grain yield, grain size and thresh ability**
- Seed samples of ***Rato Kodo* were collected from various locations** to capture the diversity and it was mixed.
- **True type of *Rato Kodo* panicles were selected** from the bulk population, it was further multiplied and the seed was distributed to many farmers.
- Required information was collected and the **variety was registered** in the National Seed Board by Hanku Community Seed Bank, Jumla.
- Hanku Community Seed Bank, Jumla produces and distributes seed of the registered variety every year.

Grassroots breeding of future smart crops

Case example 3: *Rato marse* (Red amaranth), Hanku, Jumla District

Background and the process of grassroots breeding

- A mandate crop identified for research at Jumla District by the **Local Crop Project** in 2015.
- It was **grown by 30%** of the households at the Hanku Village of Jumla District. It is planted as a **boarder crop** rather than as a main crop.
- Several accessions collected from around the community were tested at Talium Village including *Rato Marse* (Red Amaranth) of the same locality.
- ***Rato Marse* from Talium, Jumla was preferred** by farmers compared to other varieties due to high yielding and large grain size.
- **Panicle selection was performed, seed was multiplied and distributed** to many farmers.
- Required information was collected and the **variety was registered** in the National Seed Board.
- Hanku Community Seed Bank, Jumla produces and distributes seed of the registered *Rato Marse* every year.



Grassroots breeding of future smart crops

Case example 4: *Dudhe Chino* (Milky Proso-millet), Chhipra, Humla District

Background and the grassroots breeding process of

- A mandate crop identified for research at Humla District by the **Local Crop Project** in 2015.
- It was **grown by 89% of the households** at the Chhipra Village of Humla District, **second most common cereal crop** after finger millet in the district.
- **22 accessions were collected and tested** at Chhipra Village including *Dudhe Chino* (Milky Proso-millet) of the same locality.
- The *Dudhe Chino* from Chhipra, Humla preferred compared to other varieties in terms **of taste and easy processing/de-husking**,
- Panicle of true type of *Dudhe Chino* were selected from different farms, it was multiplied and the seed was distributed to many farmers,
- Required information was collected and the **variety was registered** in the National Seed Board by Chhipra Community Seed Bank, Humla.
- Chhipra Community Seed Bank, Humla produces and distributes seed of the registered variety every year.

Lessons learned

- **The grassroots breeding has multiple advantages –** a simple process of plant breeding that empowers farmers and their institutions; strengthens the local seed system and on-farm management of local varieties/agrobiodiversity. Thus countries with reach crop diversity should consider grassroots breeding as a strategy to cope with climate change.

- **Advantages to plant breeders:** They can confidently use the grassroots breeding bred varieties in their breeding programme as parents - basic information about the variety is easily available.

- **An innovation that happens in the farmers field:** Grassroots breeding does not require a huge amount of resources and time. There is no need of DUS and IP low. Thus, research institute should support farmers' organization to work on such initiatives that also contribute to the realization of Farmers' Rights as outlined in the Article 9 of the ITPGRFA.

- **Local solution to fight climate change:** The cases shared are examples of how locally adapted crops promoted through grassroots breeding can contribute to meet local needs.

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Acknowledgment:

- Farming communities and four community seed banks of LCP sites,
- UNEP/GEF, MoALD Nepal
- Bioversity International, NARC/National Genebank.

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VEGETABLE COMPANY STRATEGIES TO ADDRESS THE CHALLENGE OF PRODUCING MORE FOOD UNDER INCREASINGLY HARSH CONDITIONS AND HOW THE PLANT BREEDERS' RIGHTS (PBR) SYSTEM CAN HELP BREEDERS TO COPE WITH SUCH CHALLENGES

Ms. Astrid Schenkeveld
Specialist Plant Breeders' Rights & Variety Listing Rijk Zwaan, Zaadteelt en Zaadhandel B.V., Netherlands

The challenge is clear: there will be more mouths to feed (10 billion worldwide in 2050) with increasingly scarce resources (energy, water, arable land). Plant breeding has many keys with which to unlock sustainable solutions. To allow breeders to explore, develop and implement these solutions, certain preconditions must be met.

One of them is a solid, efficient and enforceable – yet enabling – IP protection system. The UPOV 1991 Act provides the system to protect plant varieties while enabling innovation.

A vegetable breeding company like Rijk Zwaan contributes to food and nutrition security and climate-smart agriculture by breeding varieties:

- with higher yields and the right resistances;
- fit for new cultivation methods that lead to a higher productivity and more sustainable (water-efficient) cultivation, such as hydroponics;
- that are able to cope better with harsh conditions like heat, drought and salinity, causing trouble to growers in, e.g., the Middle East. Rijk Zwaan has a research team that focuses on abiotic stress;
- with a longer shelf life;
- for almost all markets worldwide, and specifically for Africa and Asia. For example, for the African market, we have developed improved (hybrid) varieties of traditional crops such as African hot pepper, African eggplant and African kale. This goes along with sharing our knowledge and educating the farmers (e.g. through public-private partnerships like the Seeds of Expertise for the Vegetable Sector in Africa (SEVIA). Figure 1 shows one of our hybrid habanero varieties, an improved traditional African crop. Instead of 1 kg (traditional variety), the improved variety produces 3-4 kg per plant.

One of the essential solutions of vegetable breeding companies resistance breeding. Here are some examples:

- Melon varieties having intermediate resistance (IR) to cotton aphid. Cotton aphid is a vector of specific viruses. Due to the resistance, the aphids are unable to multiply. As a consequence, fewer crop protection products are needed to keep the crop healthy.
- Cucumber varieties having high resistance (HR) to mosaic virus (CGMMV). After an infection with mosaic virus, the plants of these cucumber varieties continue to grow normally. No virus symptoms, or very few, occur in the plants or on the fruits, resulting in a better quality and production than in normal (susceptible) plants infected by this virus. The virus multiplies more slowly in the plants than is the case in normal (susceptible) cucumber varieties. The concentration of the virus in the plant is, therefore, much lower, which slows down the spread from plant to plant considerably.
- Pepper varieties having an intermediate resistance to powdery mildew (*Leveillula taurica* (Lt)). This means that they are less susceptible to damage by mildew than standard varieties. The varieties are able to slow down mildew growth and development.

Figure 1

The benefits include:

- cost savings;
- better working conditions;
- an environment more conducive to natural enemies of mildew, necessitating the use of even fewer crop protection agents;
- less residue in line with retailers' wishes
- Cucumber varieties having an intermediate resistance (IR) to *Fusarium oxysporum f. sp. cucumerinum*.

Fusarium is a soil and substrate fungi that infects the root system. This fungi may persist for long periods in the soil. Having infected the plants, *Fusarium* initially causes just a few leaves to wilt slightly, and plants might be able to recover the first days under dark conditions. A few days after the first infection, the plants cannot recover further and will wilt completely. These plants are subsequently a source for infecting other plants in the greenhouse. Disinfection of the soil and grafting the plants has been the only solutions so far. With our *Fusarium*-resistant varieties we offer a new line of defense for cucumber crops.

One of the solutions of vegetable breeding companies for higher productivity and more sustainable (water-efficient) cultivation is hydroponics. Worldwide, hydroponic production of crops such as lettuce is becoming increasingly popular. Rijk Zwaan has been working for many years on varieties that are suitable for growing in water. We have developed a wide range of leafy vegetables that are specifically suitable for hydroponic production methods. When developing varieties that can be grown in water, Rijk Zwaan pays attention to aspects such as fast and compact growth, lack of delicate leaf edges, good color intensity in the case of red varieties, a healthy and uniform crop and ease of processing and packaging.

Water-based growing systems make it possible to produce lettuce with efficient use of water and nutrients and with no or limited use of crop protection agents. Hence, we are helping growers to meet consumers', retailers', foodservice companies' and processors' demands for clean and more sustainable products. The leaves are free from sand, grit and dirt, so the lettuce no longer needs to be washed thoroughly to remove such residues. LED lighting enables growers to provide the precise amount of light to stimulate optimum crop growth. The crops can even be produced in multiple layers which increases the efficiency. Furthermore, the yield is stable because the harvest is less dependent on the natural climate. As a result, retailers can also collaborate with producers in countries with poor soil conditions.

Another solution for sustainability comes from creating varieties, contributing to reduction of waste. The trait here is delayed pinking of fresh cut lettuce, which we have introduced as an additional CPVO DUS characteristic as Leaf: wound-induced discoloration.

Convenience is an important trend in vegetables and also represents a way to increase vegetable consumption. One of our most recent convenience innovations is: a trait which reduces pinking in lettuce after cutting. As a result, this trait extends shelf life and therefore reduces waste. Rijk Zwaan has already introduced this trait into around ten lettuce types. This is the result of ten years of development work. Since this trait means that lettuce no longer always needs to be packed in low-oxygen packaging, it lowers costs and offers more options when blending. The longer shelf life also contributes to a reduction in food waste. And because the lettuce stays fresh for longer in consumers' homes, there is a higher likelihood of repeat purchases and hence increased sales.

Without access to genetic resources, there is no future. There are, roughly speaking, four sources:

- own collection;
- *in situ* material (wild relatives);
- *ex situ* material (genebanks, markets);
- competitor varieties.

Competitor varieties can be used under the breeder's exemption in plant breeder's rights.

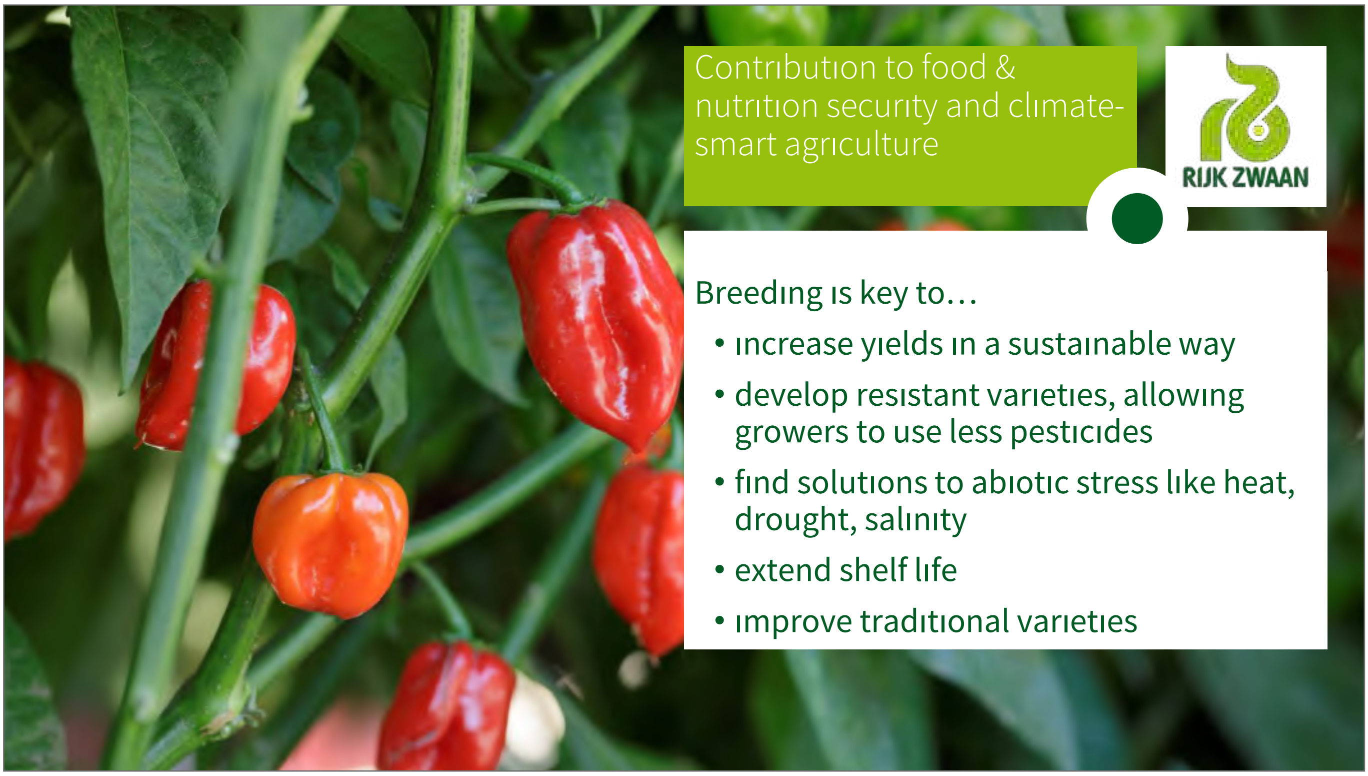
Having access to or making use of these sources is not enough. Only now does the process of breeding start. It takes on average 6 to 16 years – depending on the species and the complexity of the desired trait, to develop a new commercial vegetable variety. Innovation in plant breeding can accelerate the development, but variety development is not only about breeding; it is also necessary to test of new varieties in practice before market introduction and seed production, requiring several years. It goes without saying that this involves a large investment in R&D. Rijk Zwaan spends about 30% of its turnover yearly on R&D. This comes down to €160 million a year. Return on investment is necessary to continue developing new varieties.

Concluding, we can say that the PBR system helps breeders to cope with such challenges because:

- the breeder's exemption makes open innovation possible;
- it enables the breeder to obtain the necessary return on investment.

These two factors make plant breeder's rights *the* IP protection system for plant varieties, so that we and others can continue to use sources and invest to find solutions for today's challenges to the benefit of the farmers and consumers.

Presentation made at the Seminar



Examples

RIJK ZWAAN

- Strong focus on resistance breeding
  - against *aphids* > less use of chemicals
  - against *mosaic virus* > better quality/higher yield
  - against *leveillula taurica* > less chemicals, lower residue level
  - against *Fusarium oxysporum f. sp. Cucumerinum* > prevents loss of plants, better yield

Ag DEFENSE Bon DEFENSE For DEFENSE Lt DEFENSE

Examples

RIJK ZWAAN

Hydroponics

- Clean and soilless, water-based growing method
- Efficient use of nutrients and water
- No or limited use of crop protection agents
- Stable and higher yield, less dependent on natural climate

Examples

RIJK ZWAAN

Delayed pinking of fresh cut lettuce
(Leaf wound-induced discoloration)

- Extended shelf life
- Less waste
- Suitable for Food Service
- Stronger against cracking
- Less sensitive for leaking seals

Access to genetic variation is essential for breeding

RIJK ZWAAN

- Own collection
- In situ material (wild relatives)
- Ex situ material (genebanks, markets)
- Competitor varieties


The role of plant breeder's rights
RIJK ZWAAN
• Return on investment is necessary to continue developing new varieties
• PBR is THE IP protection system: providing adequate protection, while others can continue to find solutions to today's challenges – Open Innovation


Sharing a healthy future
RIJK ZWAAN
Closing remarks
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QUESTIONS

NGWEDIAGI Patrick (Mr.), Chair of the Administrative and Legal Committee, UPOV (moderator)

We are moving to question and answer session and which will be for ten minutes.
You are welcome, participants, to ask questions..

HUERTA Yolanda (Ms.), Legal Counsel and Director of Training and Assistance, UPOV

Patrick, there is a question from Noluthando from South Africa.

NGWEDIAGI Patrick (Mr.), Chair of the Administrative and Legal Committee, UPOV (moderator)

Noluthando, you are welcome.

NETNOU-NKOANA Noluthando (Ms.), Director, Genetic Resources, Department of Agriculture, Rural development and Land Reform, Pretoria, South Africa

Good morning, colleagues. My question is to Pitambar on grassroots breeding. I think in Nepal.

NGWEDIAGI Patrick (Mr.), Chair of the Administrative and Legal Committee, UPOV (moderator)

In Nepal.

NETNOU-NKOANA Noluthando (Ms.), Director, Genetic Resources, Department of Agriculture, Rural development and Land Reform, Pretoria, South Africa

Yes. I would just like to know what criteria is used to have the varieties registered in the catalogue. Thank you.

NGWEDIAGI Patrick (Mr.), Chair of the Administrative and Legal Committee, UPOV (moderator)

Pitambar, please.

SHRESTHA Pitambar (Mr.), Programme Advisor, Local Initiatives for Biodiversity, Research and Development, (LI-BIRD), Pokhara, Nepal (speaker)

Thank you very much for the question. I mentioned earlier in my presentation that our legislation has a different provision for the registration of farmers' varieties. So, we have a separate provision but I cannot tell you in details about all of those criteria, but basically the format involves basic information, agronomic practices, what farmers follow, and other qualitative and quantitative traits based on farmers' experiences. It is – the data is collected by interviewing ten to twenty farmers and that information is used – those information collected through interviews is used for developing a proposal. It's very simple. It's very simple data.

In our case, like with our support, farmers can develop a proposal and they can defend their variety registration proposal in the national seed board.

So, now I just can say it's very simple and if you would like to know more about the variety registration process following grassroots breeding, you can direct your email to me. I can provide you detailed information.

We also had organized a side event about the registration process of local varieties in the recently held ninth session of the Governing Body of the International Treaty on Plant Genetic Resources for Food and Agriculture (ITPGRFA) in New Delhi. So, we can share many presentations and other information about the variety registration process following grassroots breeding. Thank you.

NGWEDIAGI Patrick (Mr.), Chair of the Administrative and Legal Committee, UPOV (moderator)

Thank you, Pitambar. I think Noluthando's question was based on the fact that you said you do not do DUS. So, if you do not do DUS, I think the follow-up question is how do you differentiate the varieties? Of course, if we want the details, we can contact you, but I think we wanted to know, how do you differentiate the varieties if you do not describe them.

SHRESTHA Pitambar (Mr.), Programme Advisor, Local Initiatives for Biodiversity, Research and Development, (LI-BIRD), Pokhara, Nepal (speaker)

We normally use farmers' criteria, how farmers describe the variety. That is described in the proposal and that is submitted to the National Seed Board. That is what I can say now. Thank you.

NGWEDIAGI Patrick (Mr.), Chair of the Administrative and Legal Committee, UPOV (moderator)

Thank you very much.

THEMATIC SESSION 4:

Plant breeding for climate change adaptation and mitigation in agriculture: breeding strategies and techniques

Moderator: Mr. Manuel Toro Ugalde,
Vice-Chair of the Administrative and Legal Committee, UPOV

"A smart green future" and "climate resilience underpinning breeding programmes"
Ms. Emma Brown, General Manager, Plant Varieties, and Mr. Zac Hanley, General Manager Science, Plant & Food Research, New Zealand

Use of new technologies (molecular markers and speed breeding) in the development of drought-tolerant cereal varieties in Morocco
Mr. Moha Ferrahi, Head, Genetic Resources Improvement and Conservation Department (DACRG), Scientific Division, National Institute for Agricultural Research (INRA), Morocco

Breeding for the future
Mr. Stefan van der Heijden, Associate, Innova Connect, Netherlands

The role of variety characteristics on climate footprint (disease resistance, nitrogen utilization and yield)
Mr. Morten Lillemo, Professor, Norwegian University of Life Sciences Faculty of Biosciences, Norway

Questions

Research into market-driven and climate smart crop varieties: tolerance to biotic and abiotic stresses
Mr. Francis Kusi, Acting Director, Savanna Agricultural Research Institute, Council for Scientific and Industrial Research Institute (CSIR-SARI), Principal Research Scientist (Host Plant Resistance), Ghana

Genetic improvement by mutagenesis of oilseed crops to cope with climate change: case of rapeseed and sesame
Mr. Abdelghani Nabloussi, Researcher, Meknès Regional Agricultural Research Centre (CRRA), National Institute for Agricultural Research (INRA), Morocco

Connecting different research clusters with the aim to develop more accurate breeding
Mr. Muath Alsheikh, Field Operations Unit Manager, Graminor AS, Norway

Advances in the development of new varieties better adapted to climate change in crops and forages: a South American perspective
Mr. Fernando Ortega Klose, Forage Plant Breeder, Chilean Agricultural Research Institute (INIA), Carillanca regional center, Chile

Breeding Program to mitigate climate change and environmental pressures on crops
Mr. Dave Bubeck, Research Director, Corteva, United States of America

Questions

"A SMART GREEN FUTURE" AND "CLIMATE RESILIENCE UNDERPINNING BREEDING PROGRAMMES"

Ms. Emma Brown
General Manager, Plant Varieties, Plant & Food Research, New Zealand

Mr. Zac Hanley
General Manager Science, Plant & Food Research, New Zealand

The New Zealand Institute for Plant and Food Research Limited / Rangahau Ahumāra Kai (Plant & Food Research) in Aotearoa New Zealand is government owned, and public and private sector funded. As a Crown Research Institute, Plant & Food Research's core purpose is to enhance the value and productivity of Aotearoa New Zealand's horticultural, arable, seafood, and food and beverage industries to contribute to economic growth and the environmental and social prosperity of Aotearoa New Zealand.

Our mission
To create the world's most sustainable food production systems

We believe that our science can make the world a better place; that by working together, we can create a smart green future, for Aotearoa New Zealand and the world. For us, a smart green future means we use all available knowledge to produce healthy, nutritious food from the land and sea, while ensuring we protect our environment and create opportunities for future generations.

To achieve this core purpose Plant & Food Research conducts a wide range of scientific capability across the value chain in a range of sectors, including operating and investing in breeding programs both alone and with partners in Aotearoa New Zealand and offshore. It is through these breeding programs that Plant & Food Research has created world-leading varieties that underpin brands such as Jazz™, Envy™, Rockit™ and SunGold™ Kiwifruit. The varieties that Plant & Food Research has bred contribute billions of dollars into the Aotearoa New Zealand economy. We have every expectation of repeating this success in the future.

The development of new varieties requires decades. New technologies may accelerate development, but the level of investment required remains very high. A competitively scaled program of international standing for a significant exporter or domestic supplier needs a minimum investment of approximately NZ$1M (€600k) per annum and the investment required is proportional to the complexity and opportunity. Effective Plant Variety Intellectual Property (PV IP) protection at the UPOV convention level and national legislation levels must take account of the timeframes, of potential disruptions from new technologies and of the considerable delay between investment and commercial return. The changing pace of innovation in variety development and commercialization models is also a critical determinant in this rapidly changing environment in the face of climate change.

Innovation in plant breeding is a key contributor towards success in biologically based primary industries. Therefore strong PV IP protection that balances the interests of breeders, growers and society is essential to horticulture and arable agriculture supporting Aotearoa New Zealand's future.

PLANT & FOOD'S RESEARCH BREEDING PROGRAMS

The majority of Plant & Food Research's breeding programs are located in Aotearoa New Zealand, and we operate 14 research centers hubbed primarily around the core crop production regions. We conduct a wide range of breeding programs in a range of species, varying in scale and breeding targets. In some species we operate multiple breeding programs with different focuses, in different regions of Aotearoa New Zealand and around the world. Our current breeding programs include (but are not limited to): kiwifruit, apple, pear, grape, blackcurrant, blueberry, raspberry, boysenberry, blackberry, apricot, hop, kiwiberry, potato, pea, wheat, barley, oat, rootstocks for several species, and a range of ornamental species such as Gentiana and Limonium.

Additionally, we operate, together with our commercialization partners, breeding programs offshore. One of the most important reasons for this is to build resilience to our changing climate by challenging our candidate varieties in climates different to those in Aotearoa. These include:

- the Hot Climate Program, an apple and pear breeding program located in Catalan, Spain, with our partners the Institute of Agrifood Research and Technology (IRTA), Fruit Futur and VentureFruit Global Limited;
- a machine-harvest raspberry program, located in Washington State, USA, operated by our joint venture company Pacific Berries LLC;
- a dragon fruit program, located in Viet Nam, in close collaboration with our partners Southern Horticultural Research Institute (SOFRI);
- an apple rootstock program, located in and conducted with our partners in China.

Global challenges and new breeding techniques

Breeding programs around the world face common challenges and, like Plant & Food Research, are reacting. Feed, forage, and fiber production systems are under scrutiny for their carbon emissions, predicted to be 15Gt of carbon dioxide equivalents by 2050. This is far above the target of 4Gt required to keeping global warming below 2°C. New variety innovation is more than a wise investment for economic return this century; it is a social necessity.

At the same time, the development of highly productive, zero-input varieties is an imperative, because a 52% shortfall exists between expected food demand in 2050 and current global food production. New cultivars and new growing systems have always aimed to improve production efficiencies, producing more nutrients for the same, or less, inputs and impacts. Today's challenge is one of unprecedented magnitude. The world requires plant varieties that provide leaps in production without vanishing inputs and with only positive impacts. We need better cultivars faster.

Existing breeding approaches and intellectual property protection schemes such as Plant Variety Rights (PVR) are unlikely to meet this urgent challenge. New breeding technologies such as gene editing may provide more certainty, in certain applications, but cannot offer a global solution while regulated differently by different national jurisdictions. Consumers are not all aware of the scale of the challenge facing food production in the future and of the role these technologies can play so they remain wary, creating little incentive even to progress discussions about regulatory reform. Even existing breeding technologies are subject to uncertainties, which can disincentivize investment in the necessary innovation. Plant variety IP protection is, as with gene editing laws, a regulatory patchwork as different countries take differing approaches to the application of the UPOV conventions.

Nevertheless, innovation occurs. Investment occurs, benefits occur. Is the pace sufficient? There are reasons for hope. The molecular basis of commercial traits - the genes, the underlying cellular causes - are being rendered amenable to breeding. Traits such as vertical flowering and branching (important for growing in climate-controlled high-yield container systems) are breeding targets. There are unprecedented possibilities, such as the accelerated domestication of new plant species in years instead of millennia. Fundamental sciences can combine with a fuller understanding of consumer and grower requirements and desires as society and our climate change faster than ever before. The investment required is high, but the scale of the crisis demands a radical response.

PLANT VARIETY INTELLECTUAL PROPERTY STRATEGY

Our PV IP and commercialization strategies vary by species, commercial partner and variety. Because an IP strategy goes hand in hand with a commercialization strategy, each are interlinked and underpin one another. We start by considering where the variety will be propagated and cultivated, where harvested material will be sold, and where would it be potentially at risk without PVR.

We also take into account the legislative protection tools available to us and what the scope of protection is, whether the underpinning legislation is UPOV 91, UPOV 78 or a sui generis regime, and whether there are particular nuances to the legislation by country we need to take into account. We also consider other legislative intellectual property tools such as trademark and whether we or our commercialization partner intend to use trademarks, either an umbrella or individual mark.

Co-evolution of breeding and protection strategies

As our climate changes and our breeding programs produce new varieties to meet these changing needs, our commercialization and IP strategies are evolving too. These must consider where, given our changing climate, they may be suitable to grow in the future.

We are taking crops into countries where they have not been grown at scale or received PV IP protection before, such as dragon fruit into New Zealand.

More than ever before this means careful planning to manage several pressing issues, including

- plant material logistics, crossing borders and navigating quarantine with new species;
- creating sufficient time for trials and evaluation in new regions and countries;
- novelty-triggering events need to be balanced with the need to evaluate, which varies by jurisdiction and from time-to-time regional interpretation;
- interspecific hybrids, which pose a challenge both for cross-border quarantine, appropriate objective descriptions, and relevant reference varieties;
- planning ahead with short windows of novelty and opportunity to secure PV IP with changing climates opening and closing commercialization opportunities;
- the challenge that defining morphological and phenotypic traits may express differently in different production models, for example field-grown vs controlled environment systems.

CONCLUSION

A smart green future for us and all globally focused breeding programs requires rapid changes. Investment in more radical innovation technologies for breeding strategies needs to increase more than incrementally. The issues are urgent. For UPOV, the opportunity is to ensure IP legislation keeps pace, at both convention and national implementation levels.

Presentation made at the Seminar

Plant & Food™ Research
Rangahau Ahumāra Kai

A smart green future and climate resilience underpinning breeding programmes

Mrs. Emma Brown, General Manager Plant Varieties

Dr. Zac Hanley, General Manager Science

The New Zealand Institute for Plant and Food Research Limited

Agenda

- Introduction to Plant & Food Research
- Challenge: it's a time of crisis (global warming), change and uncertainty
- Our response: climate resilience underpinning breeding programmes
  - Breeding strategies
  - Plant Variety Intellectual Property
- UPOV's opportunity


A smart green future. Together.
Our mission
To create the world's most sustainable food production systems

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Bonfire begonias. Nectaron® hop. Zespri SunGold® kiwifruit. JAZZ™ apple. Everleaf Tiger oat. PACIFIC ROSE™ apple. [illegible] apricot. Tahi kiwiberry. Blue Sapphire™ blueberry. Vanquish wheat. Firefly Kale. Red Rascal potato. Blushing Star Leptospermum. Tango™ tamarillo. Summer Blaze peaches. Raspberry Shortcake ornamental raspberry. Pinnacle pea. Blackadder blackcurrant. CleanCrop™ Palaton.

Our cultivars are grown in more than 30 countries worldwide

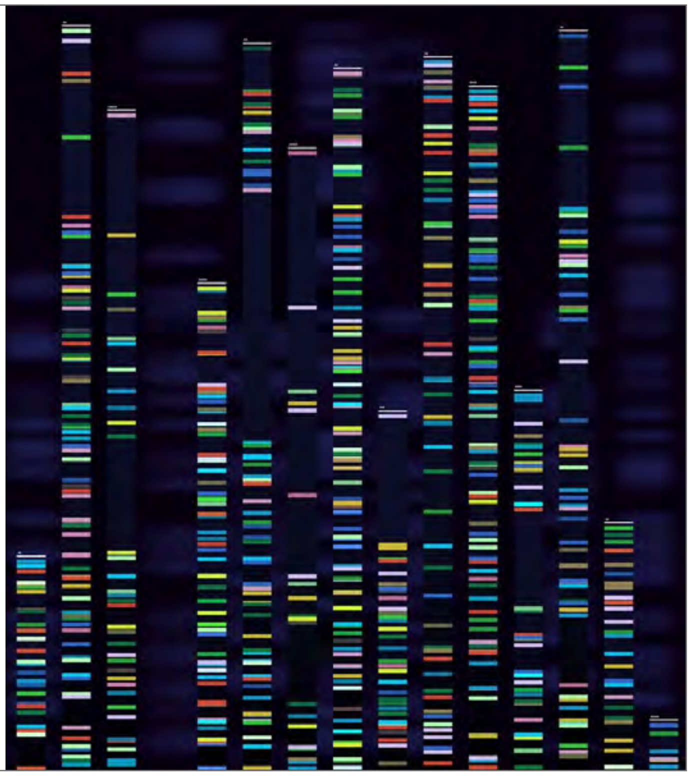
- Zespri™ Red Kiwifruit
- Wake® raspberries
- Envy™ apples
- ‘Moonlight’ potatoes
- ‘Conquest’ wheat

A smart green future. Together.

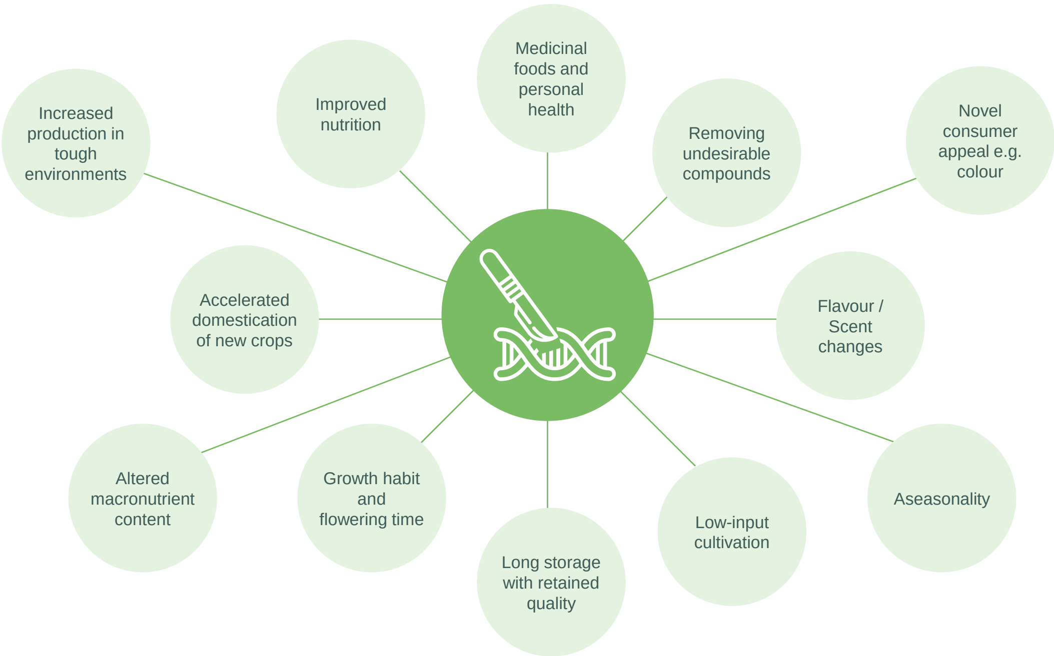
Global challenges

Applied research is revealing the molecular basis of commercial traits and creating tools for breeders to deliver better cultivars faster

- Gene identification, sequencing and mapping
- Gene function and pathway analysis
- Nutrition, consumer appeal, pest and stress tolerances
- Marker-assisted and whole-genome selection
- Gene editing

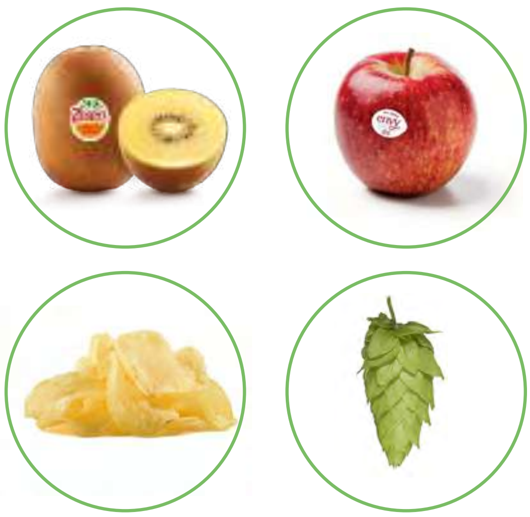


Potential for new breeding techniques & technologies



Plant Variety Intellectual Property Strategy

- Where will the variety be:
  - propagated
  - cultivated
  - harvested material sold
  - at risk without PVR
- Legislative protection:
  - PVR
    - UPOV91
    - UPOV78
    - Sui generis
  - Trade mark



Plant Variety Intellectual Property Strategy - evolution

- New countries for new crops at the new pace
  - Plant material logistics
  - Allowing sufficient time for trials & evaluations in new regions and countries
  - Novelty triggering events balanced with the need to evaluate
  - Interspecific hybrids
  - Planning ahead – rapid climate change, new production regions
- New growing methods
  - morphological / phenotypic traits that may express differently in different production models

A smart green future. Together.

Together, we need **greater investment** in **more radical innovation** in breeding strategies.

Together, Plant & Food Research – with our customers & partners – is **embracing this opportunity.**

Together, we are all on the same journey.

UPOV's opportunity ensure Intellectual Property legislation keeps pace at the Convention and at national implementation levels.

Plant & Food™ Research
Rangahau Ahumāra Kai

Thank you

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The New Zealand Institute for Plant and Food Research Limited

USE OF NEW TECHNOLOGIES (MOLECULAR MARKERS AND SPEED BREEDING) IN THE DEVELOPMENT OF DROUGHT-TOLERANT CEREAL VARIETIES IN MOROCCO

Mr. Moha Ferrahi
Head, Department of Breeding and Conservation of Genetic Resources (DACRG), Scientific Division, National Institute for Agricultural Research (INRA), Morocco

INTRODUCTION

Climate change is a major challenge facing humanity with multiple consequences, sometimes exceeding the response capacity of ecosystems. Atmospheric CO_2 levels have already had observed consequences on natural ecosystems and species. Some ecosystems and species show a natural adaptability, while others are already showing the effects of the negative consequences of current climate change.

The pessimistic scenario on the projections of the effects of climate change predicts that the suitability of land for the production of cereals in Morocco should experience a decrease of 30% by 2100. Also, according to projections, we will witness a decrease in wheat yield of about 8% under the effects of climate change by 2030. It is therefore urgent for Moroccan agriculture to develop resilience while preserving its natural resources.

During 2022 we had a severe drought with 70% drop in rainfall. And in general, from the 1980s to the 2000s, we experienced one dry year every five years, increasing to one year every three years. And now we have every other year -one good year, one dry year. We have a decrease in rainfall of 40% and an increase in temperature.

Cereal production in Morocco depends on rainfall. Around 90% of cereal production in is under rainfed (no irrigation). So, if you have a good year, you have good production. In bad years, production drops very drastically. Production is strongly linked to rainfall, as are yields (Figure 1).

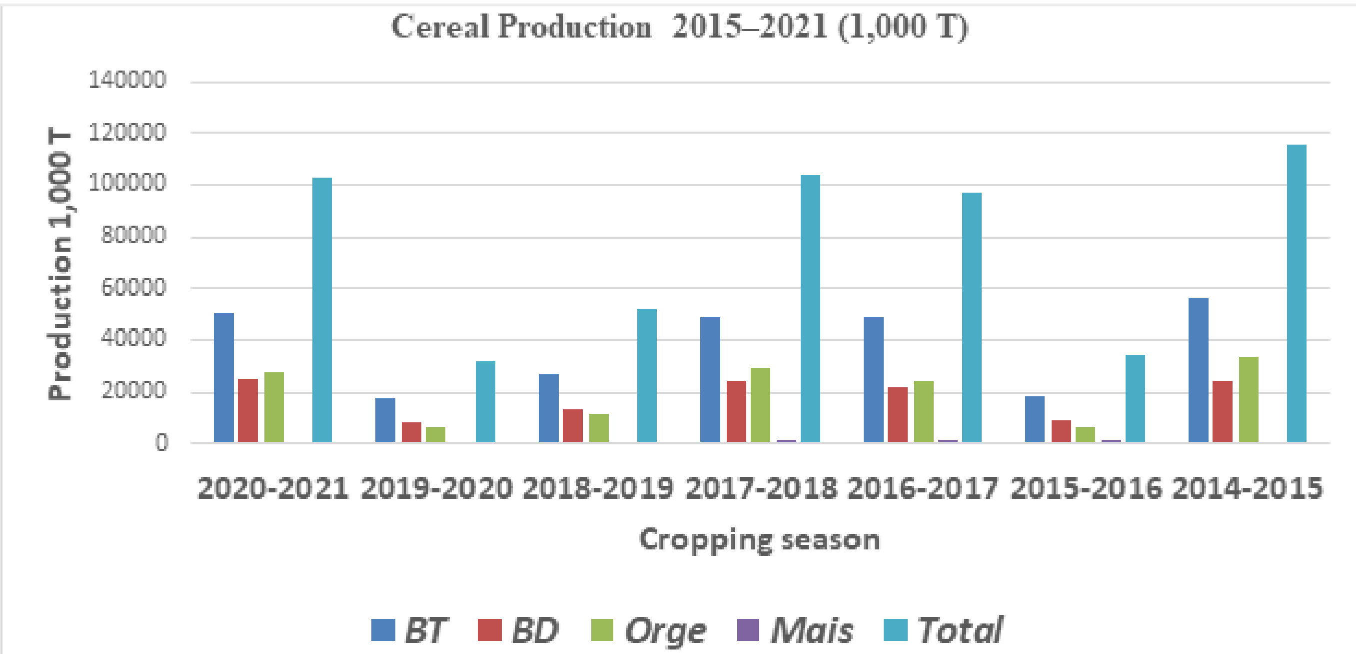


Figure 1. *Cereal production in Morocco over the last seven years.(BT: Bread wheat; BD: durum wheat; Mais: maize)*

Cereal production is linked to rainfall, and there has been major fluctuations from year to year over the last three years. In 2021–2022, similar to 2019–2020, production has been 3.4 million tons over an area of 4.3 million ha (2020–2021). The average yield is 1.6 t/ha to 2.5 t/ha (2009–2021) and the yield potential ranges from 3 to 5 t/ha for pilot farmers and in experimental stations (2009-2021).

WHEAT BREEDING PROGRAM IN MOROCCO

The cereal breeding in Morocco that goes back more than a century, and we have released several varieties. However, with the changing climate we need new varieties that can adapt to these new constraints, focusing on developing very resilient varieties that can cope with this kind of climate (drought, heat and changing races of pathogens). The environments we have been working with for cereal production on are well characterized. Several years ago, the most predominant ones were humid and semi-arid, but now conditions have changed a lot; right now at least 70% to 80% of the production environment for wheat is in dry areas.

The main objectives of the wheat breeding program at INRA are to develop new varieties that can cope with these changes in climate, varieties that can develop in at least 300 mm of rainfall and that can withstand temperature that goes beyond 30°C. In addition, these varieties must be resistant to the main biotic stresses.

Water productivity has been improved significantly. Originally around 1.5 kilograms per cubic meter of water, in recent years we have developed new varieties that can produce at least 2.2 kilograms per cubic meter of water. This is valuable in developing resilient varieties for the coming years.

More recently, new techniques have been used in developing varieties such as the pre-breeding types, using interspecies crosses and in vitro culture to advance our generations, and we have now in the pipeline very good, adapted and resilient varieties. Speed breeding is one of the techniques used to speed up the development of new varieties, resulting in at least three generations per year. We are shortening the cycle for developing varieties. Other techniques are used such as tilling and irradiation to create new genetic variation allowing the selection of new varieties. Irradiation by ethyl methanesulfonate (EMS) has allowed the selection of some good and drought- and salt-tolerant varieties, which are high yielding compared to commercial varieties, and which also have good resistance to biotic stresses.

DROUGHT-TOLERANT DURUM WHEAT VARIETY: CASE STUDY

A case study was produced in 2018 on a drought-tolerant variety of durum wheat in Morocco. It comes from an interspecific cross and is the first drought-tolerant variety with a large grain. The variety was evaluated for five cropping seasons, and it has an overall productivity 24% superior to all commercial varieties used in the study. As shown in Figure 2, you can notice that in dry years the importance of the drought variety is very important, giving an average grain yield gain of 24% to 36% when the year is dry.

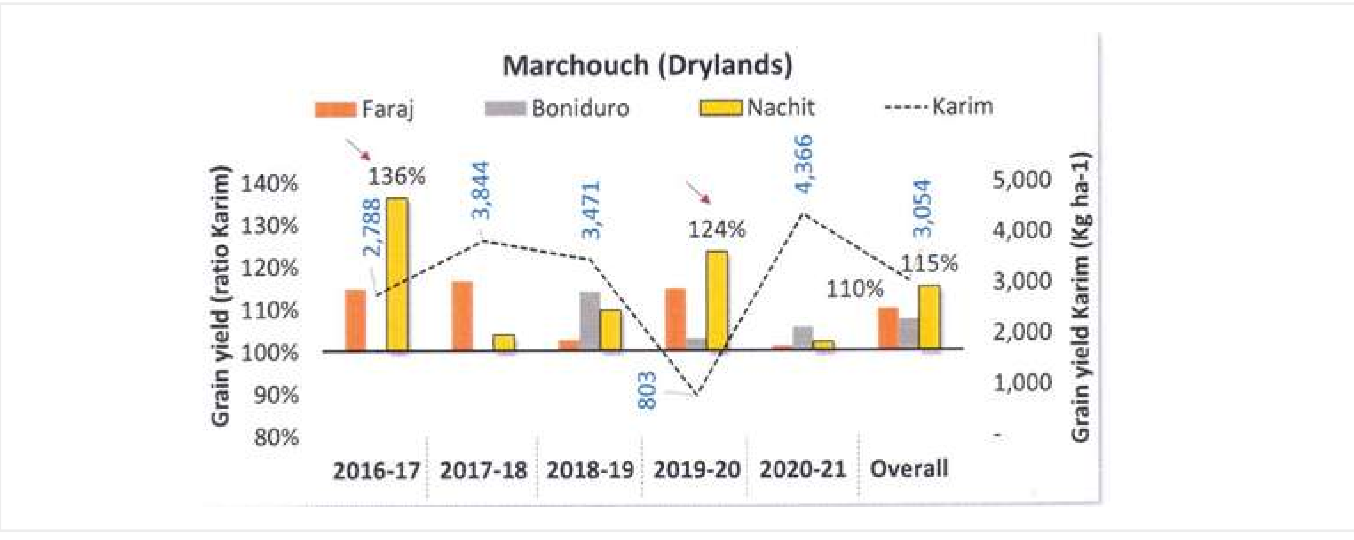


Figure 2. *Evaluation of drought-tolerant variety of durum wheat in several environments.(BT: Bread wheat; BD: durum wheat; Mais: maize)*

The drought resistance comes from three Quantitative trait loci (QTLs) for root development which you do not have in two other commercial varieties. The three QTLs have allowed an additional 3 kilograms per hectare. All these thee QTLs are necessary to gain that much in yield. We have also lines with only two QTLs and lines with one QTL which resulted in less gain. This study has allowed us to identify some Kompetitive Allele Specific PCR (KASP) markers that we are using now in our program selection for drought and heat tolerance.

For drought resistance, we need deep roots, early flowering varieties and good grain weight. For heat, we need higher spike fertility. But disease resistance is also important for both environments

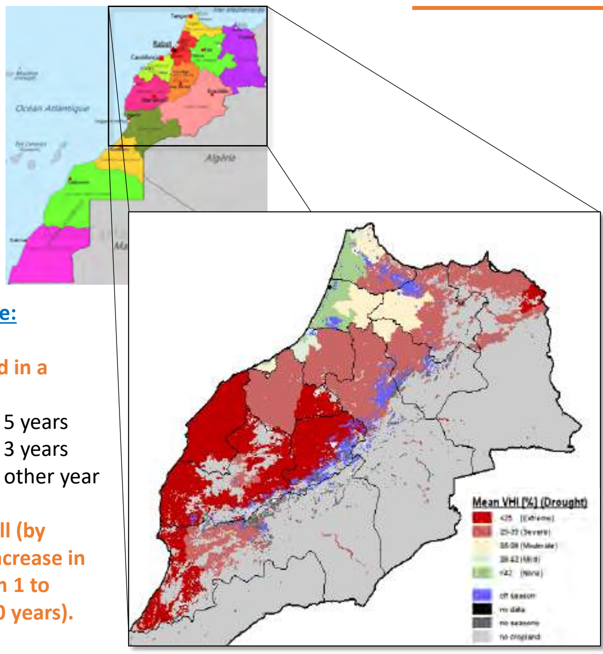
Presentation made at the Seminar

Use of new technologies (molecular markers and speed breeding) in the development of drought-tolerant wheat varieties in Morocco

UPOV seminar 11-12 October 2022

Dr. Moha Ferrahi
Head, Breeding and Genetic Resources Conservation Department
Scientific Division, National Institute for Agricultural Research

Drought and its consequences on crop establishment in Morocco

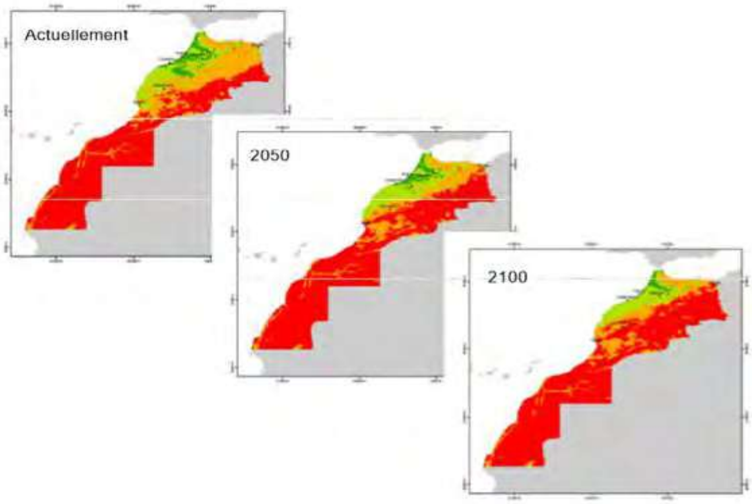


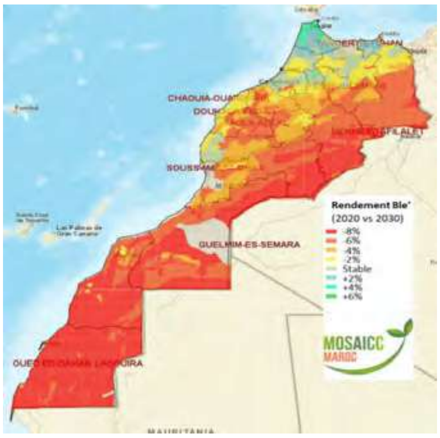
Climate change is here:

- **Morocco is located in a drought hot spot :**
  -1980-2000: every 5 years
  -2000-2020: every 3 years
  -Since 2021: every other year
- **Decrease in rainfall (by about 40%) and increase in temperature (from 1 to 1,5°C in the last 40 years).**

الجيل الأخضر GÉNÉRATION GREEN 2020 - 2030

Impact of Climate Change in Morocco



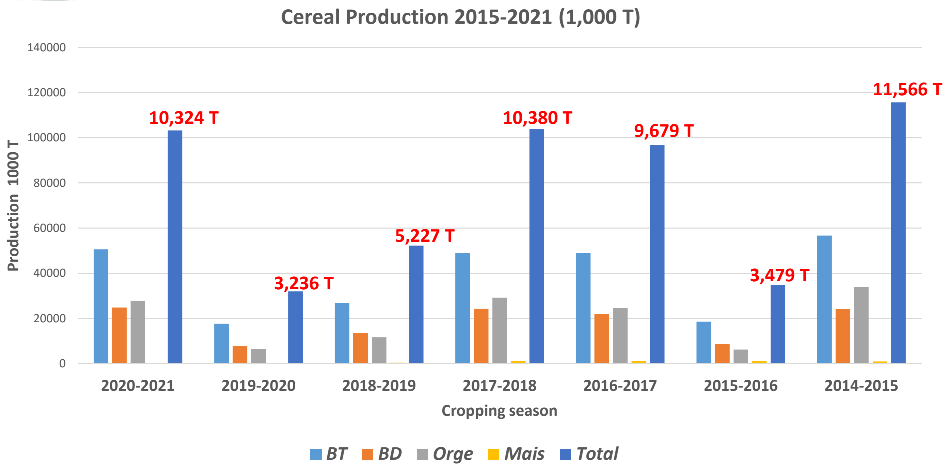


Projected reduction of 8% in wheat yields by in 2030

Impact of climate change: reduction of 30 % of cereal area in Morocco by 2050

الجيل الأخضر GÉNÉRATION GREEN 2020 - 2030

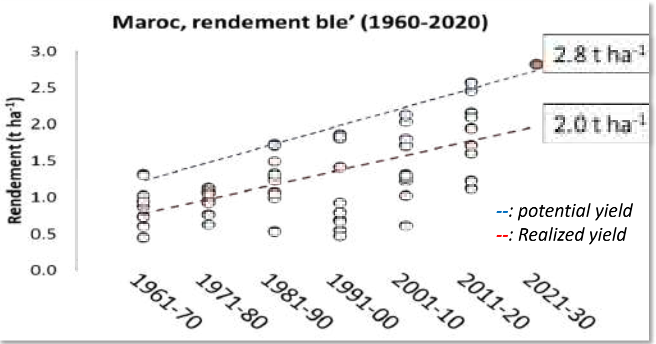
Cereal Production in Morocco



- Cereal Production is linked to rainfall, there is big fluctuation from year to year (last 3 years)
- In 2021-2022: similar to 2019-2020 with a production of 3,4 million T
- Area: 4,3 million ha (2020-2021)
- Average yield: 1,6 T/ha to 2,5 T/ha (2009-2021)
- Yield potential: 3-5 T/ha pilot farmers and in experimental station

More than a century in Cereal breeding in Morocco

Item	Value
Scientists involved	30
Support Staff	>70
Allocated area for trials each year	>200 ha
Released varieties since 1980	120
Market share of INRA varieties	15-58%



Average Annual Genetic Gain: 0.1 T/yr

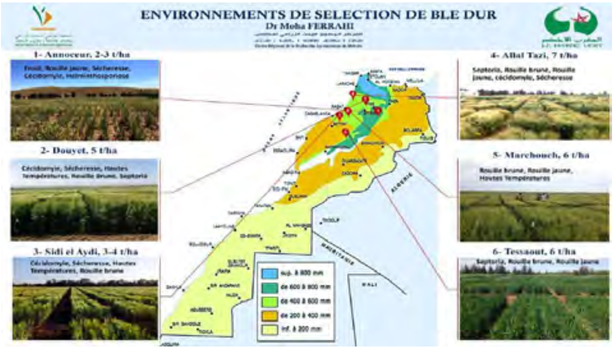
Cereal production: Environments and constraints in Morocco

- Fully irrigated or supplemented (**10% area**):
  - ✓ 3 Rusts and Septoria, tan spot and quality
- Humid and sub-humid (>450 mm, **40% area**):
  - ✓ Drought, heat, septoria, leaf and yellow rusts
- Semi-arid and arid (250 to 300 mm, **40% area**):
  - ✓ Drought, leaf rust and Hessian fly
- High altitude (350 - 600, **10% area**):
  - ✓ Drought, cold, frost, yellow rust, stem rust and TS

Cereal Germplasm Development at INRA

>10,000 Experimental plots for breeding each year

- Selection in different environments across the country
- Screening for major diseases and abiotic stresses
- More than 800 International lines evaluated each year
- Use of commercial varieties for comparison
- Use latest experimental analysis and genomics for MAS



Improving agronomic water productivity (WUE)

- ✓ The water productivity in the rainfed areas is very low (ranges from 0.506 Kg/m3 in good years to 0.149 g/m3 in dry season). Overall the water productivity varied between 1.15 Kg/m3 for Doukkala region and 3 Kg/m3 for Tadla region in Morocco (Balaghi et al., 2014);
- ✓ On the average, the varieties released by INRA have a water productivity of about 2.27 kg/m3 (Ferrahi, 2020), which is comparable to Australian varieties that are known to be drought tolerant.

Prebreeding effort for Drought tolerant germplasm development

❑ Interspecific hybridization for the transfer of Hessian fly resistance from wheat wild relatives to cultivated wheat
Crosses between durum wheat and *Triticum dicoccoides*




❑ New interspecific hybrids were obtained from cross between cultivated barley and tetraploid *Hordeum bulbosum*


Use of Advanced technologies in cereal breeding

Use of innovative technologies such as

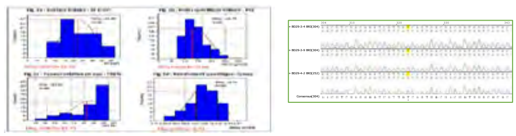
- Powerful tools in experimentation and data analysis;
- Use of speed breeding techniques/DH;
- Use of genomic as MAS;
- High throughput phenotyping to study abiotic stress;
- Use of drones to estimate yield;
- Taking into account the industry and end-use requirements;
- Farmers involvement for selection preferences ;
- Climatic changes;
- …



Application of Tilling and Irradiation to Create New Genetic Resources and Selection of Adapted Lines in Wheat

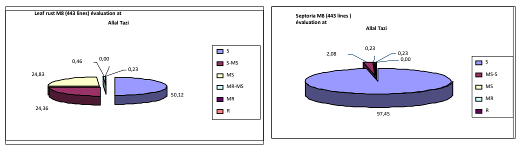
Creation of a mapping population from commercial durum and bread wheat varieties using nuclear irradiation (EMS) and selection of mutants with :

- ✓ Good Drought and Salt tolerance;



- ✓ High yield as compared to commercial varieties;

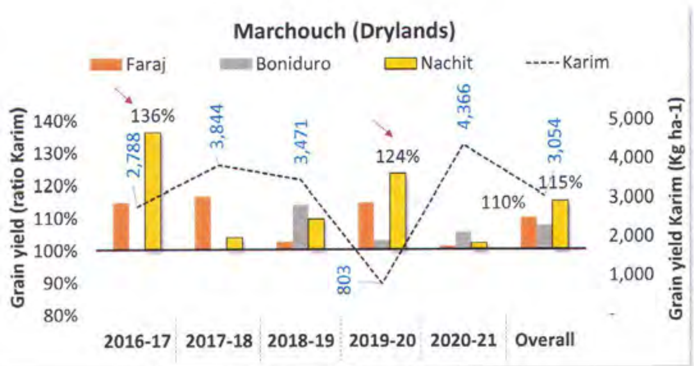
- ✓ Good tolerance to main wheat diseases.



Case study: Durum wheat "Nachit" for drought tolerance

- ✓ Interspecific cross: Amedakul/T. dicoccoides Syr//Loukus
- ✓ Released in 2018 by INRA Morocco as 'Nachit'
- ✓ Released for its drought tolerance and large grains

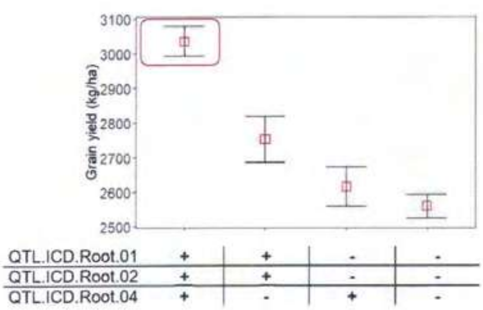
Impact of the drought-resistant durum wheat variety Nachit



- Nachit produced *15% more yield* across five seasons
  - 24% and 36% in dry years
- It has *10% larger grains*
- Resistant to *RR, LR, SR, but not to HF*
- *Where does its drought tolerance come from?*

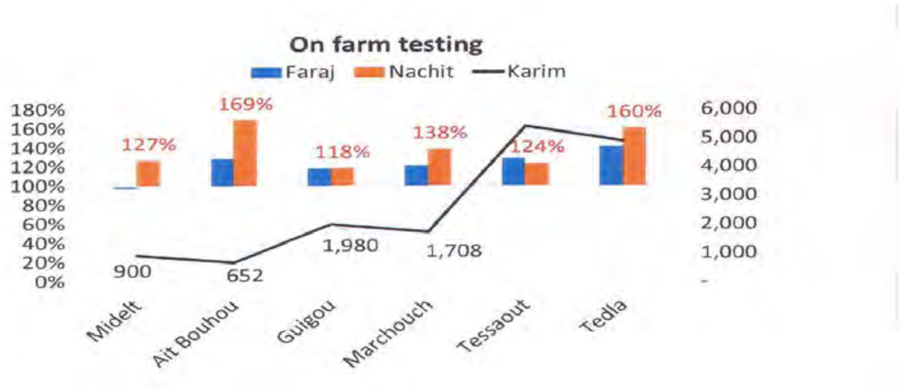
✓ The durum variety Nachit produced 15% more grain yield in 5 seasons and 24% and 36% more in two dry years.
✓ The drought resistance comes from a good root development with the identification of 3 QTLs that allow an increase of +300 kg/ha alone.

Where does come a drought-resistant durum wheat variety Nachit?



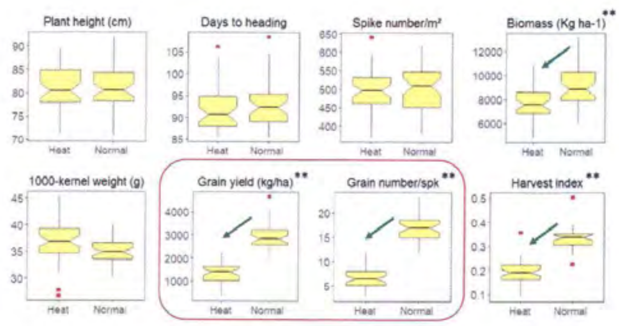
- Three QTLs controls root angel and together increase yield **+300 Kg ha^{-1}**

Durum wheat variety Nachit on farm drought tolerance



The deep roots of Nachit gave it **+38%** yield advantage under drought when tested across 19 farms in 2019-2020, and it has **+15%** larger grains.

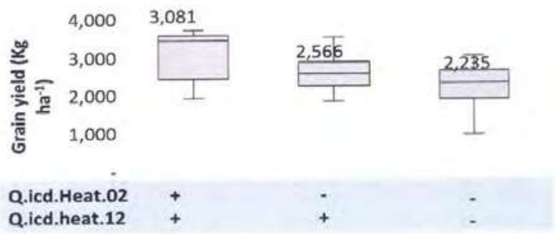
Heat tolerance: the secret of spike fertility



- Application of plastic tunnels at the time of flowering **+10 C**
- ***Grain number per spike*** (fertility) seems to be the most critical trait

KASP marker validated for heat tolerance

- 2 QTLs for spike fertility
- GY across 3 heat stressed env:
  - +500 Kg ha^{-1} (20%) on average



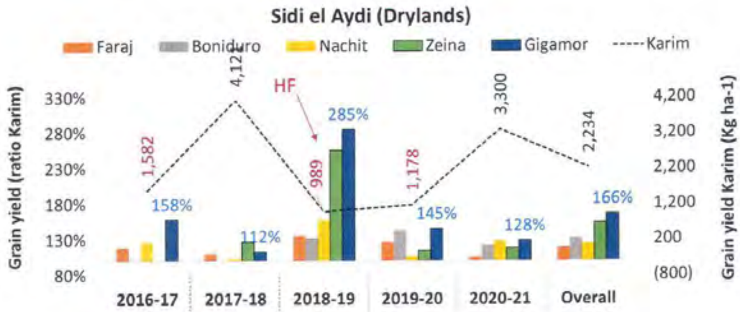
El Hassouni et al. 2019 Doi: 10.3390/agronomy9080414

Two new HF resistant and drought tolerance varieties

Two new HF resistant candidates to the catalougue

Two new entries superior to Nachit (*Gigamor and Zeina*) were presented by Dr Ferrahi

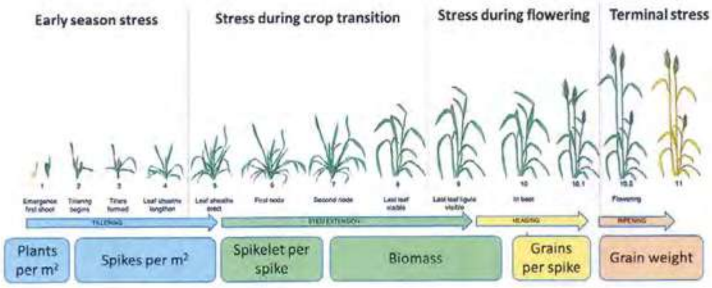
- These combine **3 roots QTL** for yield under drought, **1 QTL for HF** resistance, and top quality
- In HF years the yield advantage is ***almost double!!!***



Genetic Strategy to climate proofing

Genetic strategy to climate proofing

1. More droughts:
   - ***Deeper roots + grain weight***
   - Spike per m^2
2. More heat waves:
   - ***Higher spike fertility***
3. Shorter growing seasons:
   - *Early flowering*
4. Damaging pests and disease:
   - *Rusts (stem and leaf)*
   - ***Hessian fly***
   - *Fusarium(s)*



Thank you

BREEDING FOR THE FUTURE

Mr. Stefan van der Heijden
Associate, Innova Connect, Netherlands

Plant breeding is per definition for the future and due to the long period between initial concept and final market introduction strong interaction in the value chain is needed.

Besides that, market requirements have a tendency to change more rapidly due to climate change, less availability of inputs (e.g., fertilizers and pesticides) and energy issues. This is caused by changing regulation because of societal influences, the need for more sustainability and geopolitical influences.

To decrease the time to market the following issues are important to consider:

- duration of breeding process until the moment of IP-protection Distinctness, Uniformity and Stability (DUS) and the fact of obligatory or voluntary Value for Cultivation and Use (VCU) or the acceptance by growers and customers;
- knowledge of putative conditions of the production environments in the future and the impact of Genotype x Environment x Management interactions of abiotic and some biotic factors. Impact of these interactions on genetics and breeding process is complex and poorly understood.

In addition, the industry is facing the fact that alternative crop production strategies are needed because new methods of biocontrol do not have the same spectrum of working as the old-fashioned pesticides. This means that all parties must work together to optimize the use of resistance/tolerance in combination with soil-microbiomes, induced resilience/resistance, monitoring and other management practices.

Research in the future that can only efficiently be conducted when all knowledge of the value chain is available and integrated with a strong focus on adaptation (= resilience) to different environments. The objective is to move from reactive breeding to predictive breeding, and by transparency in the chain also reducing the introductory process by using agreed key performance indicators that rapidly can be evaluated, so avoiding a lengthy empirical descriptive testing process.

In research process many technologies can be used, such as information network based on data (omics, phenotyping, environments, germplasm coverage and access), AI-tools, mechanistic and statistical models, bioinformatics. The development of these tools should be useful in a range of species (different ploidy levels and reproduction systems). It is also important to gain more understanding of the fundamentals of crop production in the future changing climate.

This knowledge can be used to develop durable breeding concepts, including high throughput tools and access to global genetic variability for the total breeding community and not only to a small range of global crops.

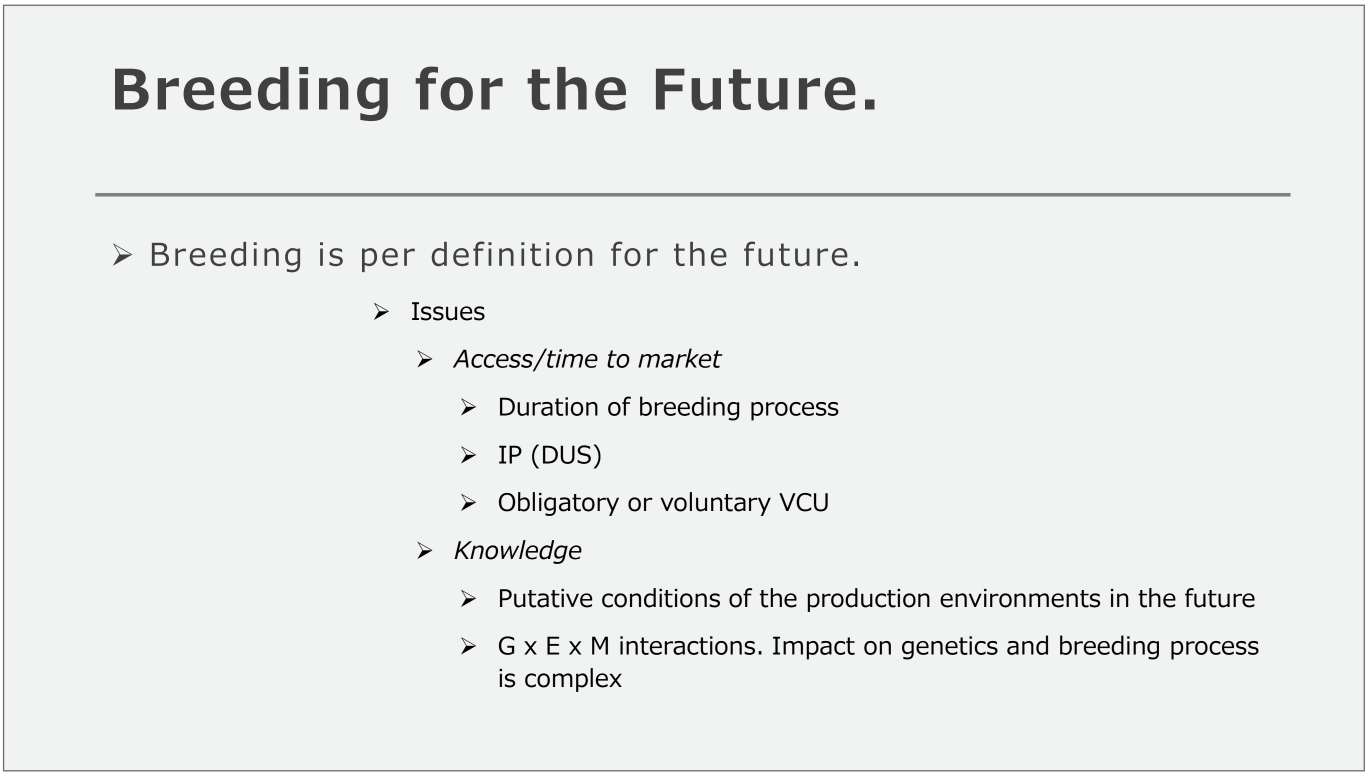
However, we must face more uncertainty on levels in the value chain, for breeders about their return of investment, for the retail concerning the supply and for the consumer because of potentially less tested products. If tools do not become broadly available there is the risk of more orphan crops and therefore a lack of adapted products in the future.

On top of that, DUS and VCU systems should not limit the introduction of new innovations, putting pressure on the development of better designed future DUS systems; and UPOV must adapt to this via faster procedures.

Transparency in the value chain is important to keep everybody well informed about these new innovations and the claims that are be made concerning sustainability and phytosanitary issues and production risks involved for growers and customers.

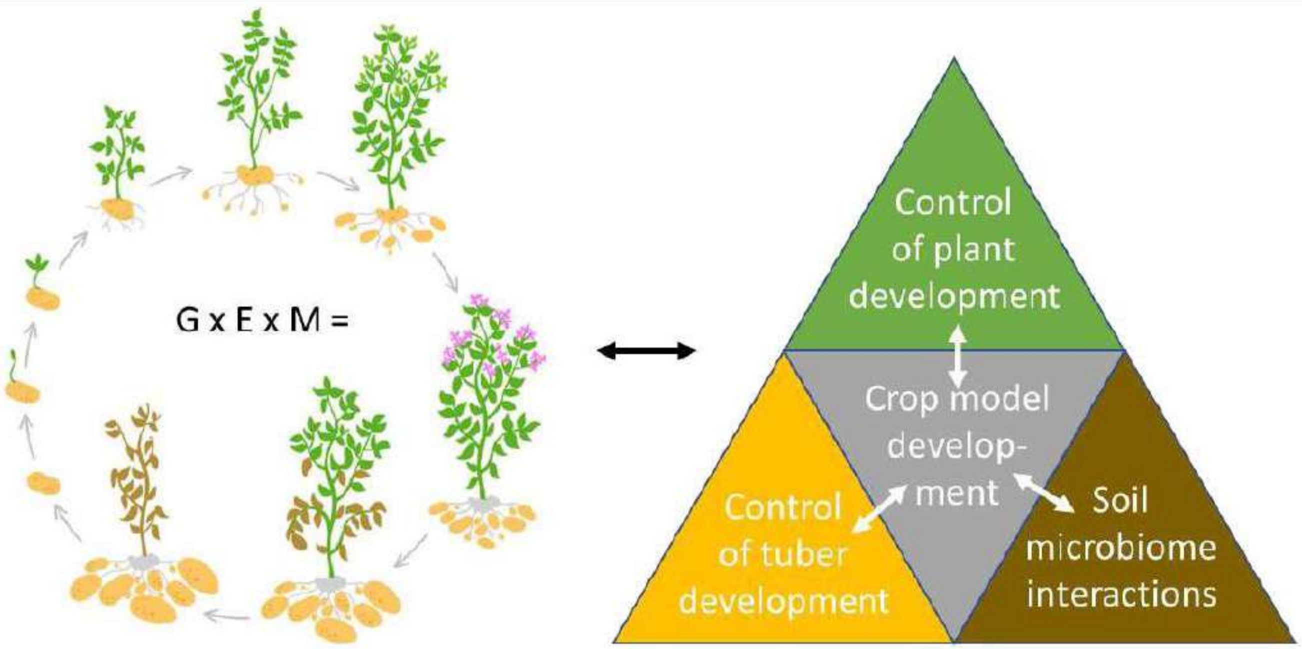
Only when these requirements are met will the industry be able to make rapid progress with complex traits and solving feed, food and ornamental issues.

Presentation made at the Seminar



Research approach for the future

- ✓ Integrating knowledge from the full value chain
- ✓ From reactive to predictive breeding
- ✓ Focus on adaption (= resilience) to different environments and reducing inputs.
  - ✓ Biotic (reasonable under control, but …)
  - ✓ Abiotic (complex genetics and difficult as breeding target)
- ✓ Predict and verify via lengthy empirical descriptive testing?
- ✓ Faster access of new products to the market is needed.



Required technologies

- Information network
    - Data (omics, phenotyping, environments, germplasm coverage and access)
    - AI-tools
    - Mechanistic and statistical models
    - Bioinformatics
    - Useful for multiple species
    - ?
- Understanding fundamentals of crop production in changing climate
- Develop durable breeding concepts
    - Tools
    - Genetic variability
- Definition of relevant parameters for verification experiments in vivo
- Access by users – transparency

Impact on the value chain

- More uncertainty in value chain
    - Breeders and Producers (income, RoI)
    - Retail (supply)
    - Consumer (trust)
- Broader portfolio is needed
- Orphan crops will increase
- Market access should not be hampered by
    - DUS
    - VCU
    - Other (IP-)issues
- Transparency and understanding of consumers in general
    - Claims.
        - Sustainability
        - Health
        - Phytosanitary

Thanks for your attention

THE ROLE OF PLANT BREEDING FOR INCREASING PRODUCTIVITY AND REDUCING CROP LOSSES

Mr. Morten Lillemo
Norwegian University of life sciences, Faculty of biosciences, Ås, Norway

Providing food for an increasing world population, while minimizing the impact on the environment, will be the grand challenge for agriculture over the decades to come. It is projected that the human population will reach 9.5 billion by 2050. An increasing proportion of the population will be urban, resulting in shifts in diets from staples to processed foods, meat and dairy products. Since meat and dairy products require large amounts of grain for animal feed, the demand in crop production will grow much faster than expected just from the population growth. As an example, the global demand for wheat is expected to increase with 60% by 2050 (Long *et al.* 2015). Looking into the past, global wheat production has tripled since 1960 without expanding the cultivated area. Over the whole period, improvements in agronomy (mainly fertilizers and chemical crop protection) and genetic gains from plant breeding have contributed roughly equal shares to this yield increase.

In order to reduce the environmental impacts from agriculture, a sustainable intensification is needed, avoiding excess use of fertilizers and agrochemicals. In other words, the 60% demand in crop production must come from using the same area, sustainable use of fertilizers and less use of agrochemicals. This means that plant breeding likely will need to play an even bigger role for future yield increases. Moreover, it will be equally crucial to avoid yield and quality losses from plant diseases. In this short presentation, I will give three examples of how plant breeding has contributed to yield increases and reduced yield losses in wheat and barley in Norway. By looking into which traits have contributed to past yield increases, plant breeders can make better decisions about which traits to improve for further yield gains.

My first example is barley yields in central Norway (Lillemo *et al.* 2010). Central Norway represents one the northernmost barley production areas in the world. The region is characterized by a cool, maritime climate with a short growing season, long photoperiod and biotic and abiotic stresses that require specific adaptation. Some of the main production constraints are the short growing season, relatively low temperature during midsummer and a humid climate with long periods of continuous wind and rain, which cause problems with lodging and difficulties during harvest. Nevertheless, there has been a steady increase in barley yields in the region, from around 2.1 t/ha in the 1940s to 3.6 t/ha six decades later. To get a better understanding of the interaction between plant breeding and changes in crop management, and to estimate the impact of genetic improvements, official yield statistics at the farm level were compared with data from variety trials in the region spanning the period from 1946 to 2008. Based on the yield statistics and known changes in farming practices, we could divide the time period into three eras. The "self-binder era" (1946–1960), which preceded the introduction of the combine harvester, was characterized by relatively stable yields with little year-to-year fluctuation.

During the "first combine era" (1960–1980) large overall yield increases took place due the increase in the use of mineral fertilizers. However, since the varieties grown were not suited for the new harvesting regime, severe yield losses were observed in years with difficult harvesting conditions due to rain. The introduction of new short-strawed and lodging-resistant varieties in the "modern varieties era" (1980–2008) stabilized the year-to-year variability and contributed to further yield increases at the farm level. Looking into the genetics, analysis of the official variety trial data identified a 46% increase in genetic yield potential from the variety "Maskin", which dominated the market in the 1940s, to the highest-yielding variety modern variety "Gaute". Over time, plant breeding contributed to an increasing share of the yield increases at the farm level, from 29% during the self-binder era to 43% during the first combine era and 78% during the modern varieties era (Lillemo *et al.* 2010). Important traits that contributed to this are early vigor, lodging resistance and ability to withstand rainy weather at maturity without pre-harvest sprouting, straw breaking and seed shattering. Improved resistance to prevailing diseases such as barley scald, net blotch and Ramularia have also been important (Lillemo *et al.* 2010).

The second example is genetic yield gains in spring wheat (Mróz *et al.* 2022). Wheat varieties grown in Norway before the 1950s were susceptible to lodging and pre-harvest sprouting, and were not suitable for mechanized harvesting. This led to the near extinction of wheat cultivation when the combine harvester was introduced in the 1950s and 1960s, which spurred breeding efforts that eventually resulted in the release of two landmark varieties, “Runar” and “Reno” (introduced in 1972 and 1975, respectively), marking the beginning of modern wheat cultivation in Norway. During the following three decades, there was a steady increase in the wheat cultivation up to today’s level of 75% self-sufficiency (Lillemo and Dieseth 2011). The yield increases at the farm level have also been considerable, from around 3 t/ha in the early 1970s to today’s level of almost 5 t/ha. To get a better understanding of the genetic contributions to these yield gains, we conducted yield trials with a collection of 24 historical spring wheat varieties, encompassing the most important varieties on the Norwegian market from 1972 to today. These were tested in yield trials over four years, using two nitrogen fertilization levels: 150 kg N/ha which is typical of today’s agronomic practice, and a low-input management of 75 kg N/ha. The results demonstrated a considerable yield increase due to plant breeding with an average genetic yield gain of 1 t/ha over the 50-year time period. The same yield trend was visible at both N-fertilization levels, meaning that plant breeding has contributed to improvements in both grain yield and resource utilization regardless of fertilization input. Yield components were investigated and show that today’s modern cultivars produce more grains per unit area, and benefit from a longer grain-filling period than the cultivars of the 1970s (Mróz *et al.* 2022).

Equally important to improvement in yield potential is protecting the yield from losses due to plant diseases. My last example concerns *Fusarium* head blight (FHB), which is ranked as the second most damaging disease on wheat globally (Savary *et al.* 2019). FHB is caused by various Fusarium pathogens and is of great concern for human and animal health due to the production of mycotoxins. In Norway, a shift in the pathogen population occurred around 2005, and the emergence of F. *graminearum* as the dominating head blight pathogen caused serious disease outbreaks in oats, barley and spring wheat (Hofgaard *et al.* 2016). Since no fully effective fungicides are available to control FHB, this is a perfect case for integrated disease control. Routine field testing since 2007 has revealed big differences in resistance among cultivars in all three cereals, and progress has been made in resistance breeding by discarding susceptible lines and only promoting lines in the better half of the resistance spectrum for variety trials and release as cultivars. Over time, susceptible varieties have been replaced with more resistant ones (Tekle *et al.* 2018). The genetics of FHB resistance in wheat is complex, involving both active and passive resistance mechanisms. A good understanding of the resistance genetics and consistent phenotyping under reliable disease pressure is needed to make progress. Data from inoculated disease trials show that plant breeders have made considerable improvements in FHB resistance over time. Currently, the dominating spring wheat varieties on the Norwegian market, “Mirakel”, “Seniorita” and “Caress”, show on average a 40% reduction in deoxynivalenol (DON) content compared to “Bjarne” and “Zebra”, which dominated the market two decades ago. Traits that have contributed to improved FHB resistance in Norwegian spring wheat include increased anther extrusion, improved resistance to both initial infection (Type I resistance), fungal spread within the spike (Type II) and active mechanisms to reduce DON content of the resulting seeds (Nannuru *et al.* 2022). The reduction in DON content from plant breeding is at a comparable level to the average effect of the most effective triazole fungicides against FHB in wheat. Similar variety differences in terms of DON content have been documented for oats (Tekle *et al.* 2018), while in barley the differences in resistance are even bigger. Thus, farmers can reduce the risk of mycotoxins in their grain harvest considerably by growing the most resistant varieties and opting for a fungicide spray at the time of flowering in years with a high risk of FHB. Overall, these breeding efforts have contributed to a more sustainable cereal production with reduced yield and quality losses due to FHB.

As shown by the examples above, plant breeding has played a crucial role in providing yield improvements and reducing yield and quality losses due to plant diseases. With future constraints on the use of fertilizers and other agrochemicals, genetic yield gains in combination with improved disease resistance will be even more important in meeting future demands for increased productivity. Knowledge about the underlying genetics of the traits involved will help plant breeders to accelerate future improvements.

ACKNOWLEDGMENTS

I am sincerely thankful to the Research Council of Norway, the Foundation for Research Levy on Agricultural Products (FFL) and the Agricultural Agreement Research Fund (JA) in Norway, and the Norwegian Council of Genetic Resources who funded much of the research that is referred to in this presentation, and the very long and fruitful collaboration with plant breeders at Graminor.

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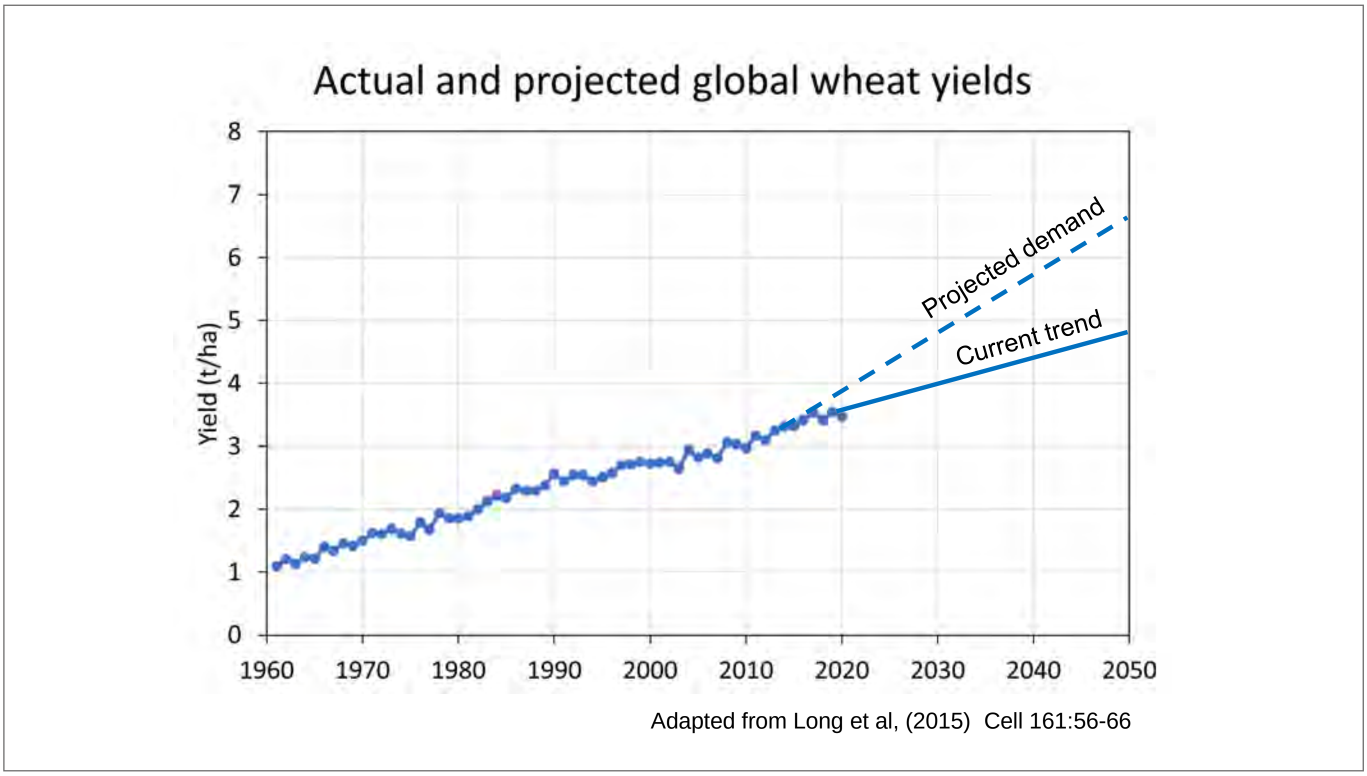
Presentation made at the Seminar



How to reduce the climate footprint of crop production?

Plant phenotyping NMBU | Norwegian University of Life Sciences | 3

Outline

- Impacts of plant breeding for improving yield
  – Case 1: Barley yields in central Norway
  – Case 2: Yield genetic gains in wheat
- Impacts of plant breeding for reducing crop lossess
  – Case 3: Fusarium head blight resistance in wheat

Plant phenotyping NMBU | Norwegian University of Life Sciences | 4

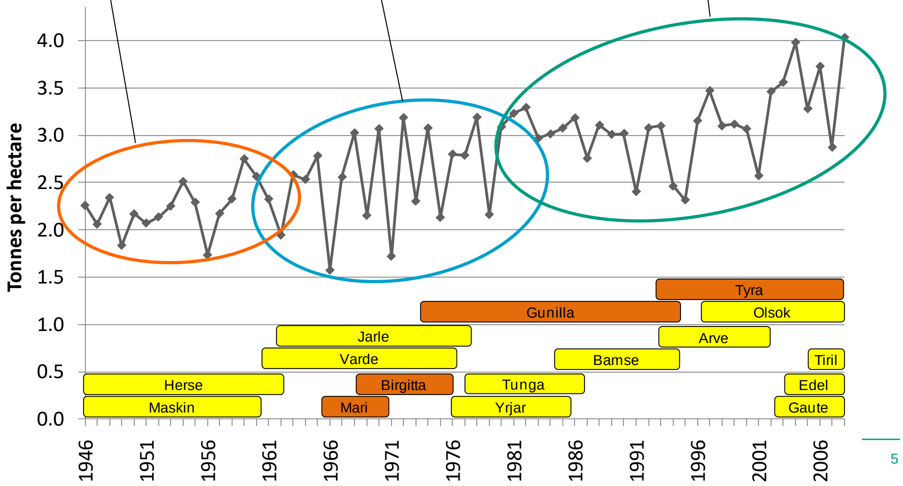
Barley yields in central Norway

NMBU

1946-1960:
"The self-binder era"
Few new varieties and little yield increase

1960-1980:
"The first combine era"
Difficult harvest conditons and unstable yields

1980-2008:
"The modern varieties era"
New and better adapted varieties



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Contributions from plant breeding

NMBU

1946-1960:
"The self-binder era"

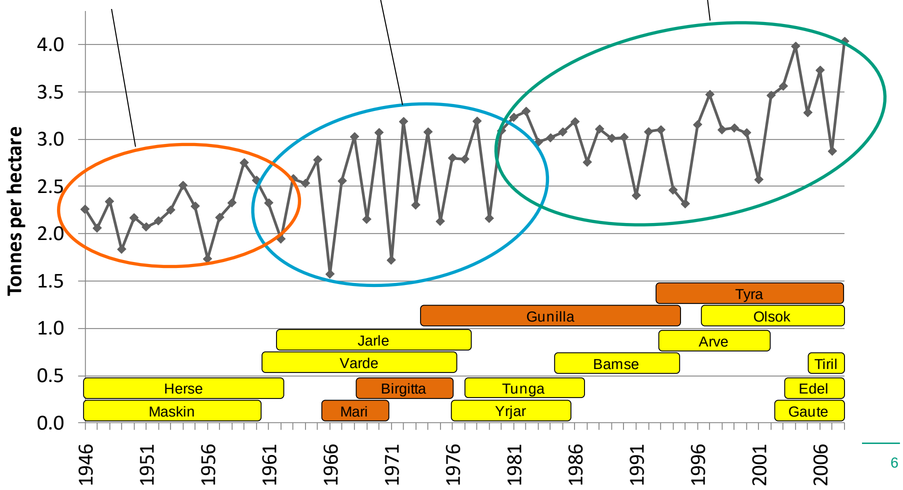
29%

1960-1980:
"The first combine era"

43%

1980-2008:
"The modern varieties era"

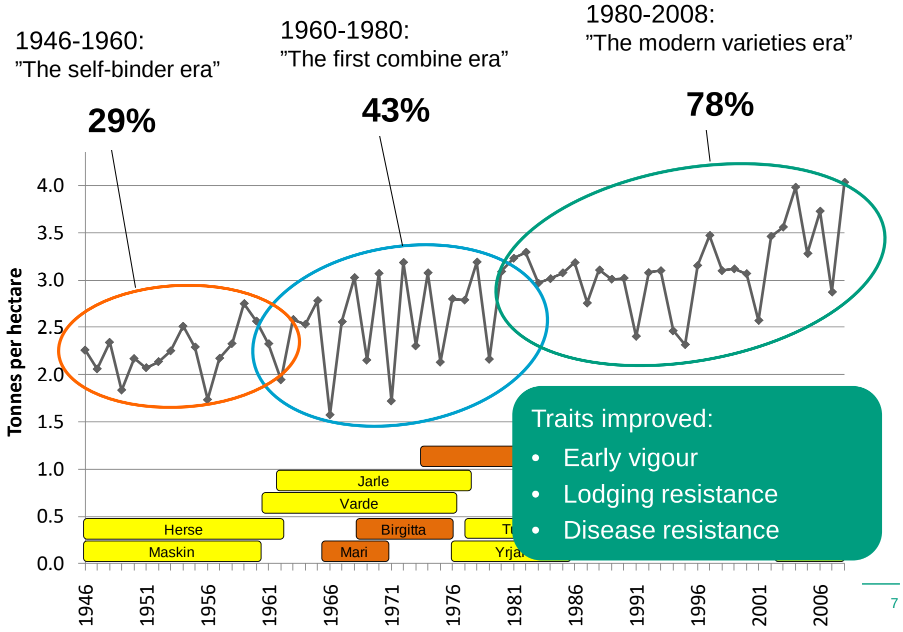
78%



6

Contributions from plant breeding

NMBU



7

Yield genetic gains in Norwegian spring wheat

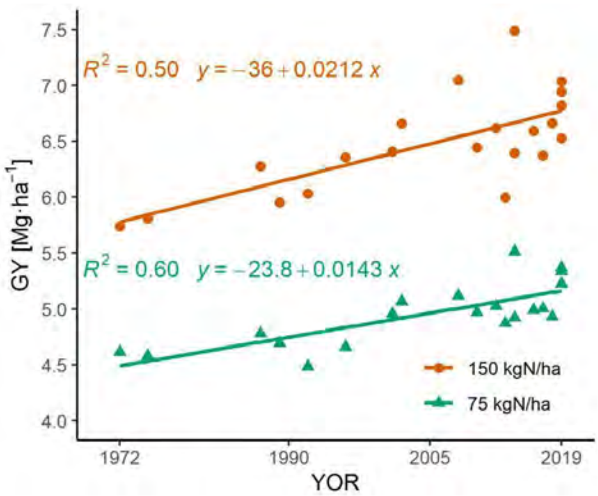
NMBU

- Yield trials with 19 varieties released during the period 1972-2019
- Two nitrogen fertlization levels:
  - 150 kg N/ha and 75 kg N/ha

Mróz et al (2022),
Crop Science 62: 997-1010
https://doi.org/10.1002/csc2.20714

Plant phenotyping NMBU   Norwegian University of Life Sciences   8

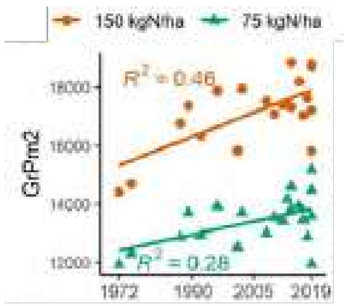
Genetic improvement of 1 t/ha



- Similar yield gains at both N-fertilization levels
- Modern varieties at low input approach the yields of old varieties at high input

Mróz et al (2022),
Crop Science 62: 997-1010
https://doi.org/10.1002/csc2.20714

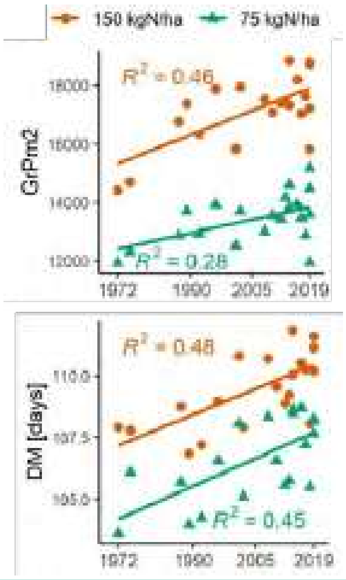
Which traits were improved?



- More grains per head and per m^2
  - producing more grains with the same available resources

Mróz et al (2022),
Crop Science 62: 997-1010
https://doi.org/10.1002/csc2.20714

Which traits were improved?



- More grains per head and per m^2
  - producing more grains with the same available resources
- Later maturity (~ 3 days)
  - Better utilization of the longer growing season

Mróz et al (2022),
Crop Science 62: 997-1010
https://doi.org/10.1002/csc2.20714

Plant phenotyping NMBU   Norwegian University of Life Sciences   11

Fusarium Head Blight (FHB)

- A major disease problem on all cereals in Norway since the 1990s
  - reduced tillage, inadequate crop rotation, cultivation of susceptible cultivars
- Caused by *Fusarium graminearum* and other Fusarium pathogens
- Accumulation of mycotoxins in the grains

Plant phenotyping NMBU   Norwegian University of Life Sciences   12

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- A major disease problem on all cereals in Norway since the 1990s
  - reduced tillage, inadequate crop rotation, cultivation of susceptible cultivars
- Caused by *Fusarium graminearum* and other Fusarium pathogens
- Accumulation of mycotoxins in the grains
- No easy solution:
  - no fully effective fungicides available
  - no cultivars with complete resistance
- A good case for integrated disease control

Plant phenotyping NMBU   Norwegian University of Life Sciences   13

Components of FHB resistance

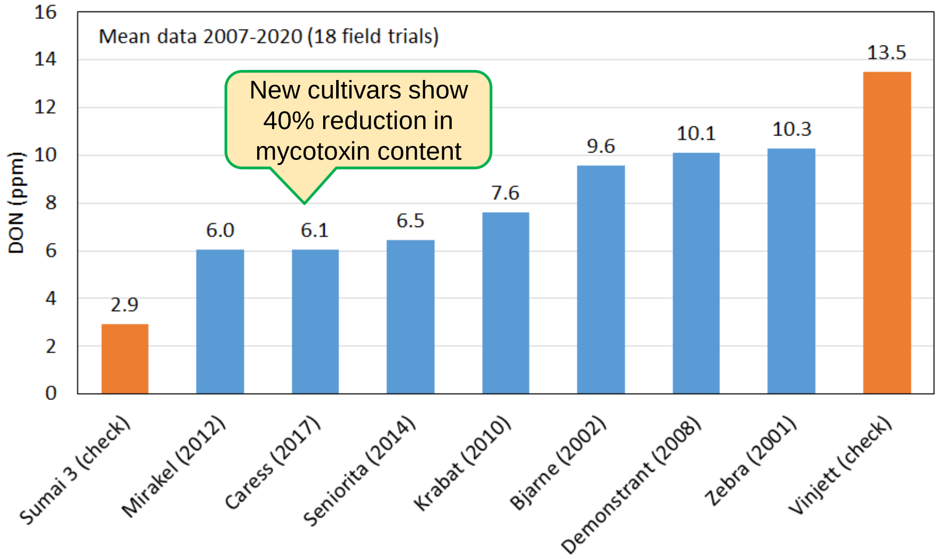
Active resistance	Evaluation
Type I: Resistance to invasion	Severity after spray/spawn inoculation
Type II: Resistance to spread	Severity after point inoculation
Type III: Mycotoxin accumulation	DON content
Type IV: Kernel infection	% FDK
Type V: Tolerance	Yield

Passive resistance (avoidance)
Increased plant height
Flowering biology: anther extrusion, cleistogamy, flower opening, etc.

We need a good genetic understanding of these traits

Plant phenotyping NMBU   Norwegian University of Life Sciences   14

Progress in breeding for FHB resistance in spring wheat



Summary

- Plant breeding works!
- Increased productivity
  - Case 1: Yield stability of barley cultivars – better adapted to new harvesting regime
  - Case 2: Higher-yielding spring wheat cultivars with better nitrogen utilization
- Reduced crop losses due to disease
  - Case 3: New cultivars with 40% reduction in mycotoxin content

NMBU

Acknowledgements

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Graminor

The Research
Council of Norway

QUESTIONS

TORO UGALDE Manuel (Mr.), Vice-Chair of the Administrative and Legal Committee, UPOV (moderator)

Now have a brief moment for questions to our speakers if anyone has a question. Mr. Fernando Ortego Klose from Chile.

ORTEGA KLOSE Fernando (Mr.), Forage Plant Breeder, Chilean Agricultural Research Institute (INIA), Carillanca regional center, Chile (speaker)

Thank you very much. A question for Morten. I understood that the new varieties of some of your cereals, the phenological period is longer than the older varieties. Is that an advantage or a disadvantage in the drought tolerance?

LILLEMO Morten (Mr.), Professor, Norwegian University of Life Sciences Faculty of Biosciences, Norway (speaker)

So, in our country, we have a quite short growing season and we typically don't have problems with drought. So, and because of the warming of the climate, we have higher temperature in the growing season and also spring starts earlier and autumn comes a little bit later. So, it's beneficial for us to have longer growing periods for the varieties, but this also comes at the risk because sometimes we have rain in the spring, which means that the farmers come and plant for the farm they want to plant and we could have a lot of rain in autumn, which makes harvesting commissions difficult.

It's a balance here and it's a dilemma also, but there is the demand on the market for having both early maturing and late maturing varieties, also to diversify the risk.

ORTEGA KLOSE Fernando (Mr.), Forage Plant Breeder, Chilean Agricultural Research Institute (INIA), Carillanca regional center, Chile (speaker)

Okay. Thank you.

RESEARCH INTO MARKET-DRIVEN AND CLIMATE SMART CROP VARIETIES: TOLERANCE TO BIOTIC AND ABIOTIC STRESSES

Mr. Francis Kusi, Mr. Joseph Adjebeng-Danquah, Mr. Gloria Boakyewaa Adu,
Mr. Richard Oteng-Frimpong, Mr. Samuel Oppong Abebrese, Mr. Emmanuel Boache Chamba,
Dr. Kwabena Acheremu, Mr. Peter Anabire Asungre, Mr. Richard Yaw Agyare,
Mr. Kenneth Opare Obuobi, Ms. Francisca Addae-Frimpomaah and Mr. Nicholas Denwar,
Council For Scientific And Industrial Research – Savanna Agricultural Research Institute (Csir-Sari), Ghana

BACKGROUND

Savanna Agricultural Research Institute (CSIR-SARI) is one of the 13 research institutes under the Council for Scientific and Industrial Research, Ghana. The institute is based in Nyankpala in the northern region of Ghana, and has a mandate over the five regions in northern Ghana. The mandate area falls within the Guinea and Sudan savannah agroecologies which together cover about 40% of the total land mass of Ghana. This area is characterized by a monomodal rainfall pattern which is often erratic. In addition to flooding and terminal drought, intermittent drought also occurs even during the rainy season, thereby reducing the yields of several crops (Amikuzuno and Donkoh 2012).

The institute has a technical mandate to conduct agricultural research into food and fiber crop farming in northern Ghana for the purpose of introducing improved technologies that will enhance overall agricultural productivity. The mandate crops include sorghum, millet, rice, maize, cowpea, groundnut, soybeans, bambara groundnut, pigeon pea, yam, cassava, sweet potato, frafra potato, cotton, vegetables and, recently, neglected and underutilized species such as fonio.

To be able to adequately carry out its activities over the vast mandate area, CSIR-SARI has two out-stations in Manga (Upper East region) and Wa (Upper West region) in addition to the main station in Nyankpala, and these out-stations oversee the research activities in the various regions.

CHARACTERISTICS OF AGRICULTURE IN THE MANDATE AREA

Agriculture in the northern parts of Ghana where CSIR-SARI is mandated to conduct research is characterized by several climate-related constraints (Figure 1). Some of these include intermittent and terminal drought, susceptibility to pests and disease of crops and animals, sporadic outbreak of pests like fall armyworm, larger grain borer and others (Antwi-Agyei *et al.* 2012). There are high postharvest losses, mycotoxin contamination, aflatoxins and others. Low crop yields resulting from poor soils with low input use and use of low yielding varieties are also prevalent in the area. In addition, poor market outlets and the seasonal nature of the production has often resulted in glut of most of the agricultural commodities in the area. The area is also vulnerable to rampant annual bush fires which sometimes result in loss of farms and livelihoods of households. All these challenges are expected to increase in the future as a result of climate change (IPCC 2014). The annual bushfires have enormous effects on both vegetation and soils since the soil-fire relationship has been found to define the structure of the soil, functions and the dynamic of the ecosystem (Amoako and Gambiza 2019). Soil's physical and chemical properties are altered during the burning of the biomass. For instance, nutrients such as nitrogen (N) are volatized due to their sensitive temperature threshold (DeBano *et al.* 1976).

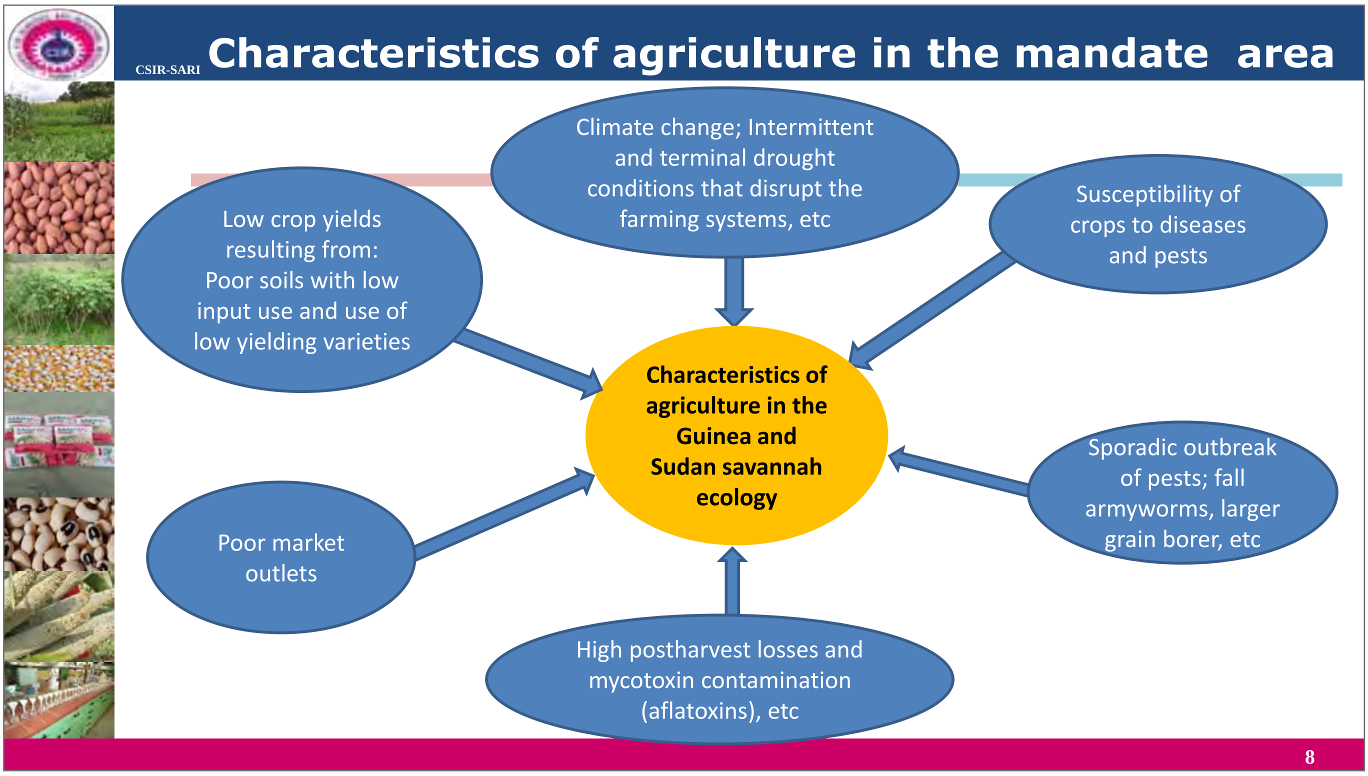

Figure 1. *Characteristics of agriculture in the Guinea and Sudan savannah ecologies.*

THE RESEARCH APPROACH

The institute operates a system known as Farming Systems Research that actively involves farmers and other end-users who may need our technologies (Figure 2). This system facilitates the identification and prioritization of the needs of farmers and other end-users of the agriculture value chain. With this system, each of the regions hosts a Farming System Research Group (FSRG) that oversees the research activities in the region. These are the Upper East Farming Systems Research Group (UER-FSRG), Upper West Farming Systems Research Group (UWR-FSRG) and the Northern Region Farming System Research Group (NR-FSRG). Each of these research groups has a coordinator who links the research and extension activities in the respective region. All the research groups are backstopped by the Scientific Support Group (SSG) which is based at the main office in Nyankpala. The SSG is composed of scientists with different backgrounds such as agronomy, plant breeding, soil science, crop protection, socioeconomics, agrometeorology and nutrition. The scientists here conduct basic research and develop technologies and packages which are then relayed back to the end-users through the coordinators of the farming systems research groups.

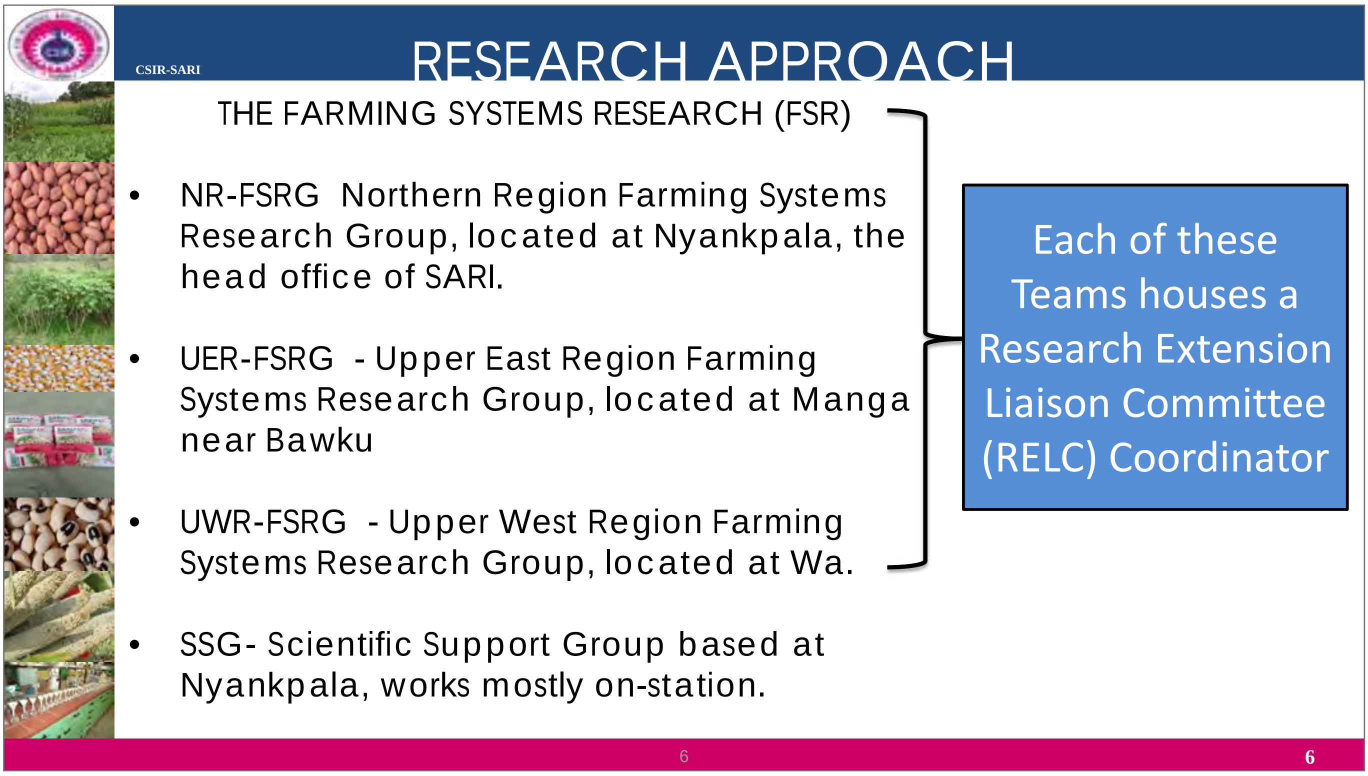

Figure 2. *The research structure adopted by CSIR-SARI.*

DEMAND-DRIVEN RESEARCH SCHEME

End-users or the demands of the market drive the research activities of the CSIR-SARI (Figure 3). Constraints or concerns identified from the end-users during stakeholder workshops or planning meetings are brought to the research platform through the Research Extension Linkage Committee coordinators who again send the feedback and solutions to the same end-users through meetings and demonstrations. During these stakeholder workshops and planning meetings, direct interactions take place between researchers, farmers, agricultural extension agents, processors, marketers, policy makers and other stakeholders to appraise the challenges and possible solutions. These interactions also allow researchers to know what problems exist and possible solutions so that technologies can be developed to meet the demands of the market. In addition to these meetings, breeders conduct participatory breeding or varietal selection during which researchers and end-users design the right product profile and select the product of their choice. This also facilitates the adoption of the resultant end product since it will meet the demands of the market.

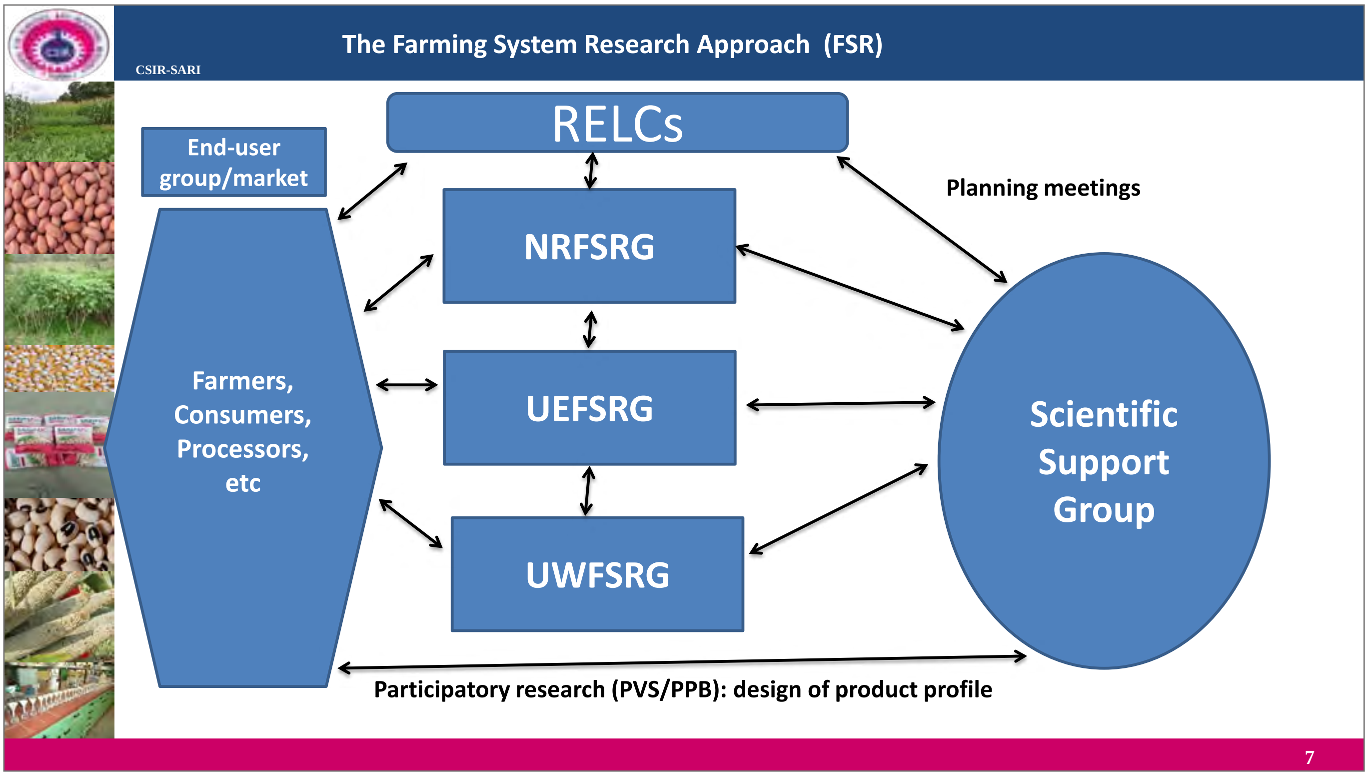

Figure 3. *The farming systems research approach showing the linkages between the teams and end-users.*

THE CROP IMPROVEMENT PROGRAM OF CSIR-SARI

End-users or the demands of the market drive the research activities of the CSIR-SARI (Figure 3). Constraints or concerns identified from the end-users during stakeholder workshops or planning meetings are brought to the research platform through the Research Extension Linkage Committee coordinators who again send the feedback and solutions to the same end-users through meetings and demonstrations. During these stakeholder workshops and planning meetings, direct interactions take place between researchers, farmers, agricultural extension agents, processors, marketers, policy makers and other stakeholders to appraise the challenges and possible solutions. These interactions also allow researchers to know what problems exist and possible solutions so that technologies can be developed to meet the demands of the market. In addition to these meetings, breeders conduct participatory breeding or varietal selection during which researchers and end-users design the right product profile and select the product of their choice. This also facilitates the adoption of the resultant end product since it will meet the demands of the market.

It is estimated that about 5% of Ghana's population are food insecure, whilst an additional 2 million are vulnerable, requiring importation to meet the deficit due to stagnation of the yields of crops such as maize, rice, sorghum, millet and groundnut, which the majority of Ghanaians depend on (Baffour-Ata *et al.* 2021). There is the need to come up with strategies that would help address these challenges that are faced by farmers in the agriculture value chain when it comes to the choice of crop variety. The goal of the crop improvement program of CSIR-SARI is to develop end-user preferred crop varieties that possess the desired attributes and fit into the agroecology of the mandate area. Some of the crop varieties are developed to specifically tolerate low soil fertility, are resistant to pests and diseases, are drought tolerant and also tolerate other constraints that characterize the farming systems in this environment. Through this, CSIR-SARI has developed and released several crop varieties for cultivation in the mandate area (MoFA 2019). Apart from varietal development, the institute also produces breeder and foundation seeds of the mandate crops which are then made available to seed-producing companies. This is done to enhance access to these varieties by farmers. Improved varieties of crops such as cowpea, maize, rice, soybean and sorghum have high market demand and are very prominent in national flagship programs such as Planting for Food and Jobs.

CURRENT CLIMATE SMART PRODUCT PROFILES

Products to address biotic stresses

Currently, the institute is developing different climate smart product profiles to address various challenges. Specifically for addressing biotic stress faced by agriculture in the mandate area, breeding objectives are targeting resistance to fall armyworm on maize and aphid resistance in cowpeas. This is because aphids are devastating when it comes to cowpea production in the northern part of Ghana. New varieties are also being screened for resistance to Macrophomina phaseolina, a polyphagous ubiquitous soil-borne fungal pathogen which has been described as one of the most important emerging plant pathogens of cowpea. This pathogen has been reported to cause up to 10% yield loss in cowpea and can wipe out a whole field in susceptible cultivars (Lamini *et al.* 2020). In the case of groundnut varieties, the target traits include resistance to early and late leaf spot in addition to high yield. Other varieties that possess high oleic content are being developed to address nutritional challenges. Cassava varieties are also being assessed for resistance/tolerance to cassava green spider mite and cassava mealy bug damage. These pests are very common in the dry season or during periods of moisture stress, and can cause severe damage to the shoot. One major biotic stress that affects and causes severe crop losses in cereals and legumes in the Guinea and Sudan savannah ecology is the parasitic weed Striga spp (Kroschel 1999; Kim et al., 2002; Muranaka *et al.* 2011). Striga hermontica (cereals) and Striga gesnerioides (legumes) can cause severe yield losses in maize and cowpea respectively. The institute is currently developing maize and cowpea varieties that are resistant to S. hermontica and S. gesnerioides respectively.

Products to address abiotic stresses

In the case of research to address abiotic stresses, the focus is on developing climate smart crop varieties to combat the emerging challenges associated with the changing climate. For instance, fonio (Digitaria exilis (Kappist) Stapf) which was originally not part of the mandate crops is now being considered because of its short duration and tolerance to low input agriculture. Additionally, frafra potato (Solenostemon rotundifolius Poir.) has also been included in the breeding program because of its resilience and short duration which makes it suitable for areas where the other root and tuber crops like cassava, yam and sweet potato cannot be cultivated. Heat-tolerant tomato varieties, drought-tolerant maize and cowpea varieties, and then nitrogen-use-efficient maize varieties are also being developed by the institute to address issues of climate change. Cassava and sweet potato are very important staples in the diets of many people in northern Ghana and have been identified as key crops capable of addressing the challenges associated with climate change. The key traits considered to address climate change are early bulking (to fit into the short rainy season), drought tolerance and stay-green in sweet potato to ensure dual-purpose utilization (roots as food for humans and vines for animal feeding).

Products to meet industry needs

To meet the demands from industry and ensure large-scale cultivation, the institute is currently targeting crop varieties with attributes that meet industry preferences. For instance, sorghum varieties with premium brewing qualities are at advanced stages of development to meet industry needs. There are also Caudatum and Guinea races of sorghum being screened for dual-purpose utilization in terms of grains and stalk as biofuel. Sweet sorghum genotypes are also being screened for ethanol production. In the case of cassava, there are advanced breeding genotypes that are being evaluated for high dry matter and high yield for industrial processing into flour and starch. The cotton improvement program of the institute is also currently evaluating some cotton hybrids for high yield potential, high percentage emergence, high ginning outturn and good lint quality. These genotypes are at an advanced stage of official release subject to the approval by the National Variety Release and Registration Committee.

CROP VARIETIES DEVELOPED AND RELEASED BY CSIR-SARI

Based on these breeding objectives to target the emerging markets, CSIR-SARI has come up with several crop varieties of our mandate crops with different attributes to meet the needs of end-users (Table 1). For maize, several varieties have been released for cultivation in the Guinea, Sudan savannah and transition ecologies of Ghana. Some of the key attributes are early maturity, drought tolerance, Striga tolerance and high and stable grain yield. They include white and yellow maize varieties to meet specific markets. The next crop is rice, which is now a major staple. Most Ghanaian consumers prefer fragrant rice, which has led to annual imports costing the country several millions of Ghana cedis. The institute has released a number of varieties to meet consumer needs. The key traits that were considered include yield, earliness, aroma and resistance to common pests and diseases associated with rice cultivation in Ghana. Soybean varieties that possess end-user preferred traits have been released for cultivation by farmers in northern Ghana. Most of the cultivated soybean varieties common to farmers in northern Ghana shatter a lot when harvesting is delayed, thereby resulting in yield losses. The objective of the soybean improvement program is to develop non-shattering soybean varieties that meet farmers' needs. Based on this, a number of varieties have been released. Some of these possess non-shattering attributes that tolerate delayed harvesting.

In the case of sorghum, two popular varieties have been released by the institute. The key traits under consideration are earliness, resistance to head bugs, Striga, drought tolerance and good brewing quality. In the case of millet five varieties have been released and attributes such as earliness, high grain yield, high grain Fe and Zn content, resistance to Striga, downy mildew resistance/tolerance, drought and other harsh weather conditions are considered. For cowpea, key attributes such as earliness, high yield and Striga resistance/tolerance, resistance to insect pests like Maruca and thrips are considered. For the groundnut varieties, the key traits considered are resistance to insect pests and diseases, high yields, early maturity, high oleic content as well as fresh seed dormancy. In the case of sweet potato, attention is given to varieties with high betacarotene and anthocyanin contents, high dry matter, early maturity and stay-green attributes for dual-purpose utilization. In the case of cassava, three varieties have been released and the key traits considered are early bulking, high dry matter, high yield, stay-green, high starch content, resistance/tolerance to African cassava mosaic virus disease, tolerance to cassava green mite and cassava mealy bugs. For yam, the institute has released five improved varieties. The key traits are high yield, good tuber appearance, food quality (boiled and pounded), low pests and disease reaction, high dry matter and tolerance to oxidation. In the case of frafra potato, five varieties have been released by CSIR-SARI. The key attributes are high yield, large tuber sizes, low disease and pest reaction. CSIR-SARI has also released two cotton varieties with good lint quality for the textiles industry.

Crop	Key traits considered	Popular varieties
Maize	Earliness, drought tolerance, Striga resistance/tolerance, high and stable grain yield	Sanzal-sima, Wang-dataa, Bihilifa, Kpari-faako, Suhudoo, Kunjor-wari, Wang-Basig, Denbea, Salin-kawana
Rice	Early maturity, market demand, yield, aroma	Gbewaa rice, Gbewaa red, Savanna rice, Malimali, Digan
Soybean	Earliness, non-shattering, high yield	Jenguma, Afayak, Favour, Quarshie, Suong Pungun
Sorghum	Earliness, resistance/tolerance to head bugs, Striga and dry spells, brewing quality	Kapaala, Dorado
Millet	Earliness, high yield, resistance/tolerance to Striga, dry spells, etc.	Akad-kom, Kaanati, Naad-Kohblug, Afribeh-Naara, Waapp-Naara
Cowpea	Earliness, high yielding, Striga resistance, resistance/tolerance to key insect pests (Maruca pod borer, thrips, etc.) and diseases	Kirkhouse Benga 1, Wang Kae, Padi Tuya, Soo sima, Difeele, Zaayura pali
Groundnut	Earliness, high yielding, resistance/tolerance to key insect pests and diseases, selection for fresh seed dormancy	SARINUT 1, SARINUT 2, Nkatie-sari,
Cassava	Early bulking, high dry matter, high yield, stay-green, high starch content, resistance/tolerance to African cassava mosaic virus disease, tolerance to cassava green mite, tolerance to cassava mealy bugs	Nyeri-kobga, Eskamaye, Fil-Ndiakong
Sweet potato	Earliness, high yield, betacarotene, anthocyanins, resistance/tolerance to sweet potato weevil, stay-green/drought tolerance, high dry matter content for industrial processing, etc.	CSIR-SARI Nan, CSIR-SARI JanLow, CSIR-SARI Diedi, CSIR-SARI Nyoribegu
Yam	High yield, tuber appearance, food quality (boiled and pounded), low pests and disease reaction, high dry matter, tolerant to oxidation	SARI-Olondo, SARI-Nyamenti, SARI-Pona,SARI-Fuseinibila, SARI-Tila
Frafra potato	High yield, large tuber sizes, low disease and pest reaction	WAAPP Piesa 1, Manga-moya, Maa-Lana, Naachem-Tiir, Nutsugah Piesa
Cotton	Earliness, high lint yield, lint quality	SARCOT1, SARCOT 5

Table 1. *Improved crop varieties developed and released by CSIR-SARI.*

FUTURE RESEARCH ISSUES

Climate variability poses a major challenge to the sustainability of agro-based livelihoods in sub-Saharan Africa due to the low adaptive capacity and weak institutional framework of the region. This has serious implications on the ability of many households in the region to meet the sustainable development goals, especially on food security and poverty alleviation (Niang *et al.* 2014; IPCC 2014). To address these foreseeable challenges, there is the need to develop strategies that could ease the vulnerability of agriculture in Ghana. This calls for the development of climate-smart crop varieties that are tolerant to biotic and abiotic stresses. Specifically, crop varieties with extended shelf life would be needed to reduce postharvest losses. There is the need to take advantage of and utilize speed-breeding techniques that will help breeders to accelerate and maximize genetic gain, especially for traits with low heritability. The use of high throughput phenotyping and genotyping techniques will also improve selection efficiency for tolerance to abiotic stresses and enhance the output of breeding programs that aim at developing priority products to meet existing and emerging markets. Modern biotechnology tools such as clustered regularly interspaced short palindromic repeats (CRISPR) gene editing and genetic modification would be very useful in exploiting resistant genes from different genetic backgrounds including wild relatives. Additionally, marker-assisted breeding and genomic selection can be used to improve existing farmer-preferred crop varieties through the introgression of novel genes. To facilitate the adoption of the resultant improved crop varieties, end-user preferences and industry requirements of non-food crops such as cotton needs to be considered in the product design. In the case of cotton, key considerations are high yield potential, high percent emergence, high ginning outturn and good lint quality. Finally, there is the need to develop and introduce integrated crop, soil and pest management practices into the cropping system in order to minimize the effect of climate change and then improve yield and productivity of the crops of interest.

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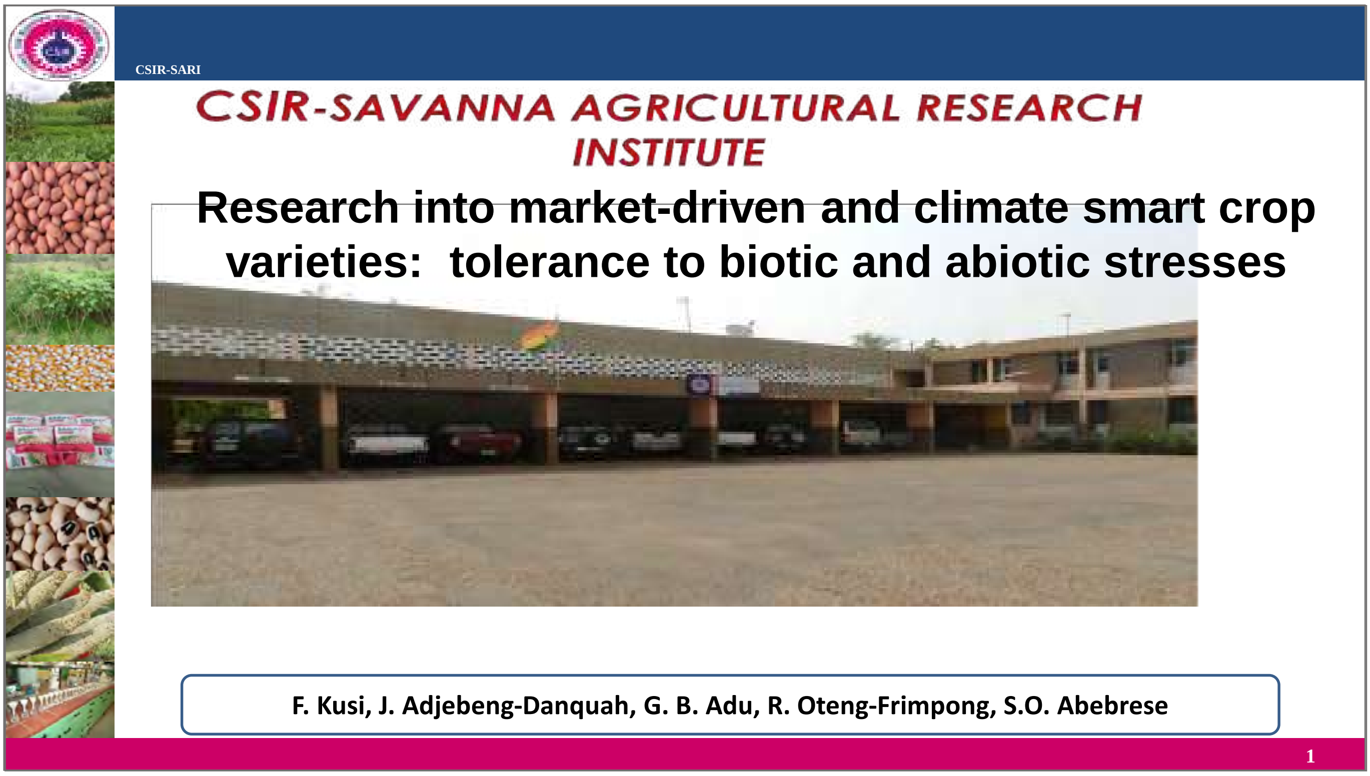
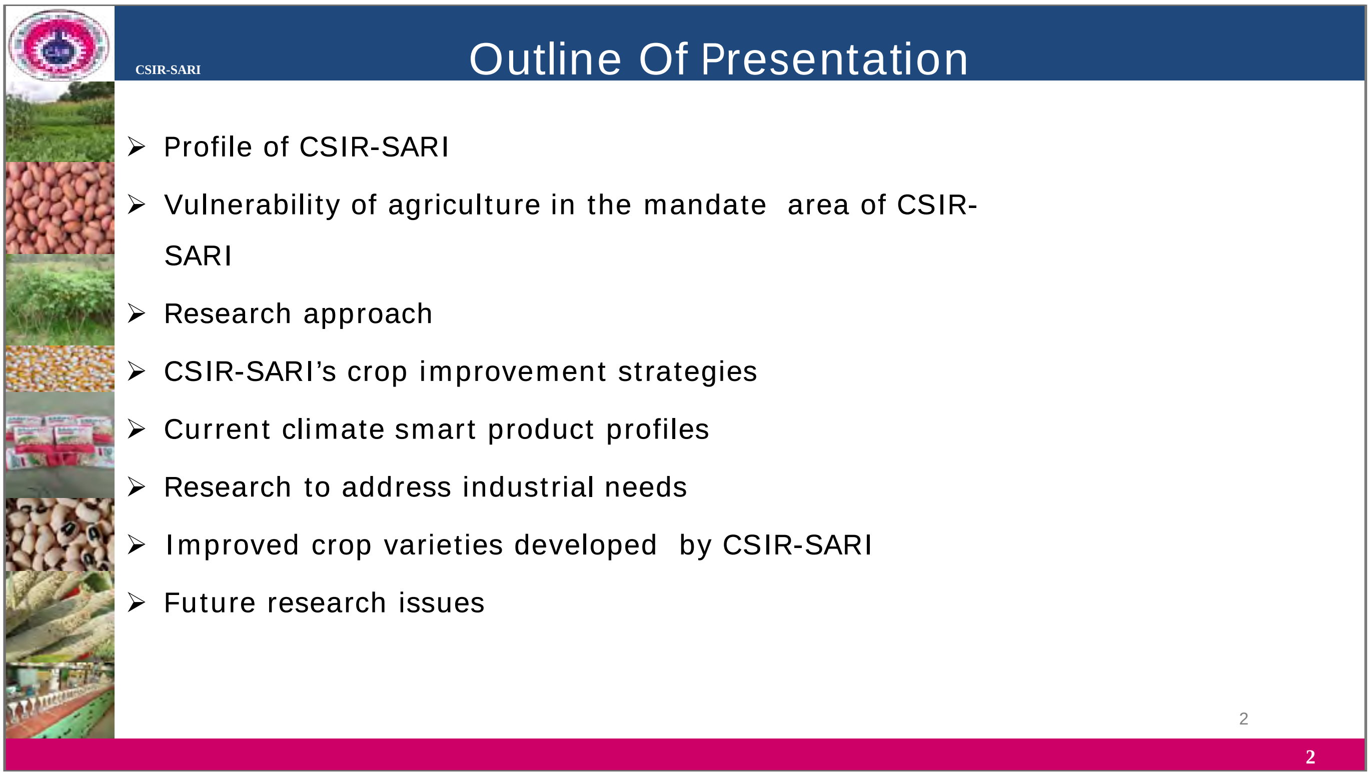
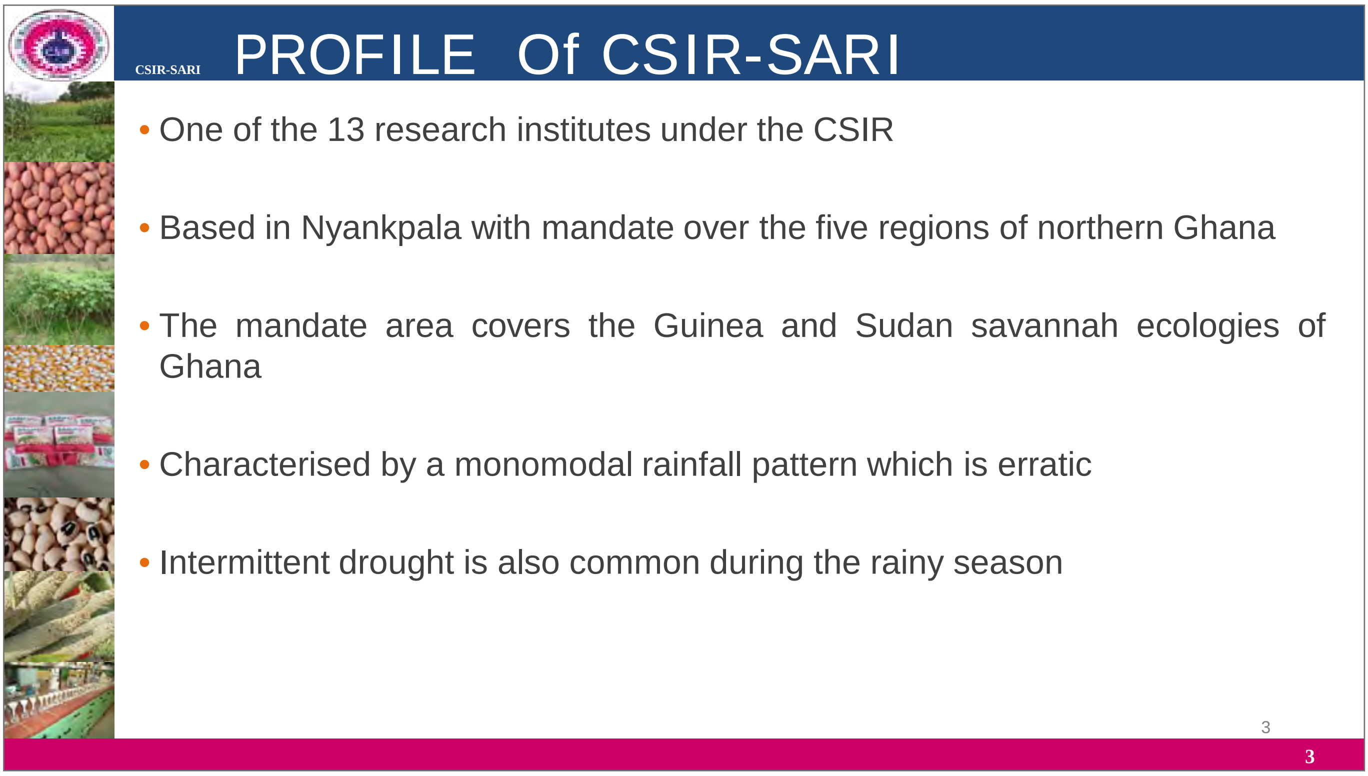
Presentation made at the Seminar






CSIR-SARI
PROFILE Of CSIR-SARI
• One of the 13 research institutes under the CSIR
• Based in Nyankpala with mandate over the five regions of northern Ghana
• The mandate area covers the Guinea and Sudan savannah ecologies of Ghana
• Characterised by a monomodal rainfall pattern which is erratic
• Intermittent drought is also common during the rainy season
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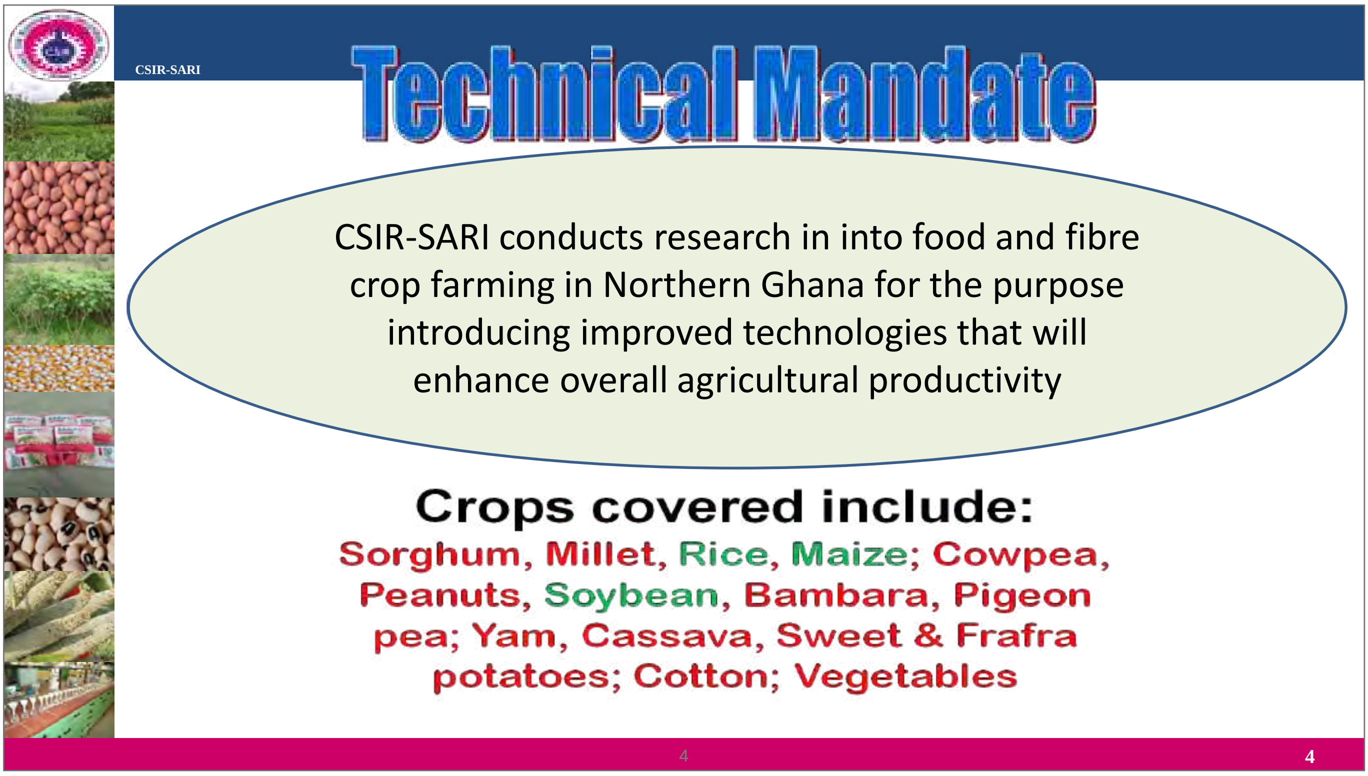
CSIR-SARI
Technical Mandate
CSIR-SARI conducts research in into food and fibre crop farming in Northern Ghana for the purpose introducing improved technologies that will enhance overall agricultural productivity
Crops covered include:
Sorghum, Millet, Rice, Maize; Cowpea, Peanuts, Soybean, Bambara, Pigeon pea; Yam, Cassava, Sweet & Frafra potatoes; Cotton; Vegetables
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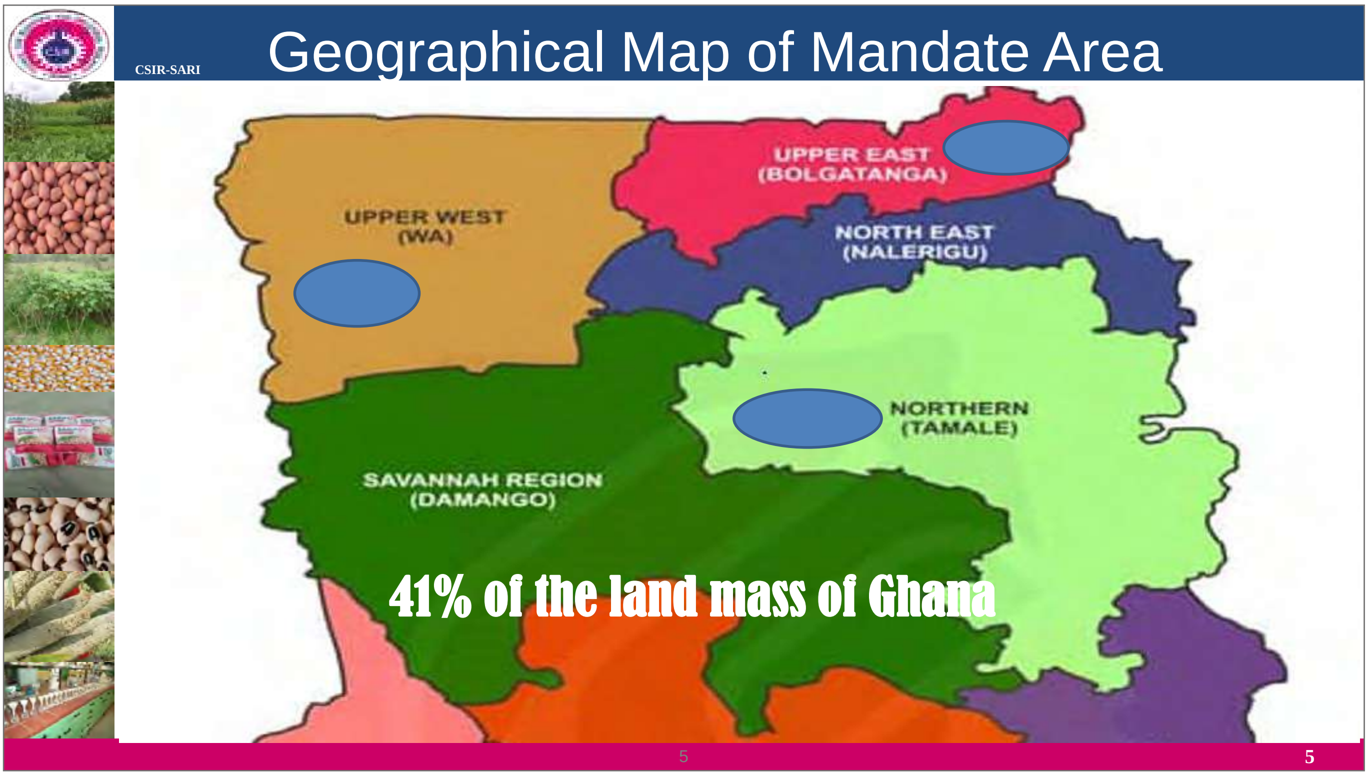

CSIR-SARI

RESEARCH APPROACH

THE FARMING SYSTEMS RESEARCH (FSR)

- NR-FSRG Northern Region Farming Systems Research Group, located at Nyankpala, the head office of SARI.
- UER-FSRG - Upper East Region Farming Systems Research Group, located at Manga near Bawku
- UWR-FSRG - Upper West Region Farming Systems Research Group, located at Wa.
- SSG- Scientific Support Group based at Nyankpala, works mostly on-station.

Each of these Teams houses a Research Extension Liaison Committee (RELC) Coordinator

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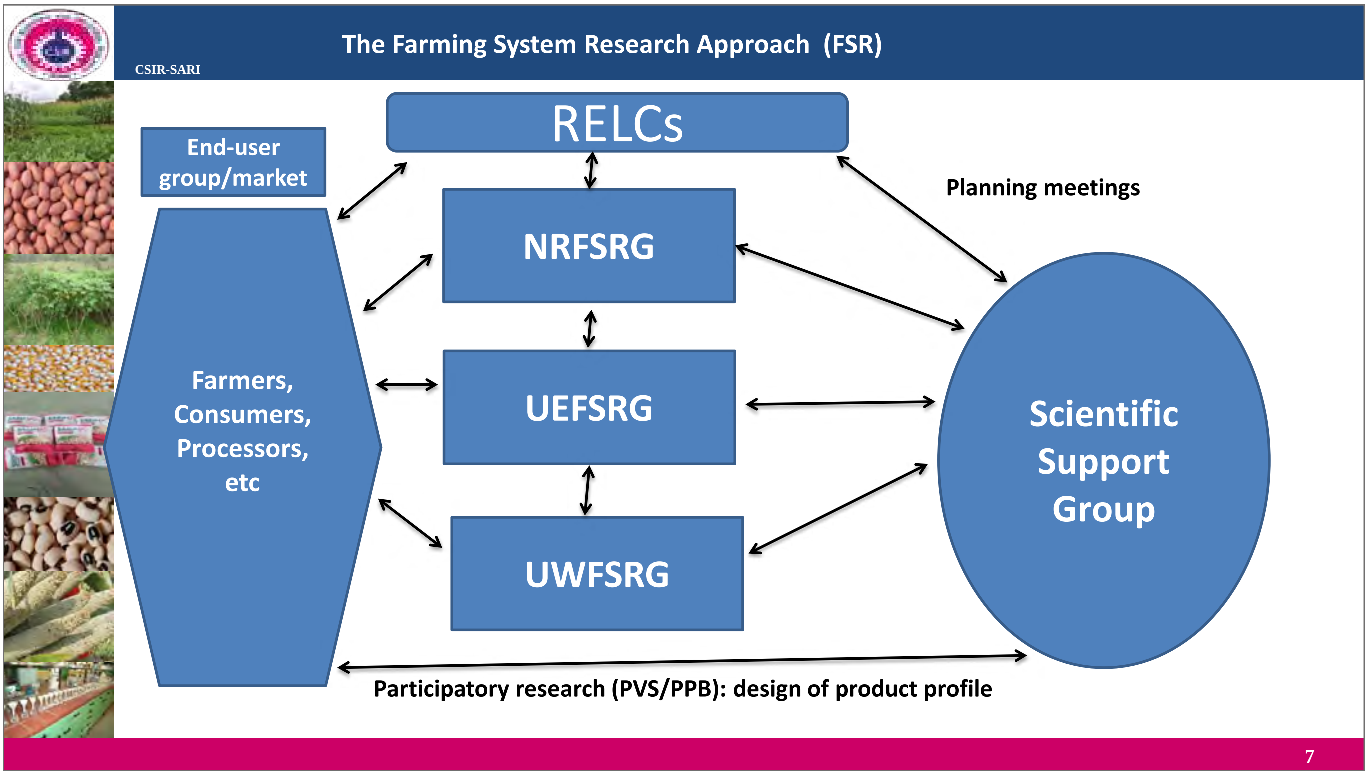
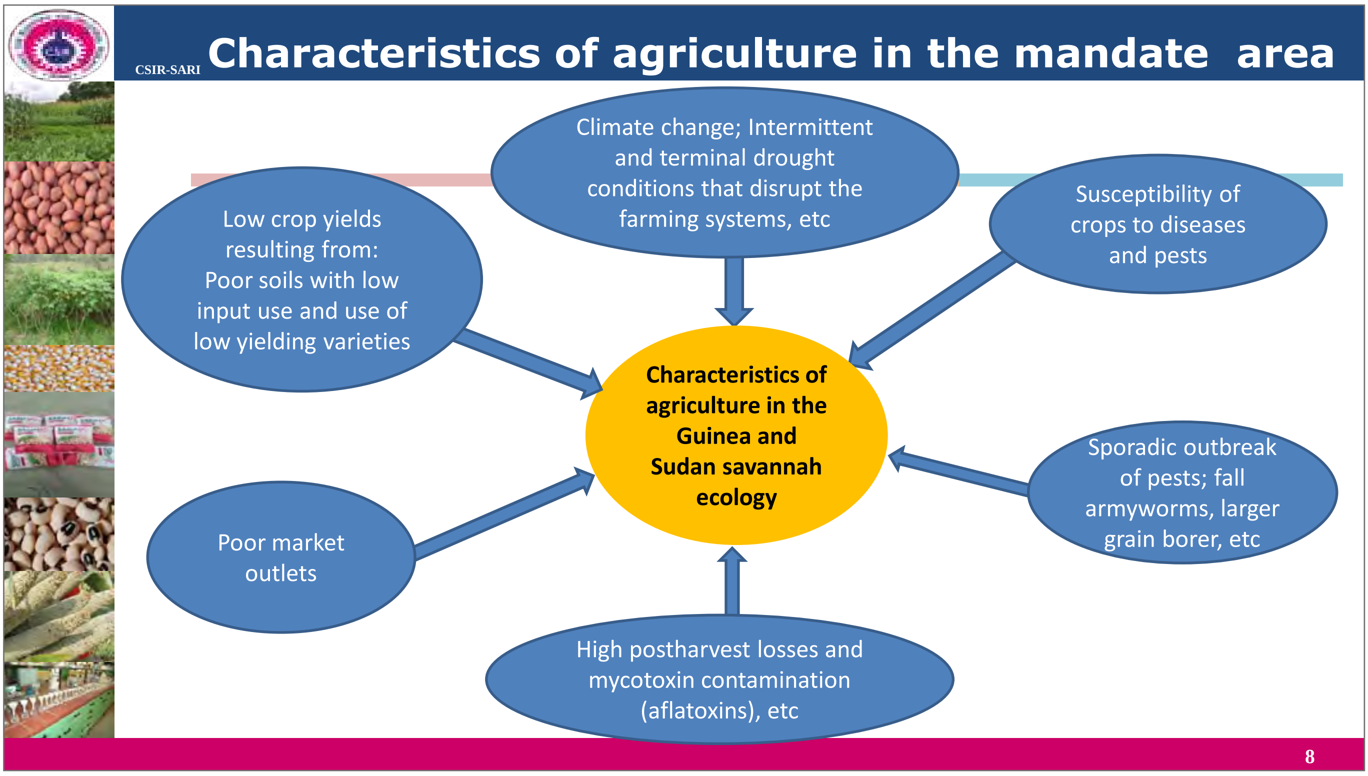

CSIR-SARI
The Farming System Research Approach (FSR)
RELCs
End-user group/market
Planning meetings
NRFSRG
Farmers, Consumers, Processors, etc
UEFSRG
Scientific Support Group
UWFSRG
Participatory research (PVS/PPB): design of product profile
7


CSIR-SARI
Characteristics of agriculture in the mandate area
Climate change; Intermittent and terminal drought conditions that disrupt the farming systems, etc
Low crop yields resulting from: Poor soils with low input use and use of low yielding varieties
Susceptibility of crops to diseases and pests
Characteristics of agriculture in the Guinea and Sudan savannah ecology
Sporadic outbreak of pests; fall armyworms, larger grain borer, etc
Poor market outlets
High postharvest losses and mycotoxin contamination (aflatoxins), etc
8

CSIR-SARI

CSIR-SARI's crop improvement strategies

- The goal is to develop end-user preferred crop varieties that fit into the agro-ecologies of the mandate area,
- Crop varieties that can withstand the specific stresses of low soil fertility, drought, pests and diseases that characterize the farming environments of our mandate area
- Produce breeder & foundation Seeds for mandate crops to enhance access
- Our varieties have high market demand; cowpea, maize, rice, soybean and sorghum varieties are used in the National flagship programme

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CSIR-SARI

Current climate smart product profiles

Development of crop varieties resistant to **biotic stresses:**

- Fall Armyworm resistant maize varieties
- Aphid resistant cowpea varieties
- Cowpea varieties with resistance to macrophomina resistance
- Groundnut varieties that are resistant to early and late leafspot diseases
- Cassava varieties with tolerance to cassava green spider mite and mealybug damage
- Cowpea and maize varieties that are resistant to *Striga gesnerioides* and *S. hermonthica* respectively

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CSIR-SARI

Current climate smart product profiles cont’d

Development of crop varieties with tolerance to **abiotic stresses**

- Neglected underutilized species that are climate resilient; fonio and frafra potatoes
- Heat tolerant tomato varieties
- Drought tolerant maize and cowpea varieties
- Nitrogen use-efficient maize varieties
- Early bulking and drought tolerant cassava varieties
- Early bulking sweetpotato varieties
- Sweetpotato varieties with stay-green attributes for dual purpose utilisation

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Research to address industry needs

Development of industry-preferred crop varieties

- Sorghum varieties for premium brewing qualities for industrial use
- Dual purpose guinea and caudatum sorghum races for grain and biofuel utilisation
- Sweet sorghum varieties for ethanol production

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Improved crop varieties developed by CSIR-SARI

Commercial maize varieties

- Sanzal-sima, Wang-dataa,
- Bihilifa, Kpari-faako,
- Suhudoo, Kunjor-wari,
- Wang-Basig, Denbea,
- Salin-kawana

- Key points to consider: Earliness, drought tolerance, Striga tolerance, high and stable grain yield,

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CSIR-SARI

Improved crop varieties developed by CSIR-SARI

Rice

- Gbewaa rice
- Gbewaa red
- Savanna rice
- Malimali
- Digan

Key points to consider: early maturity, Market demand, yield

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CSIR-SARI

Improved crop varieties developed by CSIR-SARI

Soybean

- Jenguma,
- Afayak,
- Favour
- Quarshie
- Suong Pungun

Key points to consider: Earliness, non shattering, yield ,

15

CSIR-SARI

Improved crop varieties developed by CSIR-SARI

Sorghum

- Kapaala,
- Dorado

Key points to consider : Earliness, Resistance/tolerance to head bugs, striga and dry spells, brewing quality

16

CSIR-SARI

Improved crop varieties developed by CSIR-SARI

Millet

- Akad-kom,
- Kaanati,
- Naad-Kohblug,
- Afribeh-Naara and
- Waapp-Naara

Key points to consider : Earliness, high yield, Resistance/tolerance to striga, dry spells etc

17

CSIR-SARI

Improved crop varieties developed by CSIR-SARI

Cowpea

- Kirkhouse Benga 1 and
- Wang Kae are Aphid and Striga resistant cowpea varieties
- Padi Tuya,

- Key points to consider : Earliness, high yielding, striga resistance, resistance/ tolerance to key insect pests (Maruca pod borer, thrips, etc) and diseases

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CSIR-SARI

Improved crop varieties developed by CSIR-SARI

Groundnut

- SARINUT 1
- SARINUT 2
- Nkatie-sari,

- Key points to consider : Earliness,

high yielding, resistance/ tolerance to key

- insect pests and diseases
- Selection for fresh seed dormancy

19

CSIR-SARI

Improved crop varieties developed by CSIR-SARI

- Sweetpotato
- CSIR SARI-Nan,
- CSIR-SARI-JanLow
- CSIR-SARI Diedi
- CSIR-SARI-Nyoribegu

Key points to consider : Earliness, high yield, betacarotene, anthocyanins, Resistance/tolerance to sweetpotato weevil, stay-green/drought tolerance, high dry matter content for industrial processing, etc

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CSIR-SARI

Future research issues

- ✓ Development of crop varieties with extended shelf-life ; tomatoes, garden eggs, yam, etc
- ✓ Utilisation of speed breeding technique to maximize genetic gain
- ✓ The use of high throughput phenotyping and genotypic techniques
- ✓ Use of modern biotech tools; CRISPR, gene editing, GM, etc
- ✓ Marker assisted breeding to improve existing farmer preferred crop varieties through addition of novel genes
- ✓ Development and introduction of integrated crop, soil and pest management practices to minimize the effect of climate change yield and productivity of crops of interest

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GENETIC IMPROVEMENT BY MUTAGENESIS OF OILSEED CROPS TO COPE WITH CLIMATE CHANGE: CASE OF RAPESEED AND SESAME

Mr. Abdelghani NABLOUSSI, Mr. Souhail CHANNAOUI, and Mr. Mohamed KOUIGHAT
institut national de la recherche agronomique (INRA), Morocco

INTRODUCTION

Morocco has a large deficit in vegetable oils and proteins from oilseeds. Currently, sunflower and rapeseed are the two oilseed crops grown in limited areas, with an average area of less than 40,000 ha. During the last five years, this average area was about 25,000 ha, and the average national production of oil from local seeds was below 10,000 tons, covering barely 2% of the country's overall needs in edible oils estimated at over 500,000 tons. As a reminder, this coverage rate was around 14% in 1990 and 6% during the period 1993–1997! This decline can be explained by several factors including, essentially, recurrent droughts that have negatively impacted the production of oilseeds through the fall in yields and the reduction of areas reserved for these crops. Massive imports in the form of oilseeds or crude oil to fill the deficit in edible oils are very expensive for the State, with foreign currency expenditure exceeding 4 billion dirhams (400 million USD) annually.

According to a World Bank study, oilseed production will further decrease as a result of climate change effect on agricultural production in Morocco, with a rising trend in drought, heat and flooding (Gommes *et al.* 2009). This study showed that oilseed crops will suffer the most severe reduction in yields in the future, up to -10% in 2030 and -30% in 2050.

This situation is harmful for farmers, agriculture sustainability, food security and national economy. In fact, abandoning or reducing oilseed crops' extent as a result of climate change effect will affect negatively the global cropping system, since those crops play an important role in rotation with cereals, the most strategic national crops.

Furthermore, and as an importer, Morocco is beginning to be enormously impacted by the increasing prices of the entire oilseed complex (seeds, oils and cakes), which generates an additional cost of more than 3 billion dirhams to the import invoice.

In view of this strong dependence on the outside world, which has both economic and political drawbacks, the promotion and development of oilseed crops can only be one of the priorities of Moroccan agricultural policy. This will undoubtedly guarantee a reduction in the level of dependence on imports and an improvement in the balance of trade, in addition to improving the farmers' income and providing relief to Moroccan households by keeping consumer prices at an affordable level.

From the agricultural research point of view, to challenge and face the increasing abiotic stresses due to climate change, a strategy based on the development and cultivation of tolerant varieties of the existing crops, in addition to the diversification and introduction of new and alternative resilient crops, was adopted.

The objective of this short paper is to provide an overview on the main and recent achievements in oilseed crop breeding to face the most important abiotic stresses increasingly observed in Morocco, focusing on mutagenesis breeding of rapeseed and sesame.

OILSEED CROPS AND CLIMATE CHANGE IN MOROCCO

Oilseed crops cultivated

During the period 1980–1995, the annual oilseed crop sector in Morocco was marked by a phase of unprecedented development through the achievement of great technical performance. Indeed, the area reserved for the cultivation of sunflower increased drastically to reach a record of 200,000 ha in 1992, while production exceeded 160,000 t. The area planted to rapeseed crop was about 3,100 ha in 1990 and the yields achieved, with an average of 1.3 t/ha, were higher than those of sunflower, reaching in some cases 3 t/ha in sub-humid zones. Safflower cultivation in the late 1980s exceeded 4,000 ha and average yields were around 2 t/ha, obtained by some producers under a rainfall of less than 300 mm. For soybean planted under irrigation conditions, the achievements reached 10,000 ha in 1991 with peak yields of about 3 t/ha.

Since the end of the 1990s, the sector has experienced problems that have limited its development and, consequently, put an end to the boom phase that had previously taken place. Among the main constraints encountered is the recurrence of drought, especially in spring, affecting the technical performance of the sunflower crop (spring crop), and the deregulation of the sector that took place in 1996, which had repercussions on the marketing of oilseed production, with a drop in the production price from 4,400 dirhams (US$440)/t to 3,000 dirhams (US$300)/t. All these factors have led to a reduction in the area planted to oilseed crops. At the same time, as part of the reform of the oilseed sector implemented in 2000, rapeseed and safflower did not benefit from the state support allocated to sunflower. This means that there was no longer a subsidy on production prices, nor a guarantee of outlets for these two crops, which has led farmers to abandon them.

The year 2013 was a key date for the oilseed sector in Morocco. Indeed, within the framework of the strategy Green Morocco Plan (PMV), the Moroccan government and the professionals of the oilseed sector (Interprofessional Federation of Oilseed Crops, FOLEA) agreed to undertake a vast program of development of this sector by 2020, based on rapeseed and sunflower as main crops. The extension and diversification of the annual area of oilseed crops to reach 127,000 ha, including 85,000 ha of sunflower and 42,000 ha of rapeseed, was actually the main objective of this program. However, this has never been achieved, as sunflower acreage has continued to decline and rapeseed area has remained much lower than expectations, despite its rising trend.

Sesame is an ancient oilseed crop that has been cultivated in Morocco as an aromatic and medicinal plant rather than oilseed. Its area and production dropped markedly between 2000 and 2020. As a result, the import quantities and values have significantly and gradually increased during the same period. The observed decline in both the area and the production may be due to several constraints, including recurrent drought, restricted supply in irrigation water, poor cultural practices, low-yielding cultivars and pests and diseases.

Climate change

Nowadays, food security is actually impacted by increasing abiotic stresses, as a result of the global climate change. Abiotic issues such as drought, soil salinity, heat and nutrient stress are estimated to decrease crop productivity by 50–80% (Shinozaki *et al.* 2015). Drought is found to be the most severe stress that limits crop growth and production. Nevertheless, drought often co-occurs with salinity and heat, all forecast to increase around the world in the next years (Corwin 2020), which will further threaten global food production.

In Morocco, the agricultural sector dominates Morocco's economic activity and is an effective engine of economic growth and guaranteed food security. However, it is increasingly threatened by drought, a structural element of the country's climate. In the last few decades, there has been an increasing drought frequency observed throughout the entire cycle of crops, from germination to seed filling. With climate change, there is a downward trend in overall precipitation and a rising trend in average temperature. Similarly, there has been increasing flooding in some areas of Morocco, which leads to waterlogging conditions that negatively affect crops growth and yield. In fact, under sustained flooding conditions, waterlogging causes a drop in oxygen availability to plants or oxygen deficiency (hypoxia or anoxia), leading directly to roots system damage and indirectly to leaf wilting and chlorosis.

BREEDING STRATEGY TO FACE CHANGING CLIMATIC CONDITIONS

Germplasm enhancement

The enhancement and reinforcement of the existing germplasm is actually the most important and crucial element to build a relevant and effective strategy to cope with the effects and repercussions of climate change. To broaden our oilseed germplasm, three ways are adopted: introductions, hybridizations and mutagenesis.

Introductions: Several accessions of cultivated oilseed crops and their wild relatives are introduced from different gene banks over the world. Also, various germplasms can be obtained via exchange with different international and national research centers or institutes working on pre-breeding or breeding oilseed crops.

Intra- and interspecific hybridizations: Many crosses and intercrosses among genotypes from the same species and from close species (same genus) are carried out to obtain new genetic recombinations and, thus, to enlarge the existing genetic variability.

Mutagenesis: Chemical mutagenesis, via ethyl methane sulphonate (EMS), is more and more used in our breeding program as it is an effective biotechnological tool to induce novel and large genetic variability.

Characterization and evaluation under stressed conditions

All the existing and new germplasms are characterized and evaluated under abiotic stress conditions, mainly drought, to identify and select the most tolerant ones. The assessment activities are designed and implemented both under field and greenhouse-controlled conditions.

Since drought could occur at any phase of the crop cycle, the experimented water stress is applied at different growth stages, mainly germination/early seedling growth and flowering/seed filling, which are the most sensitive to this stress.

Multi-traits phenotyping: The characterization and evaluation of the investigated genotypes were undertaken for morphological, physiological, biochemical and agronomic traits.

Selection indices: By understanding the mechanisms involved in the adaptation and tolerance to such stress, we can develop some selection indices based on simple and easily measurable/observable traits that are strongly correlated to seed yield under drought conditions. Early blooming/flowering is a relevant criterion among these indices that are used for early selection in the field.

Selection of productive and adapted lines

Early field selection of desired individuals is performed based on the indices mentioned above. All of the plants selected are bagged to ensure self-fertilization and monitored during 3-4 generations to confirm their performance and tolerance to drought stress. All the fixed and stable lines will then be further evaluated, along with a check variety, for seed yield and oil content in different environmental conditions (3 locations for 3 years). The lines having shown higher seed and oil yield can be proposed as candidate lines for registration as new varieties in the official catalog of plant species and varieties.

OILSEED CROPS AND MUTAGENESIS BREEDING: RAPESEED AND SESAME RAPESEED

Rapeseed (Brassica napus L.) is one of the most important sources of vegetable oils and protein-rich meals worldwide. It is the second most important source of vegetable oil after soybean. Its production is destined for edible oil, animal feed and industrial uses, including biodiesel. Its oil has an excellent nutritive due to the abundant unsaturated fatty acids. Its meal (remains after oil extraction), used for livestock feed industry, has an ideal amino acid content and a high content of fiber, several minerals and vitamins. Even though rapeseed is well adapted to local environmental conditions in Morocco, its growth and production are more and more impacted by the increasing drought that can occur at any time during the growing season. Nevertheless, two main periods of drought are more likely: the early one that coincides with seed germination and seedling emergence and the terminal drought that is more frequent and occurs during flowering and maturity stages.

In rapeseed, mutation breeding has been adopted and used to induce novel genetic variability and select interesting and desirable economic traits, such as as earliness, resistance or tolerance to abiotic and biotic stresses, seed yield attributes and oil quality parameters (Channaoui et al., 2019a; 2020).

Germination and seedling growth under water stress

Under water stress conditions, seed germination and early seedling emergence are critical and the most sensitive stages in the life cycle of plants in general, and rapeseed in particular. Both drought and waterlogging have severe and negative effects on crop growth and yield. Waterlogging usually occurs in early winter, coinciding with germination or early seedling stages. Seeds exposed to unfavorable environmental conditions like drought or waterlogging stresses may have their establishment and also crop production compromised. Therefore, maintaining quite high seed germination percentage and proper seedling growth under drought and waterlogging conditions has been one of the most important objectives in our breeding program.

A recent study on drought effect on the developed mutants indicated that this stress affected all germination and early seedling parameters, namely germination percentage, germination rate, mean germination time, shoot length, root length and root elongation rate, in all the genotypes studied (Channaoui *et al.* 2019b). Drought levels were simulated by different osmotic potentials resulted from various concentrations of polyethylene glycol (PEG) solution. Results showed that drought stress level, genotype and interaction stress × genotype had a significant effect on the studied parameters. The studied genotypes reacted differently to various water stress levels (Figure 1). The genotype "H2M-5"' exhibited the highest average root length (RL) and root elongation rate (RER) under all drought levels. In particular, for severe drought conditions (-11 bars), "H2M-5" had an average RL of 1.54 cm and RER of 0.36 cm/d. The observed variation among the tested mutants is a reliable indicator of genotypic differential for drought tolerance in rapeseed. This suggests that the choice of the rapeseed variety to be planted in a given environment should depend upon the presence and degree of the stress observed in that environment.

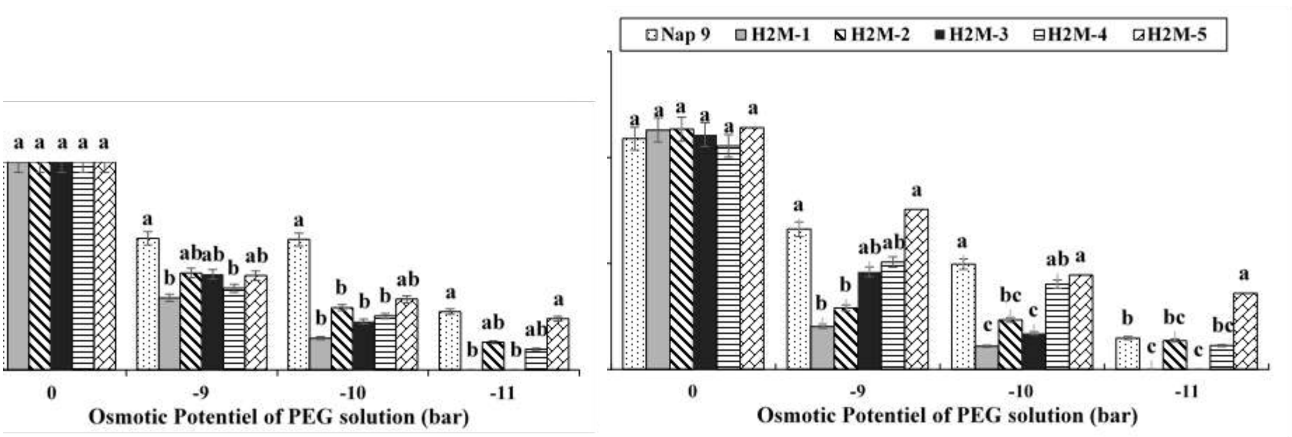

Figure 1. *Reaction of rapeseed genotypes (mutants) to various levels of drought during germination and early seedling growth.*

Another study on waterlogging stress aimed to evaluate the behavior and performance of four Moroccan varieties subjected to this stress at four plant growth stages, against the control (absence of waterlogging). The results obtained showed that waterlogging stress significantly affected most of the studied parameters for all varieties and that germination and post-emergence seedling stages were the most sensitive to waterlogging stress conditions (Figure 2). In particular, seed yield was drastically reduced for all varieties, and the reduction rate ranged from 19% for “INRA-CZH3” to 73% for “Narjisse” when waterlogging happened under rosette and young seedling stages, respectively. Overall, the “INRA- CZH3” variety presented the best agronomic performance and was the most tolerant to waterlogging occurring at different plant growth stages. This tolerance was attributed to its developed root system, its high seedling vigor and its large collar diameter. The two latter traits presented a high correlation with seed yield components and, thus, we recommend their use as selection criteria to breed for waterlogging rapeseed tolerance (Nabloussi *et al.* 2019).

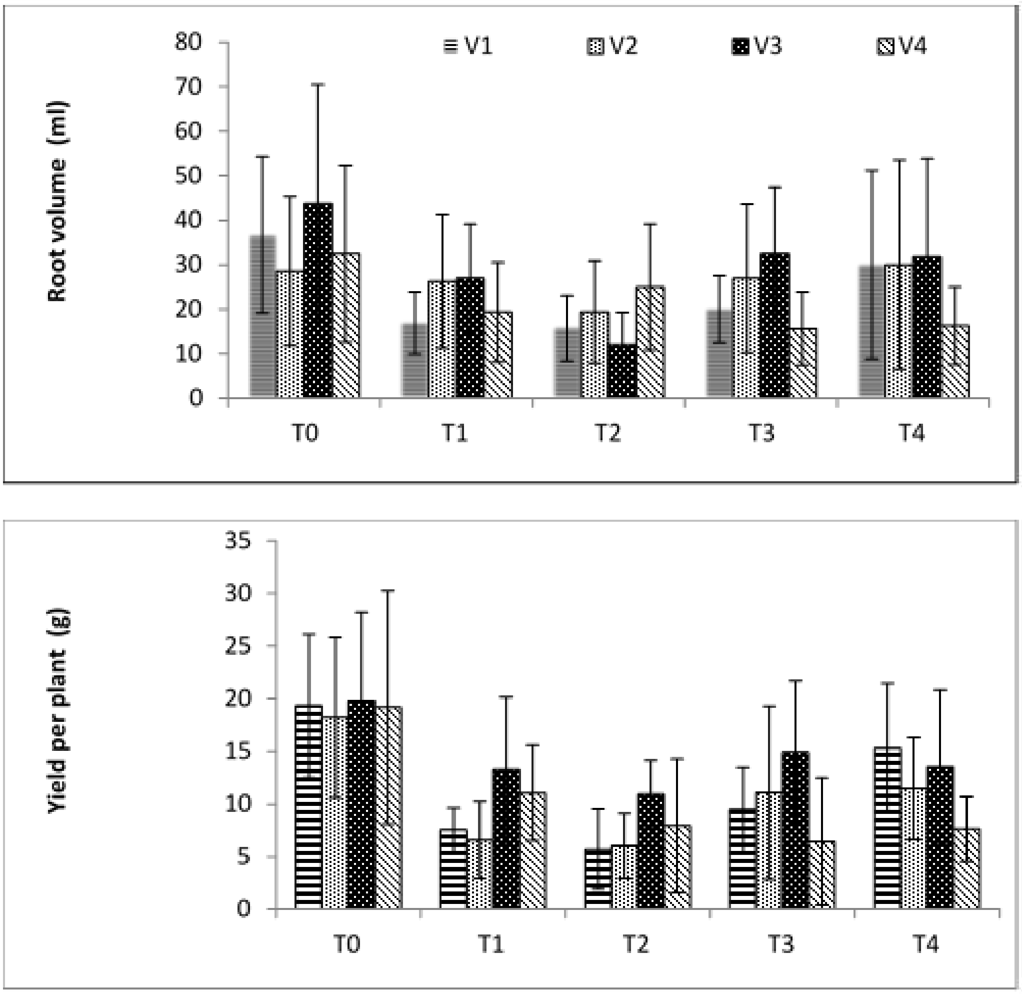

Figure 2. *Average treatment performance for each variety for root volume and seed yield per plant. (V1=Narjisse, V2=INRA-CZH2, V3=INRA-CZH3, V4=Lila), (T0=Absence of waterlogging, T1=Waterlogging during germination, T2=Waterlogging during post-emergence seedling stage, T3=Waterlogging during rosette stage, T4=Waterlogging during floral bud stage)*

Drought stress during the blooming stage

It is well known that the flowering stage is very sensitive to drought and heat in many crops, including rapeseed. Therefore, breeding for early-flowering varieties, having a short-duration cycle, would be a good strategy to escape drought and heat stress happening during flowering.

Some mutant lines developed by EMS mutagenesis breeding exhibited genetic progress, compared to the original material (the variety "INRA-CZH2"), in terms of seedling initial vigor, flowering earliness, branching and number of pods per plant. Table 1 shows the performance of these lines, compared to the check (wild material). One could observe that there was a genetic gain for some traits of agronomic interest. The most interesting mutant lines are "H2M2" and "H2M5", having shorter duration from emerging to blooming and producing a much higher number of pods per plant, compared to the wild material (Channaoui *et al.* 2019a). These lines open up the possibility of releasing earlier and more productive varieties than existing ones, as future cultivars suitable for the climate change context, mainly characterized by increasing drought and heat stresses.

Mutants M2	**Days to flowering**	**Branching**	**Number of pods per plant**	**Number of seeds per pod**	**Thousand seed weight (g)**
H2M1	87.15ef	8.05abc	309.9b	25.31ab	2.28b
H2M2	85.00f	9.65a	858.5a	25.64a	2.40b
H2M3	1024.00a	7.22bc	364.8b	20.28de	1.30c
H2M4	96.95d	6.30c	276.9b	22.27cd	1.85b
H2M5	89.85e	8.10abc	830.6a	27.05a	2.27b
H2M6	100.45c	8.55ab	279.7b	19.55e	1.88b
H2M7	97.35cd	8.85ab	454.0b	23.11bc	2.27b
H2M8	93.36b	10.10a	381.0b	18.72e	3.00a
H2M9	98.90cd	8.90ab	202.7b	21.07cde	2.30b

Table 1. *Average performance of some mutant lines for interesting agronomic traits.*

Most recently, we conducted another study under greenhouse-controlled conditions, for two years, to assess the reaction of four genotypes to contrasting water levels, during the flowering

stage, and to understand the mechanisms involved in their tolerance to drought. Results showed significant effects of genotype, water regime and their interaction on all measured parameters. The variety "Nap9" was the most productive for seed yield and oil content under all the water regime conditions (data not yet published). It is characterized by the highest root length and leaf relative water content. Thus, this genotype can be used as a relevant germplasm in rapeseed breeding program for drought tolerance. Also, high branching combined with high leaf relative water content could be considered as pertinent selection index for this breeding program.

SESAME

Sesame (Sesamum indicum L.) is a very old oilseed crop that is important from agronomic, therapeutic and industrial points of view. Its seeds are rich in oil (50–60%), with antioxidant properties. Sesame seeds are used for making confectioneries, cakes, margarines and breads. Sesame has also many industrial uses such as paint formulation and the manufacture of soaps, cosmetics, perfumes, insecticides and pharmaceutical products. Traditionally, this crop has been cultivated mainly in some Asian and African countries, including Morocco. However, the sesame cultivated in this country faces many constraints and challenges that limit its production potential. Among these problems, one can cite recurrent drought, restricted supply in irrigation water, poor cultural practices, pests and diseases and low-yielding cultivars. Also, sesame still shows some wild characteristics, such as capsule dehiscence, indeterminate plant growth and asynchronous capsule maturation, which lead to low seed yield. Furthermore, sesame is grown in Morocco as a catch summer crop, planted between June and October. Thus, this crop is fully irrigated to overcome the drought and high evaporation demand occurring during the entire life cycle of the plant. On average, seven irrigations are applied throughout the crop cycle (Kouighat *et al.* 2022a), which is excessive in the actual context of climate change and decreasing water resources. To overcome most of these challenges, breeding and varietal selection remain the most relevant means. For this purpose, a high level of genetic variability should be available. However, recent studies have shown there is a restricted genetic diversity among the Moroccan sesame cultivars (El Harfi *et al.* 2018; 2021).

Therefore, expansion and broadening of the existing diversity in Moroccan sesame germplasm are needed. A chemical mutagenesis, using ethyl methane sulfonate (EMS) was applied to induce novel genetic variability. Mutant plants with a tetra-carpellate capsule, three capsules per leaf axil, determinate growth, diverse seed colors and a highly developed root system were selected and characterized (Kouighat *et al.* 2020). They are promising and useful for sesame breeding programs that aim to develop productive and high-quality cultivars, particularly for stressful environments.

Germination and seedling growth under water stress

Even though sesame is reported to be more tolerant to drought than other oilseed crops, this water stress often co-occurs with heat or high temperatures, which negatively and seriously affect sesame production. Harmful effects on seed yield and quality are especially and significantly observed when drought happens at germination and flowering stages. Seed germination is the first critical and most sensitive stage of the plant life cycle as it is directly and strongly associated with seedling establishment and early growth. Any soil moisture decline may delay or even inhibit germination. The magnitude of decrease in germination and early seedling growth depends upon the drought level and the cultivated genotype.

However, the sesame crop is fully irrigated to overcome drought and high evaporative demand occurring during all plant life cycle, which causes salinization of the soil and, thus, deterioration of its quality, besides the increasing waste of water. Therefore, there is a need to grow drought-tolerant cultivars to reduce irrigation frequency from the germination stage until plant maturity. As a result, a large amount of irrigation water would be saved, and the soil would be healthier. It would be a relevant and sound strategy to promote and develop this crop in Morocco as well as other African areas (Kouighat *et al.* 2022a).

The sesame mutants obtained that have exhibited their superiority, compared to the wild type, were investigated in vitro for their reaction to moderate (-0.6 MPa) and severe drought stress (-1.2 MPa of PEG-6000) at germination and early seedling growth during two generations (M2 and M3). There is a significant effect of genotype, drought, and drought × genotype interaction on all parameters investigated. Under severe drought, seeds of seven genotypes, including wild types, were not able to germinate, while there was a drastic decline of all parameters for the rest (Figure 3). Interestingly, two mutants, “ML2-5” and “ML2-10”, were identified as the most tolerant to severe drought and the most stable over both generations (Kouighat *et al.* 2021). These are the first sesame germplasm ever reported with such a high level of tolerance to drought during germination and early seedling growth stages.

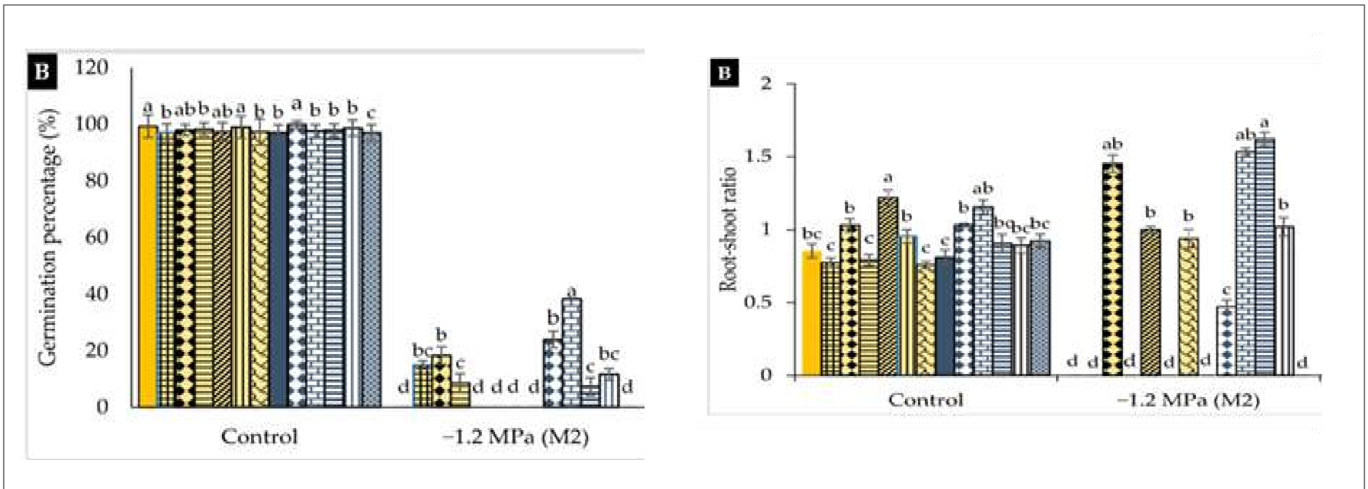

Figure 3. *Reaction of sesame genotypes (mutants) to severe drought during germination and early seedling growth.*

Flowering and seed filling under water stress

Sesame crop productivity is much impaired by the adverse effects of climate change, mainly the increased frequency of drought and heat stress, and the decreased availability of water resources. For sustainable production, adapted and stable cultivars with good performance under both well-watered and stressed conditions are needed. These cultivars could ensure a good and stable sesame production in regions with contrasting water conditions.

Flowering and seed filling are crucial plant stages that are too sensitive to drought. Therefore, water stress at these stages should be avoided to increase sesame seed yield and viability, or the planted cultivars should be tolerant to the same, by showing less yield decline compared to well-watered conditions.

The same promising mutants evaluated for their level of drought tolerance during seed germination and early seedling growth stages were used in another study, as a logical continuation, to assess their reaction to drought occurring at flowering (Kouighat *et al.* 2022b). There was a large and significant variation among the mutants for all parameters studied, except the number of seeds per capsule (Figure 4). The mutants "ML2-5", "ML2-72" and "ML2-37'" were found to be the most tolerant to drought, exhibiting the lowest stress sensitivity index and highest seed yield (Kouighat *et al.* 2022). This is the first report on sesame mutant lines with such high tolerance to drought during flowering. They could be used for developing high-performing cultivars with tolerance to drought during the flowering stage.

CONCLUSIONS AND PROSPECTS

In Morocco, there is a problem in seed oil food security, with a very low production that does not exceed 2% of the national requirement. Despite the agreement between the Moroccan government and the profession of this sector, there has been a decline in sunflower and sesame cultivation while there has been a significant increase in rapeseed during the last decade. With the rising temperature trend and the downward trend in precipitation, all sub-regions of the Mediterranean Basin, including Morocco, are increasingly impacted and threatened by climate change. Thus, there is a need to develop and implement a global strategy to cope with climate change.

With regard to breeding activity, an integrated based on germplasm introductions (including novel resilient and alternative oilseed crops), intra- and interspecific hybridizations, and mutagenesis has been designed and implemented. In particular, mutagenesis breeding was successfully and effectively used in rapeseed and sesame and, as a result, novel and promising germplasms tolerant to severe drought during germination and flowering stages were identified and selected. These germplasms will be useful in developing and releasing drought-tolerant and high-yielding varieties of rapeseed and sesame in the future.

However, further works on heat and flooding are needed to identify genetic materials that exhibit a high level of tolerance to all those abiotic stresses. Finally, these germplasms will be evaluated and monitored under stressed field conditions for many years to select high-performing and adapted lines.

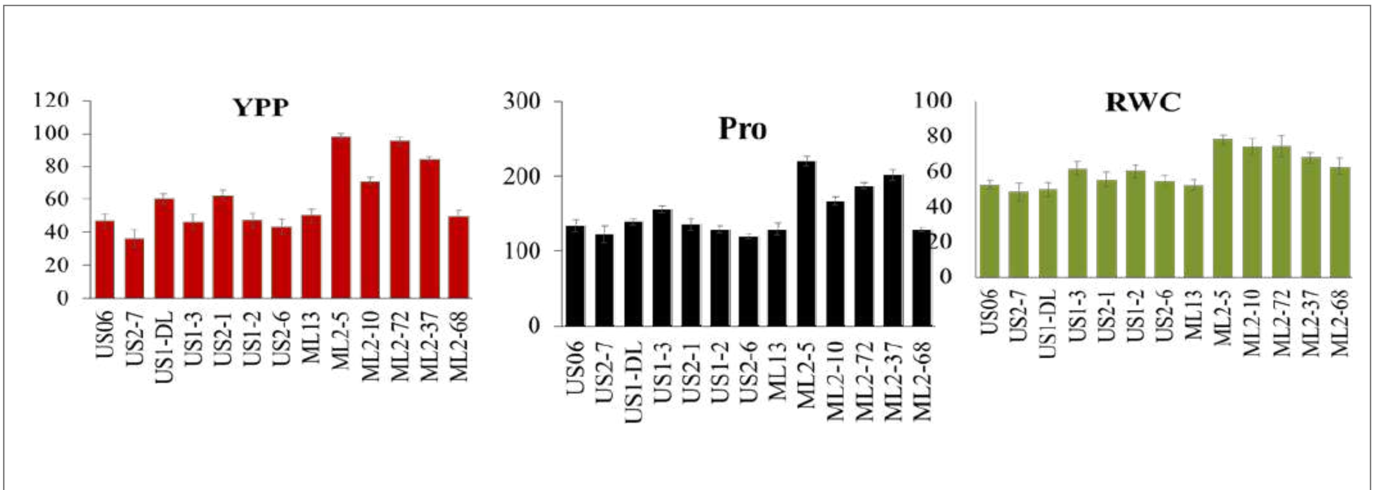

Figure 4. *Performance of different sesame genotypes (mutants) under drought conditions for seed yield per plant (YPP), proline content (Pro), and relative water content (RWC).*

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Presentation made at the Season Seminar

GÉNÉRATION GREEN 2020 – 2030

Seminar on the role of plant breeding and plant variety protection in enabling agriculture to mitigate and adapt to climate change

Thematic Session 4: Plant breeding for climate change adaptation and mitigation in agriculture: Breeding strategies and techniques

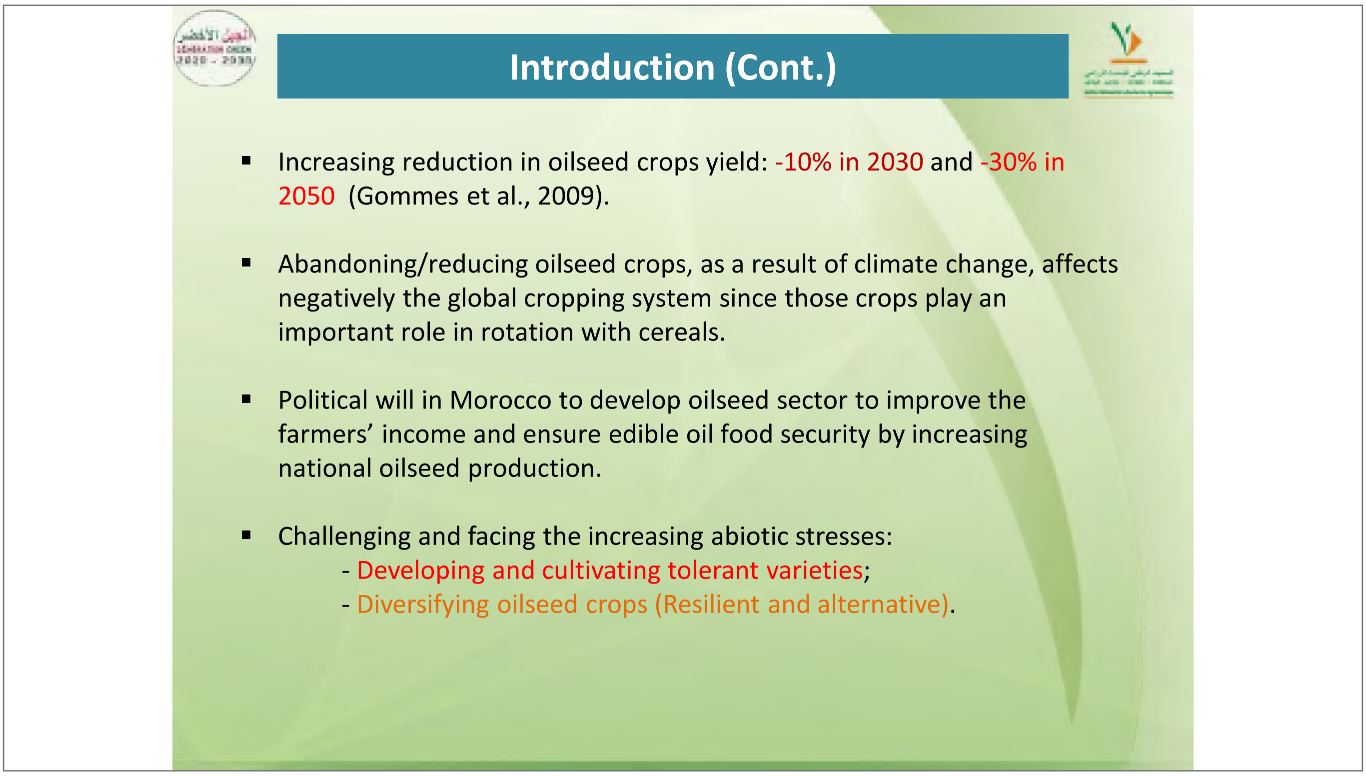
Genetic improvement by mutagenesis of oilseed crops to cope with climate change: case of rapeseed and sesame

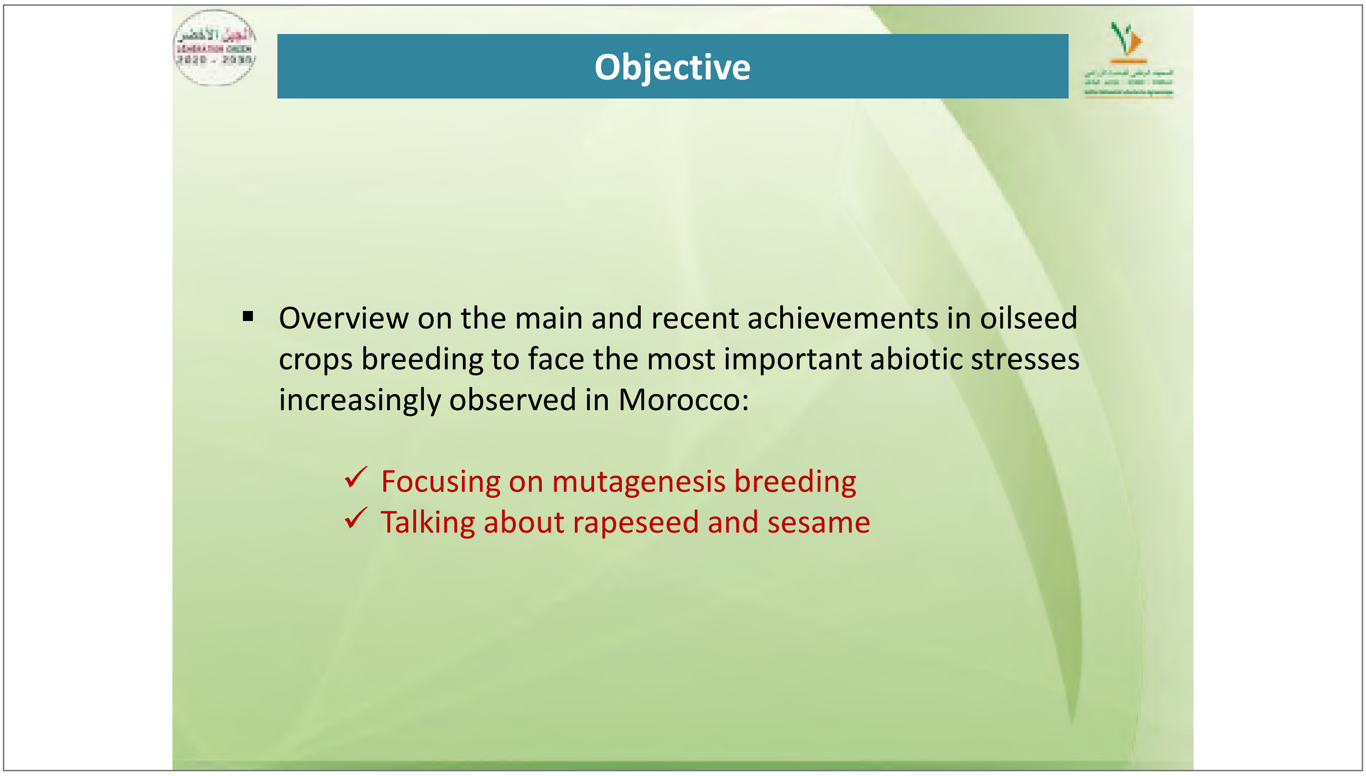
Dr. Abdelghani Nabloussi, National Institute of Agricultural Research (INRA) of Morocco

UPOV/SEM/GE/22/1
Geneva, October 11 and 12, 2022 (virtual meeting)

Introduction

- Morocco is suffering a food security problem in edible oils : Overall national production, including olive and oilseed crops, covers just 20% of the country needs.
- Edible oils from oilseeds (only sunflower 25,000 ha, and rapeseed 10,000 ha) represent only 2%.
- The gap is covered by importation: Negative repercussions on the national economy and food security.
  Annual Cost > 4 billions MAD (400 million USD)
- World bank study: Oilseed production will decrease as a result of climate change effect on agricultural production in Morocco. Rising trend in:
  - Drought;
  - Heat;
  - Flooding


Introduction (Cont.)
Increasing reduction in oilseed crops yield: -10% in 2030 and -30% in 2050 (Gommes et al., 2009).
Abandoning/reducing oilseed crops, as a result of climate change, affects negatively the global cropping system since those crops play an important role in rotation with cereals.
Political will in Morocco to develop oilseed sector to improve the farmers' income and ensure edible oil food security by increasing national oilseed production.
Challenging and facing the increasing abiotic stresses:
- Developing and cultivating tolerant varieties;
- Diversifying oilseed crops (Resilient and alternative).


Objective
Overview on the main and recent achievements in oilseed crops breeding to face the most important abiotic stresses increasingly observed in Morocco:
Focusing on mutagenesis breeding
Talking about rapeseed and sesame

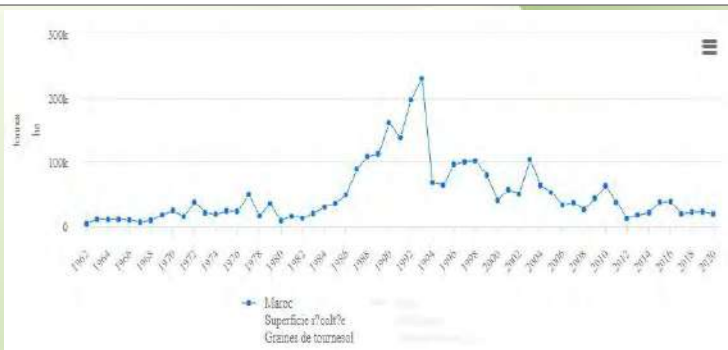
Oilseed crops and climate change in Morocco

Oilseed crops cultivated

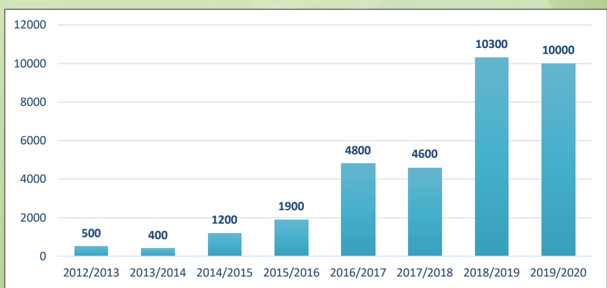
- Before 2000: Sunflower, rapeseed, safflower, soybean (sesame)
- From 2000 – 2012: Sunflower, (sesame)
- From 2013 – Today: Sunflower, rapeseed, (sesame)
  - 2013: Year of the agreement between the government and oilseed sector's Interprofession (FOLEA)

Climate change

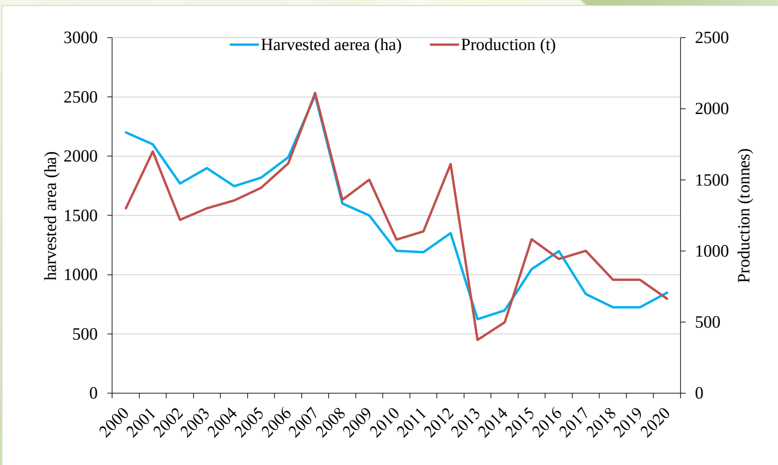
- Importance of drought, as a structural element of the country's climate
- Net reduction in the overall rainfall.
- Increasing heat trend.
- large fluctuation in the amount and frequency of rainfall from year to year and among locations within year.
- Increasing flood trend in some regions.
- Appearance of new pests and diseases.



Evolution of harvested sunflower area during 1962-2020 (FAOSTAT, 2022)



Evolution of harvested rapeseed area after 2013-CP agreement (FAOSTAT, 2022)



Evolution of sesame harvested area and production during 2000-2020 (FAOSTAT, 2022)

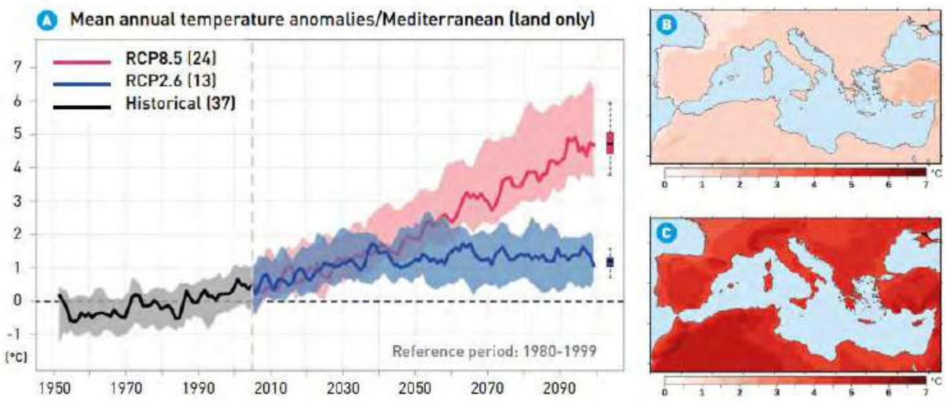


Figure SPM.2 | Projected warming in the Mediterranean Basin over land. Projected changes in annual temperature relative to the recent past reference period (1980-1999), based on the EURO-CORDEX 0.11° ensemble mean, A: simulations for pathways RCP2.6 and RCP8.5, B: warming at the end of the 21st century (2080-2099) for RCP2.6, C: idem for RCP8.5

MedECC 2020 Summary for Policymakers. In: Climate and Environmental Change in the Mediterranean Basin – Current Situation and Risks for the Future. First Mediterranean Assessment Report [Cramer W, Guiot J, Marini K (eds.)] Union for the Mediterranean, Plan Bleu, UNEP/MAP, Marseille, France, pp 11-40.

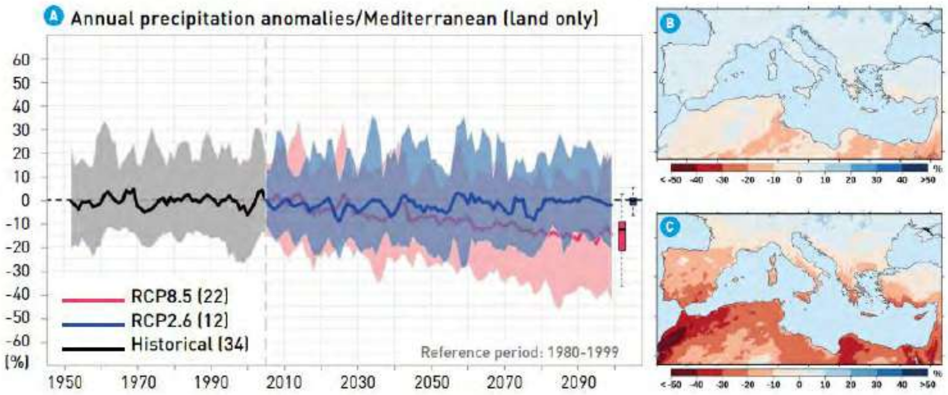


Figure SPM.3 | Projected rainfall change in the Mediterranean Basin. Projected changes in annual rainfall relative to the recent past reference period (1980-1999), based on the EURO-CORDEX 0.11° ensemble mean, A: simulations for pathways RCP2.6 and RCP8.5, B: rainfall anomalies at the end of the 21st century (2080-2099) for RCP2.6, C: idem for RCP8.5.

MedECC 2020 Summary for Policymakers. In: Climate and Environmental Change in the Mediterranean Basin – Current Situation and Risks for the Future. First Mediterranean Assessment Report [Cramer W, Guiot J, Marini K (eds.)] Union for the Mediterranean, Plan Bleu, UNEP/MAP, Marseille, France, pp 11-40.

Breeding strategy to face changing climatic conditions

- Introductions
- Intra & interspecific hybridizations
- Mutagenesis

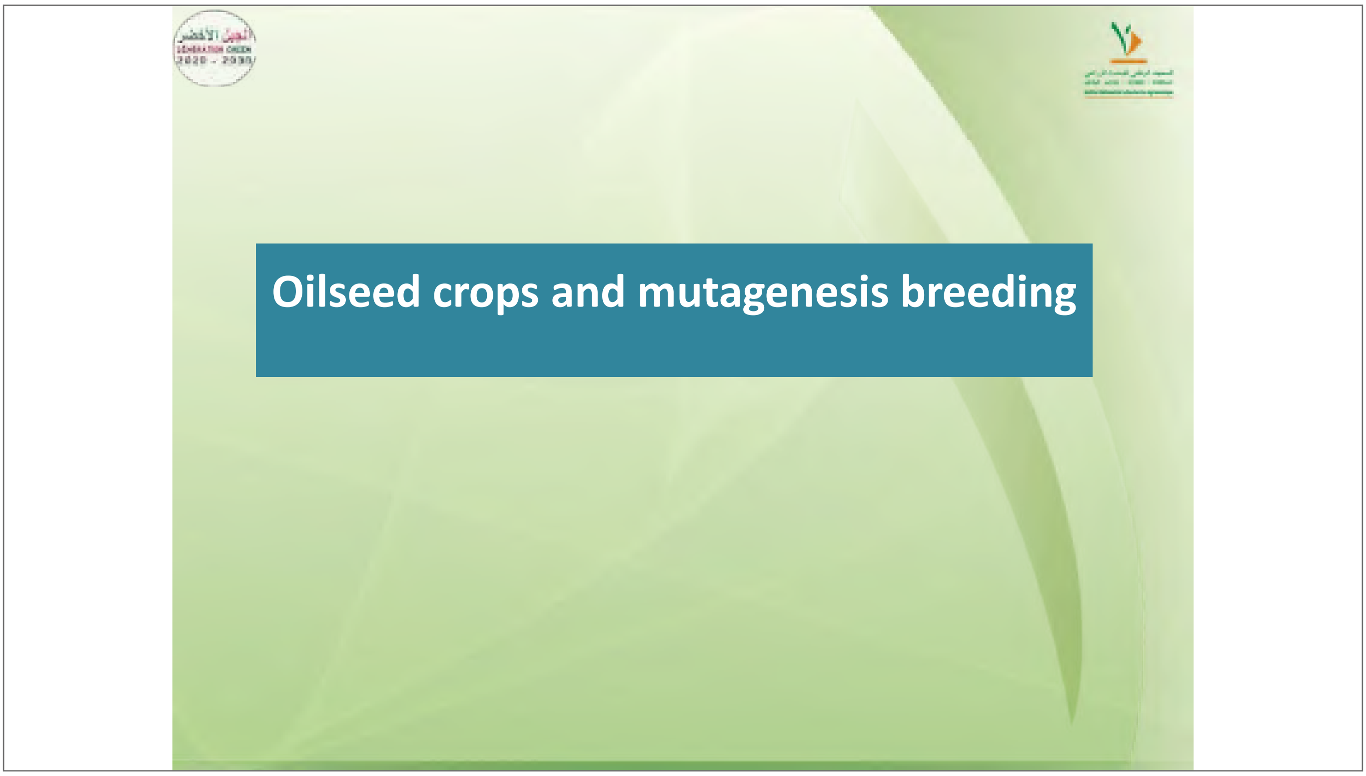
Germplasm enhancement

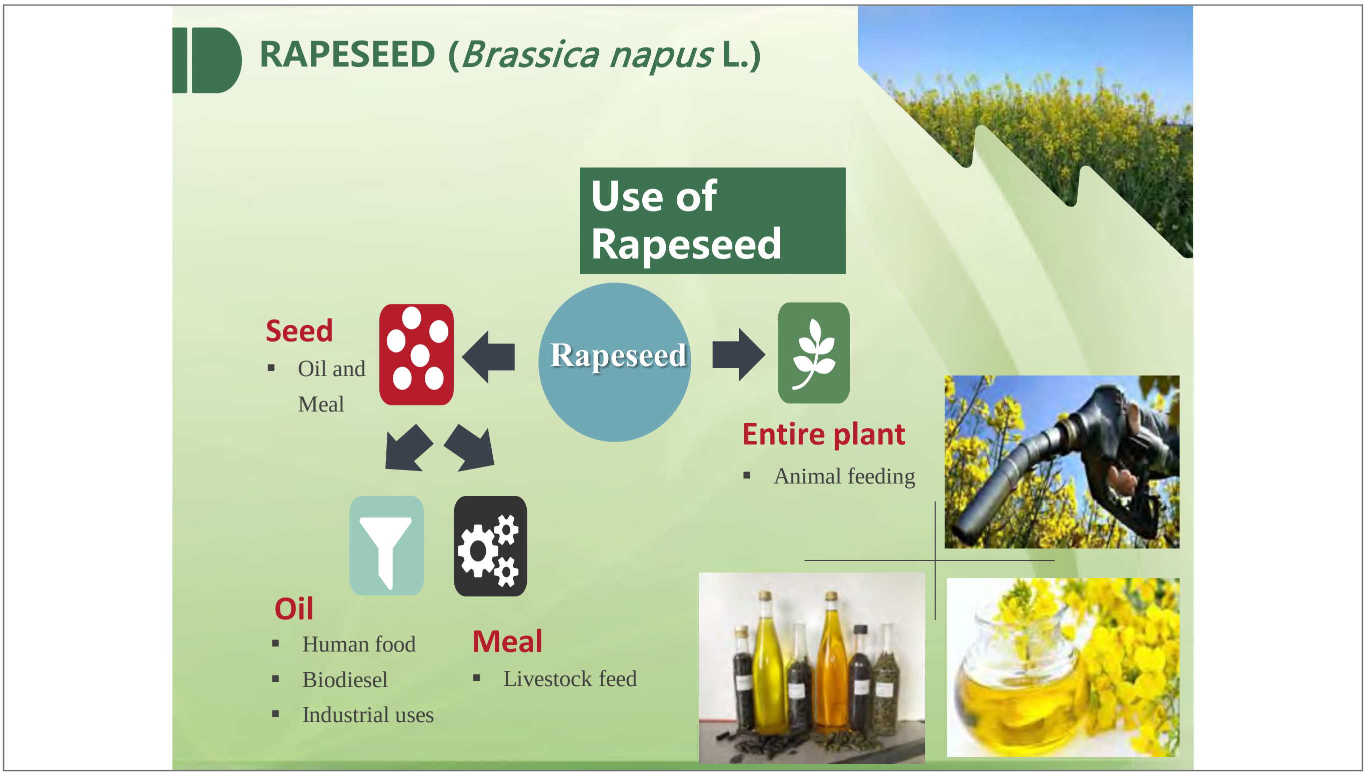
Characterization and evaluation under stressed conditions

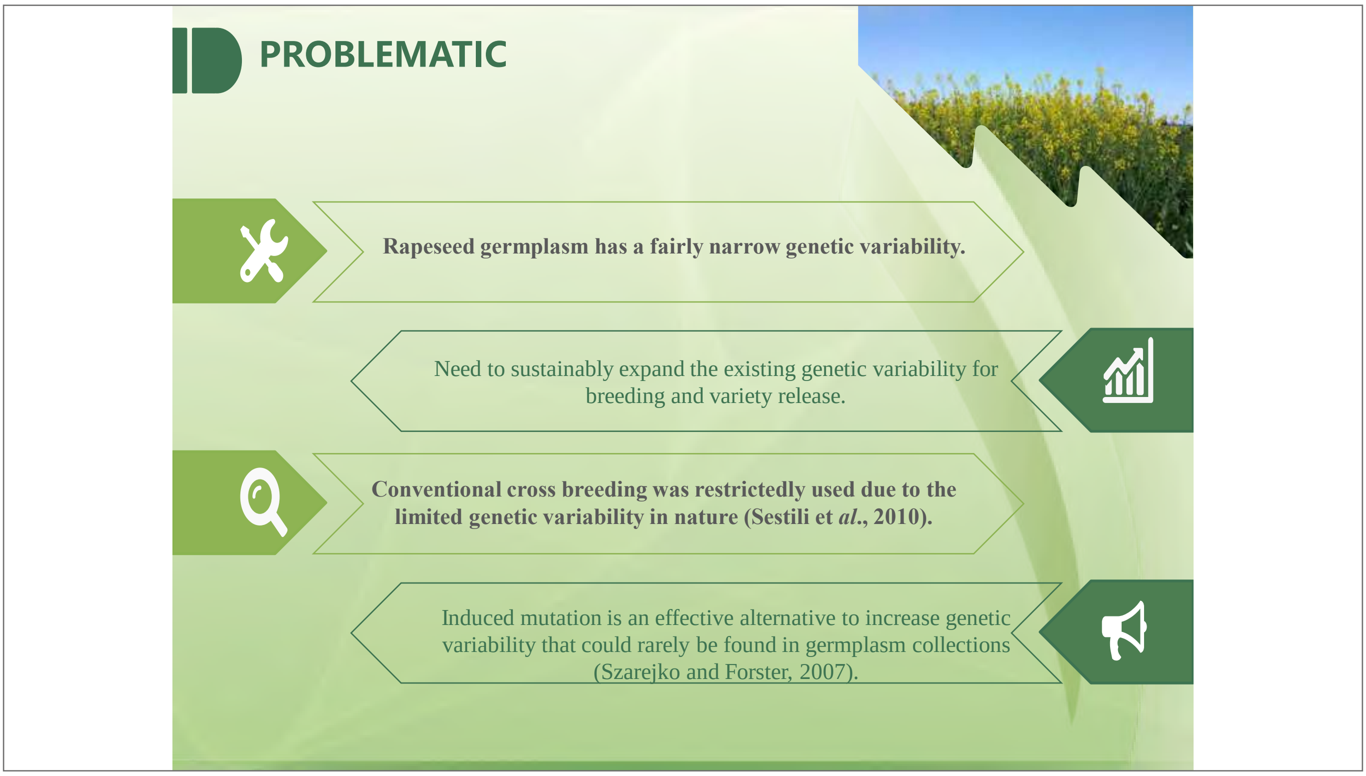
- Different growth/development stages
- Multi-traits phenotyping
- Selection indices definition

- Tolerance to stresses (Selection indices)
- Stability
- High yielding

Selection of productive and adapted lines


Oilseed crops and mutagenesis breeding


RAPESEED (*Brassica napus* L.)
Use of Rapeseed
Rapeseed
Seed
Oil and Meal
Entire plant
Animal feeding
Oil
Human food
Biodiesel
Industrial uses
Meal
Livestock feed



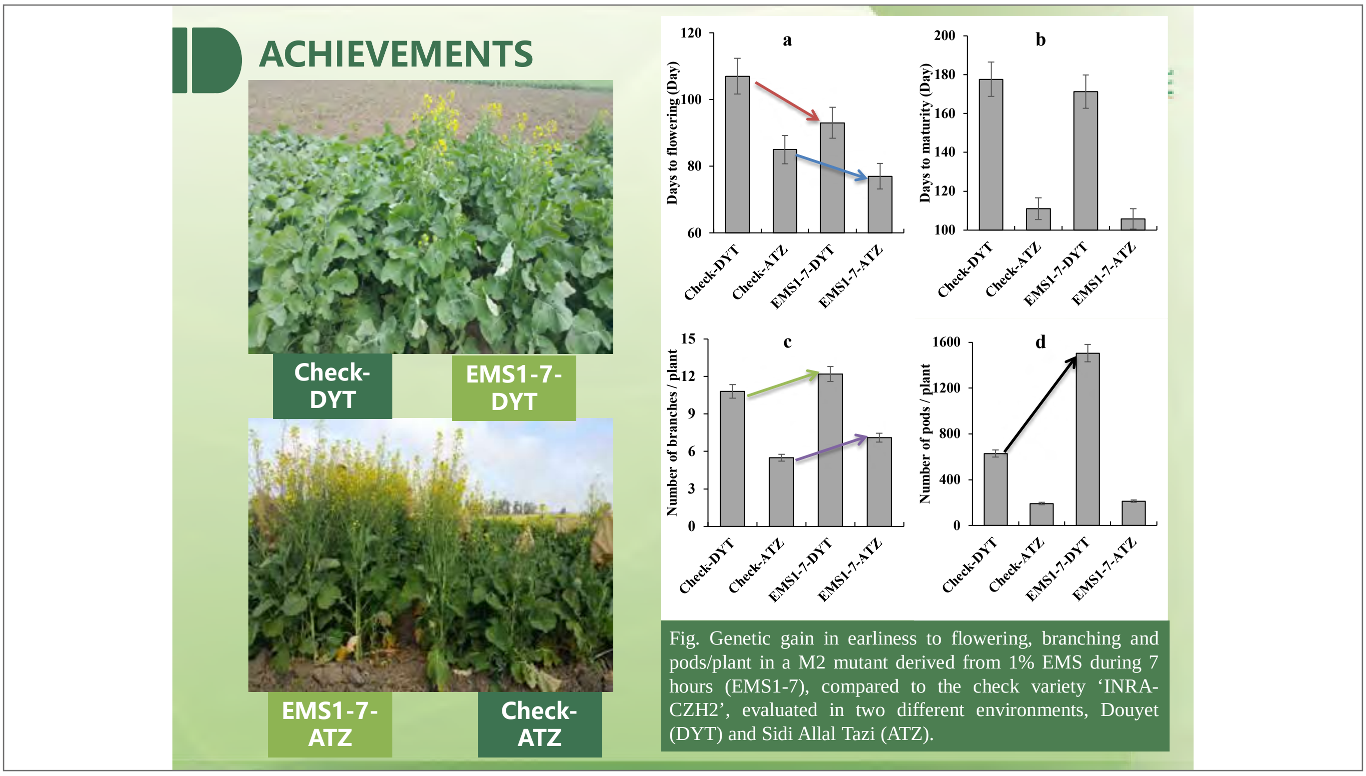


Fig. Genetic gain in earliness to flowering, branching and pods/plant in a M2 mutant derived from 1% EMS during 7 hours (EMS1-7), compared to the check variety ‘INRA-CZH2’, evaluated in two different environments, Douyet (DYT) and Sidi Allal Tazi (ATZ).

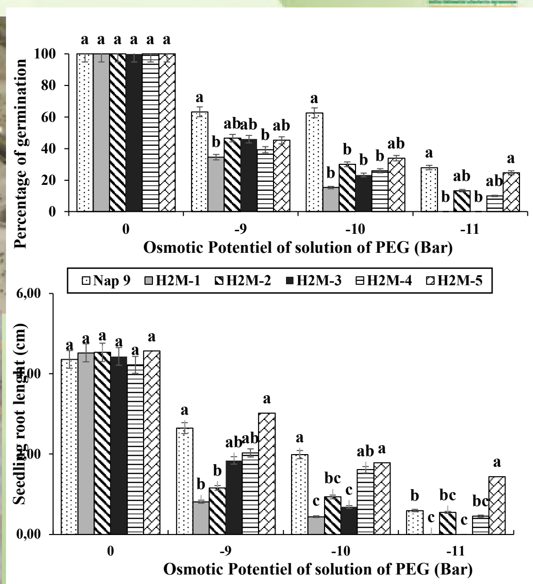
ACHIEVEMENTS

Compared to the check or wild-type material (INRA-CZH2), the mutant H2M-5:

- flowered and matured earlier,
- had higher number of pods per plant in different environments,
- showed higher level of adaptation to stressful conditions associated with low rainfall, high temperature and late planting.

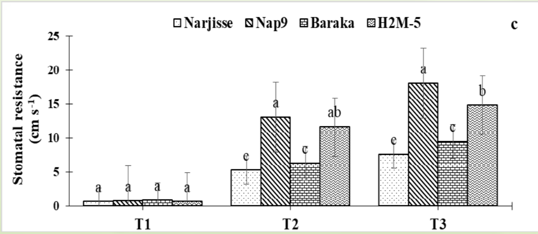
Channaoui et al., 2019a, Pak. J. Botany.

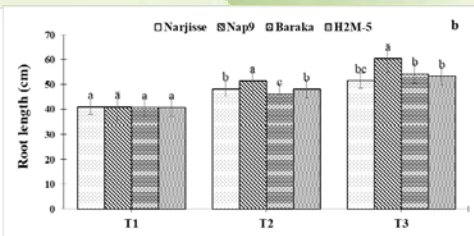
ACHIEVEMENTS



Reaction of rapeseed genotypes (mutants) to various levels of drought during germination and early seedling growth
Channaoui et al., 2019b, OCL.

ACHIEVEMENTS





T	G	NBP	NPP	AB (g)	NSP	TSW (g)	SY (g)	HI	OC
T1	Narjisse	9 b	431 b	162.64 ab	14 bc	2.30 b	12.37 b	0.33 b	40.80 a
	Nap9	10 a	486 a	151.65 b	18 a	3.88 a	20.86 a	0.64 a	40.48 a
	Baraka	8 b	411 b	179.31 a	16 b	2.60 b	13.90 b	0.39 b	41.74 a
	H2M-5	7 c	404 b	129.51 b	15 b	2.74 b	12.58 b	0.34 b	39.10 a
T2	Narjisse	7 b	324 b	107.45 b	12 bc	1.70 c	11.43 b	0.55 b	37.54 b
	Nap9	8 a	355 a	106.27 b	16 a	3.17 a	15.86 a	0.78 a	40.31 a
	Baraka	6 c	277 b	125.29 a	14 b	2.50 ab	11.51 b	0.32 c	40.07 a
	H2M-5	6 c	344 b	105.88 b	13 b	2.20 b	11.65 b	0.43 bc	38.36 b
T3	Narjisse	6 a	198 b	83.47 ab	11 bc	1.36 b	7.20 c	0.54 a	36.28 b
	Nap9	6 a	190 a	74.90 b	16 a	2.02 a	12.45 a	0.79 a	40.26 a
	Baraka	5 b	207 a	99.49 a	13 b	1.81 ab	8.63 b	0.24 b	39.14 a
	H2M-5	5 b	215 a	79.76 ab	12 b	1.78 ab	8.48 b	0.47 a	36.44 b

Saghouri Idrissi et al., 2022, J. Crop Improv. (Under review)

ACHIEVEMENTS

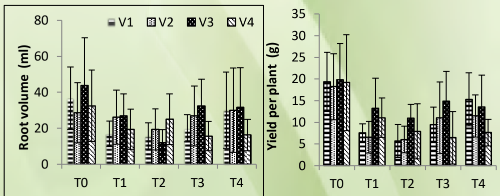
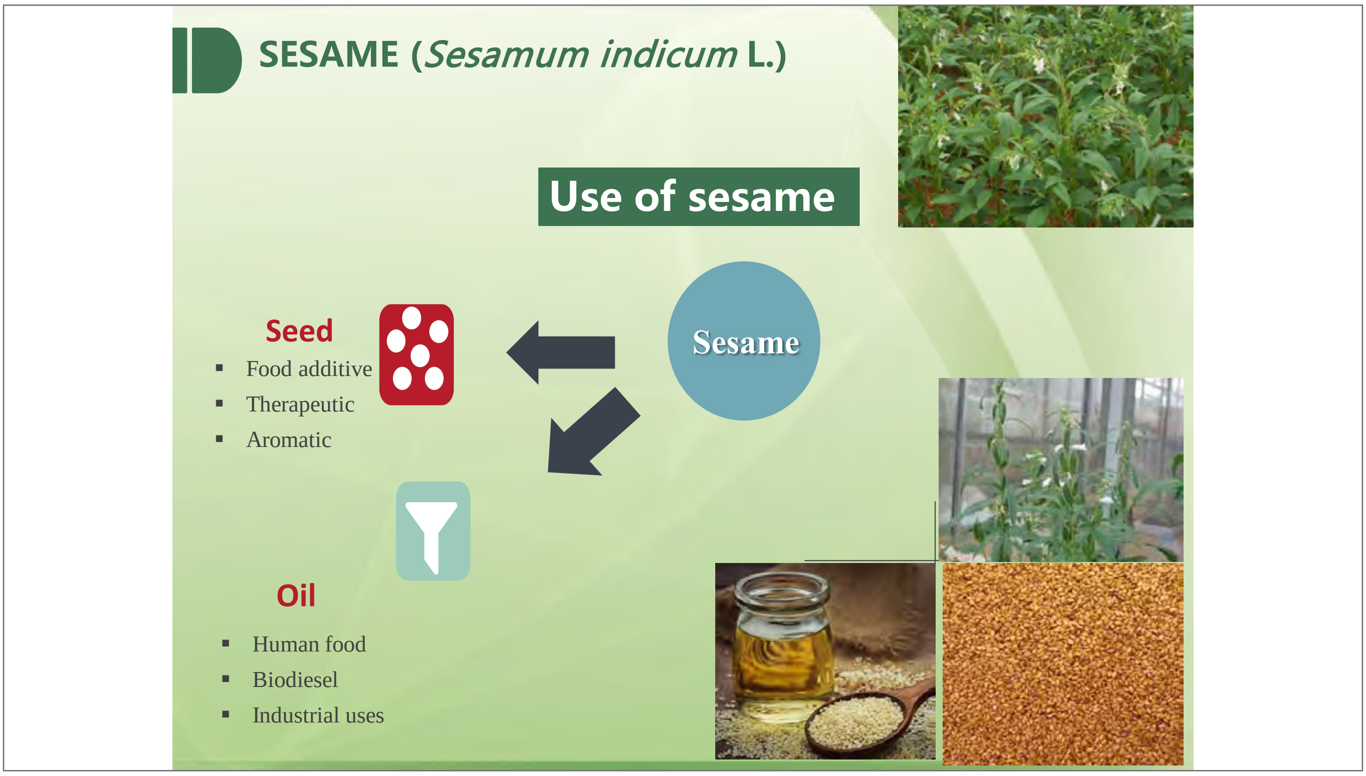
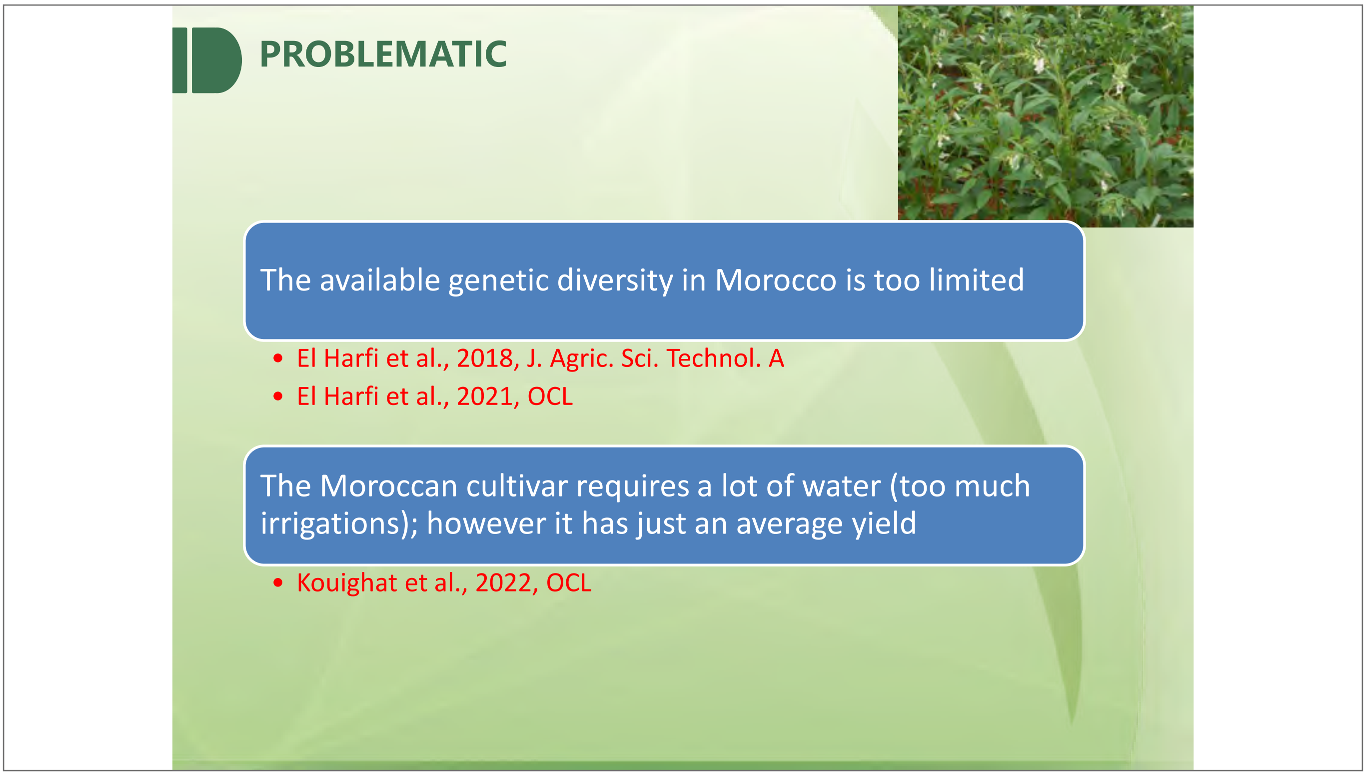
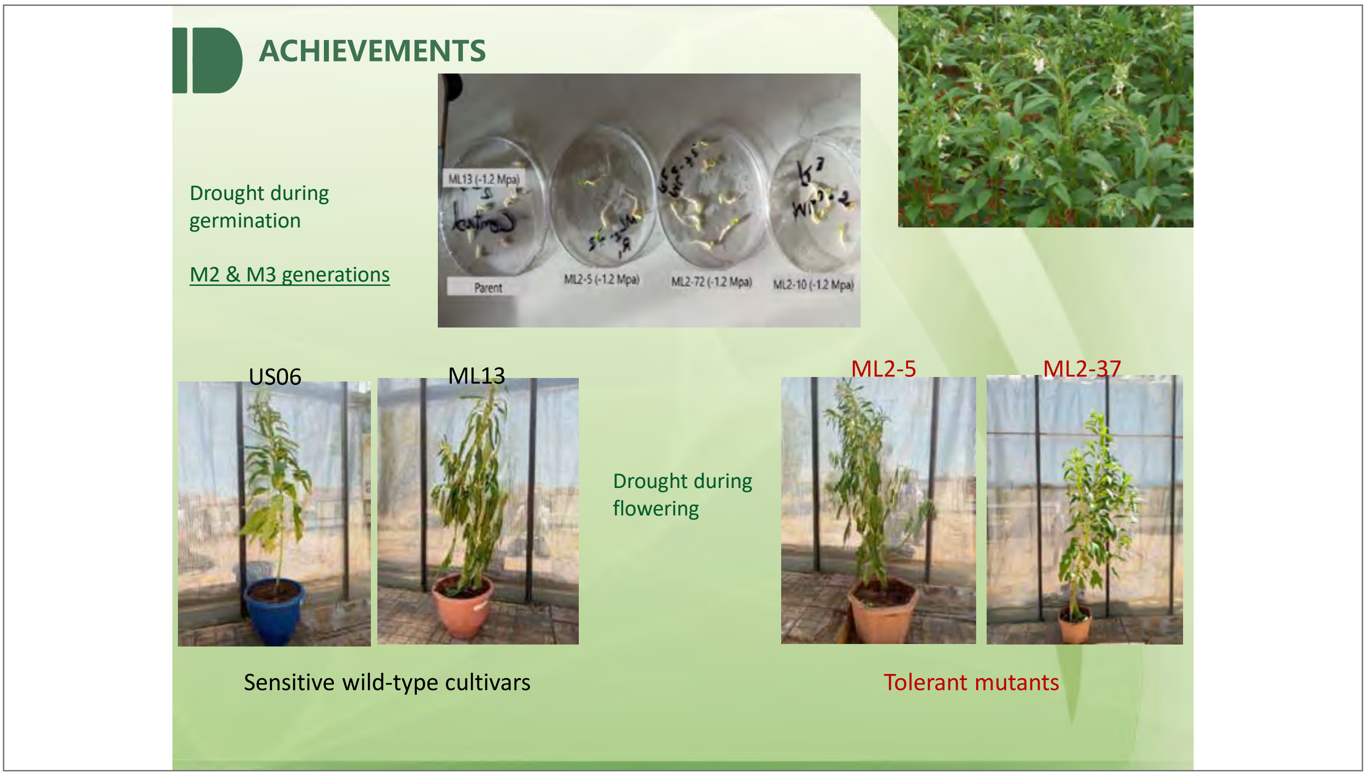


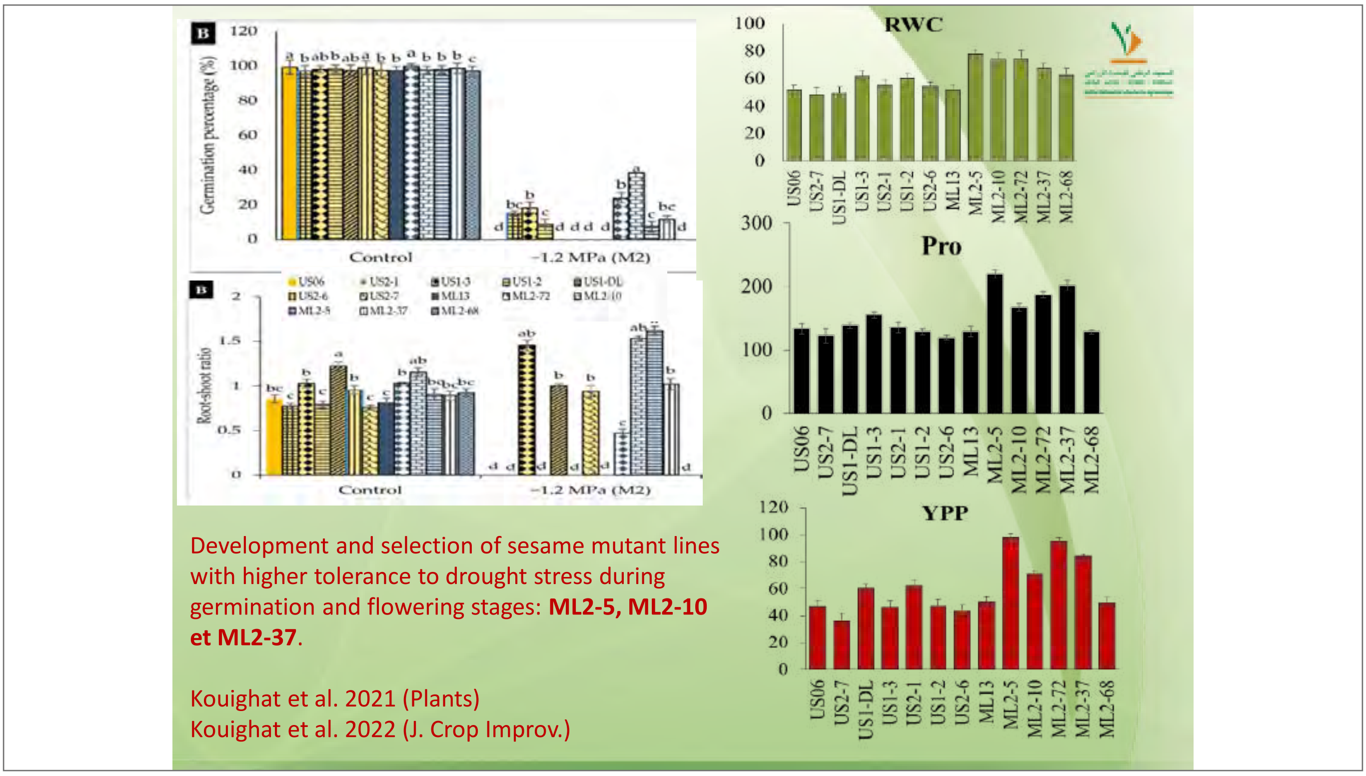
Fig. Average treatment performance for each variety for root volume and seed yield per plant. (V1=Narjisse, V2=INRA-CZH2, V3=INRA-CZH3, V4=Lila), (T0=Absence of waterlogging, T1=Waterlogging during germination, T2=Waterlogging during post-emergence seedling stage, T3=Waterlogging during rosette stage, T4=Waterlogging during floral bud stage)

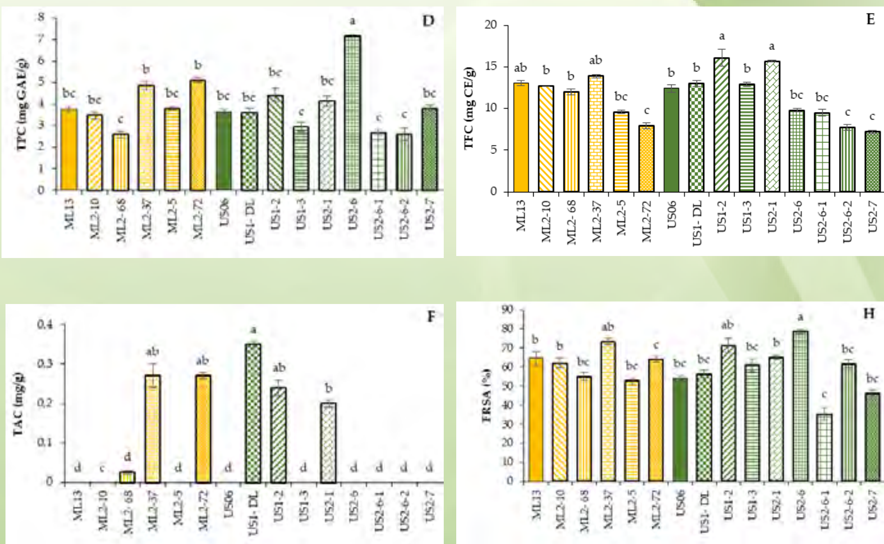
Nabloussi et al., 2019, OCL


SESAME (*Sesamum indicum* L.)
Use of sesame
Sesame
Seed
Food additive
Therapeutic
Aromatic
Oil
Human food
Biodiesel
Industrial uses


PROBLEMATIC
The available genetic diversity in Morocco is too limited
El Harfi et al., 2018, J. Agric. Sci. Technol. A
El Harfi et al., 2021, OCL
The Moroccan cultivar requires a lot of water (too much irrigations); however it has just an average yield
Kouighat et al., 2022, OCL


ACHIEVEMENTS
Drought during germination
M2 & M3 generations
ML13 (-1.2 Mpa)
Parent
ML2-5 (-1.2 Mpa)
ML2-72 (-1.2 Mpa)
ML2-10 (-1.2 Mpa)
US06
ML13
Drought during flowering
ML2-5
ML2-37
Sensitive wild-type cultivars
Tolerant mutants


Germination percentage (%)
Control
-1.2 MPa (M2)
US06
US2-1
US1-3
US1-2
US1-DL
US2-6
US2-7
ML13
ML2-72
ML2-10
ML2-5
ML2-37
ML2-68
Root-shoot ratio
RWC
Pro
YPP
Development and selection of sesame mutant lines with higher tolerance to drought stress during germination and flowering stages: **ML2-5, ML2-10 et ML2-37**.
Kouighat et al. 2021 (Plants)
Kouighat et al. 2022 (J. Crop Improv.)



In addition, mutant lines with genetic gain in terms of nutritional quality traits were identified and selected.

Kouighat et al. 2022 (Plants).

Conclusions and prospects

- **In Morocco: Decline in sunflower and sesame cultivation vs. Increase in rapeseed cultivation were observed in the last decade.**
- **In the future: Rising temperature trend vs. Downward trend in precipitation: All sub-regions of the Mediterranean Basin, including Morocco, are increasingly impacted and threatened by climate change (CC).**
- **Need to develop and implement a global strategy to cope with CC.**
- **Integrated breeding strategy: Introductions (including novel resilient and alternative oilseed crops), intra & interspecific hybridizations, mutagenesis.**

Conclusions and prospects

- Mutagenesis breeding effectively used in rapeseed and sesame: Novel and promising germplasms tolerant to severe drought during germination and flowering stages.
- Usefulness of these germplasms to develop and release drought-tolerant and high-yielding varieties of rapeseed and sesame.
- Need to work also on heat and develop tolerant germplasm.
- Evaluation, monitoring and selection of high-performing and adapted lines under stressed field conditions for many years.
- TILLING and CRISPR Techniques towards genomic selection.

Thank you

CONNECTING DIFFERENT RESEARCH CLUSTERS WITH THE AIM TO DEVELOP MORE ACCURATE BREEDING

Mr. Muath Alsheikh
Head of Research and Development, Graminor AS, Norway

My name is Muath Alsheikh. I am the Head of Research and Development, in the Norwegian plant breeding company in Norway, Graminor. Today I will briefly present how research clusters can contribute to the development of plant breeding in the face of the future climate.

Several speakers before me stressed the importance of plant breeding and its contribution to sustainable nationally and international food security.

In the Figure 1, you see the main step of the plant breeding process; starting from the crossing of favorite varieties or breeding lines, followed by several years of evaluation and selection.

The evaluation and selection steps are time consuming and require substantial investment. It can take between ten to twenty years depending on the specie.

Another important step in plant breeding is pre-breeding. Pre-breeding is the step where plant breeders introduce new source of genetic to their breeding program. Each of breeding steps have its own challenges. Here, and as I see it, three main challenges:

(I) genomic challenges: mainly genomic complexity in the plant comparing to animals (e.g., polyploidy, genome size);

(II) genetics by environment interaction; and

(III) breeding for multi-traits.

I addition to the genomic complexity is the commercial complexity and the cost associated with breeding specially for high labor cost countries such as Norway. Therefore, plant breeders always seek for new methods and technologies to increase their selection accuracy, mainly with relatively low cost.

In general, enabling technologies is very important for plant breeding, especially high throughput technologies.

In Figure 2 shows two main technologies that are in focus in many breeding programs inlcuidng Graminor; the phenomics based technologies such as sensor technologies, and imaging technologies, and the molecular based or genomic based technologies such as molecular assisted breeding and genomic selection. Please keep in mind that these technologies need to be combined with visual selection to maximize outcomes.

These technologies require different types of competencies (e.g., and among many others: IT, and programing, statistic and modeling). It is unlikely that one company has competent in all technologies under one roof. Therefore, collaborative and multidisciplinary approaches (e.g., clusters) are the most effective way to go forward in plant breeding development.

Figure 3 presents two examples of such a collaboration, the Nordic Public-Private Partnership for Pre-breeding, and the National Norwegian Cluster for Climate (Climate Future)

I will briefly go through them. PPP for Pre-breeding: It’s a Nordic collaboration between practical plant breeding and breeding research. This initiative started in 2012 and is still running as today. The funding is 50/50 between the plant breeding entities and the Nordic governments. The initiative is coordinated by NordGen in Sweden.

The main goals of this collaboration are:

(I) to strengthen plant breeding in Nordic countries;

(II) to promote the use of genetic resources in plant breeding;

(III) development of efficient tools and methods such as phenomics and genomic tools;

(IV) networking.

Since 2012, we had seven projects that covered several crops in cereal, foraging crops, and or fruits and berries. Four projects have finished in 2020and three projects currently running in wheat, potato and in high throughput phenomics.

From this collaboration, we have obtained extensive knowledge and competence between the Nordic countries. We built a strong pre-competitive collaboration (network) and developed breeding tools that are currently used in all Nordic breeding programs.

The second collaboration is our National Climate Futures project. Climate Futures is a center for research-based innovation project. It is funded by the Norwegian Research Council, started in 2020 and will run for 8 years, with a value a budget of more than 15 million euros. Thirty partners are involved in this initiative including agriculture, oil industry shipment industry, etc. They all are interested in climate.

The idea of this initiative is to develop solutions for managing climate risk for short-term, mid and long term.

For plant breeding, the idea is to integrate and predict GxE in plant breeding via genomic and phenomics models.

Another breeding research here is to predict the performance of different varieties in different environments so to reduce the number of trial. Also, in this project we are aiming to identify current locations that represent future climate to evaluate the performance of varieties and future crossing.

Presentation made at the Seminar

Connecting different research clusters with the aim to develop more accurate breeding

Muath Alsheikh, PhD, MBA
Head of Research and Development/Breeder
muath.alsheikh@graminor.no
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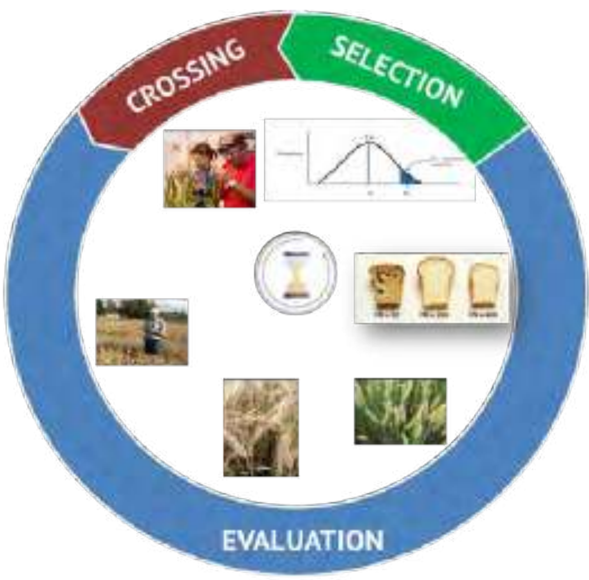
www.graminor.no

Graminor

Plant breeding

- ✓ Plant breeding is one of the most sustainable way to improve food security
- ✓ Breeding main steps are – (pre-breeding) crossings, evaluation and selection
- ✓ It takes between 10-20 years to produce a new improve cultivar.
- ✓ Challenges: genome complexity, multi-trait, G x E
- ✓ Plant breeders all the time seek for methods that can increase their selection efficiency and accuracy at low cost



Graminor

__Figure 1:__ Standard plant breeding process

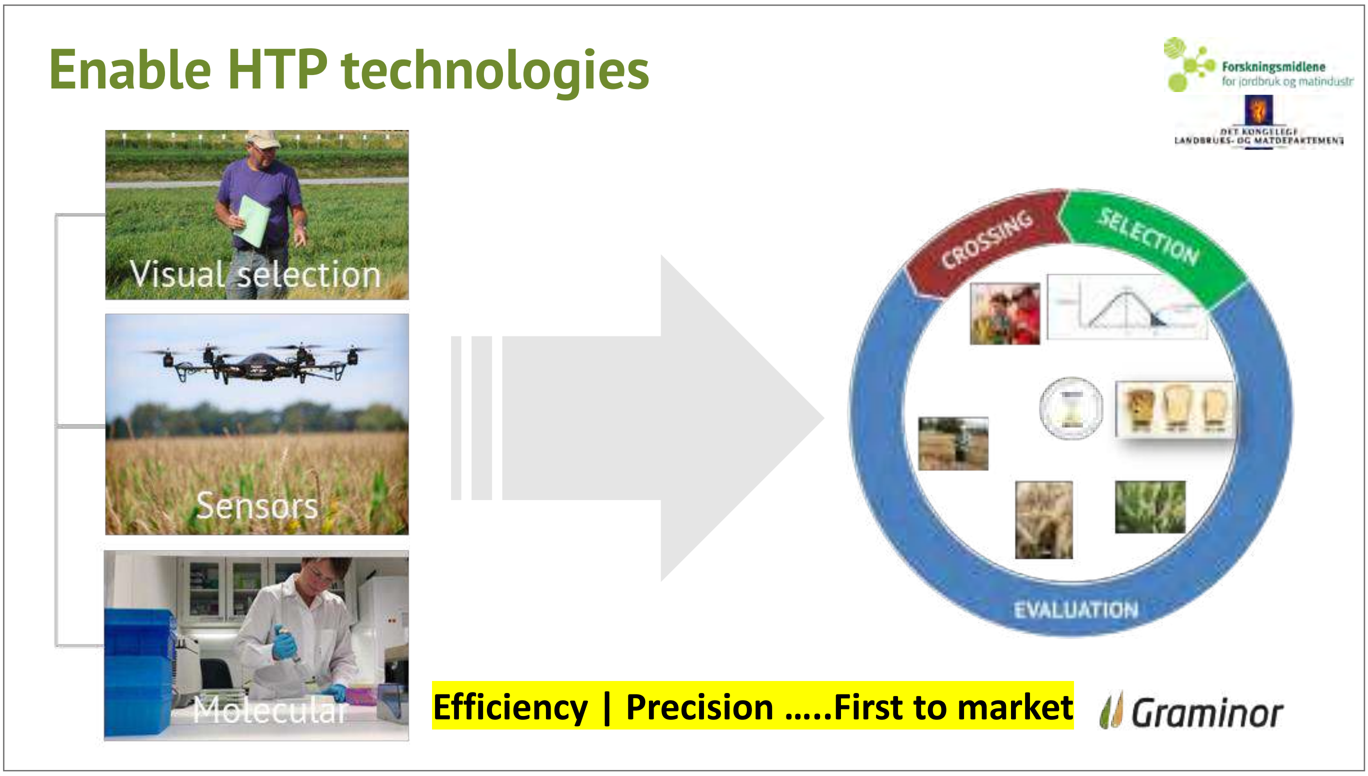


Figure 2: *HTP Technologies*

Figure 3: *Example collaboration in Nordic Public Private Partnerships for Pre-breeding (PPP)*


sfi
Centre for Research-based Innovation
NORCE
The Research Council of Norway
Forskningsmidlene for jordbruk og matindustri
climatefutures
Navigating Climate Risk
Graminor


NORGES BONDELAG
COLLABORATIVE R&D PROJECTS
gartnerhallen
RESILIENT SOCIETIES
Norsk Landbruksrådgiving
Graminor
SUSTAINABLE FOOD PRODUCTION
klp
Rogaland fylkeskommune
Vestland fylkeskommune
HUB
VIKEN FYLKESKOMMUNE
Statsforvalteren.no
Develop solutions for managing climate risk on time horizons from 10 days to 10 years (and more) into the future
HAVFORSKNINGSINSTITUTTET
Searis
EIDE FJORDBRUK
NORCE
NR Norsk Regnesentral
NHH
NERSC
Norwegian Meteorological Institute
Graminor

Breeding, environment and market

Graminor

Climate Future: Breeding goals

- Short, medium and long-term climate prediction
- Prediction of variety performance (+offspring) in different environments (short-medium-long terms) – based on current and historical information.
- Identify current locations that represent future medium- and long-term climate
- Potential new crops for Nordic market

Graminor

Thank you!

Graminor

ADVANCES IN THE DEVELOPMENT OF NEW VARIETIES BETTER ADAPTED TO CLIMATE CHANGE IN CROPS AND FORAGES: A SOUTH AMERICAN PERSPECTIVE

Dr. Fernando Ortega Klose
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INTRODUCTION

Chile is a very long country located in the south of America with diverse climate conditions along and across the country. With more than 4,000 km from north to south and a width ranging from 90 to 445 km from the ocean to the peaks of the Andes, the country has really contrasting environments for agricultural activities. These particular conditions represent an opportunity to complement economic agricultural activities within the country and to export seed (off-season seed production) and fruits to the world. The country also offers remarkable sanitary conditions for agriculture due to the natural “isolation barriers” offered by the Andes range, the Pacific Ocean, the desert in the north and the Patagonia in the south.

The area covered by agriculture in Chile (less than 2 million ha) is reduced compared to the national continental territory (c. 75 million ha). The reduced area and diverse environments are a challenge for professionals and researchers who need to optimize production systems adapted to each condition, especially for plant breeders. The limited arable land and the many different environments for agriculture reduce the size of the market for each plant variety, and national plant breeding programs need to be properly planned according to this limitation. Another challenge for plant breeding is climate change, which will be analyzed later.

The Institute of Agricultural Research of Chile, INIA-Chile, is the main R&D organization in the country, belonging to the Ministry of Agriculture. INIA-Chile was established in 1964, and has national coverage with regional and experimental centers throughout the country (Figure 1).

CLIMATE CHANGE

Climate change models suggest different effects along and across the country, but in general the predicted main effects forecast is an average temperature increase of 2–4°C by the end of the century, a reduction of the snow in the Andes, a decrease in precipitation in most of the country and a reduction in the water available for irrigation (Figure 2). Higher temperatures, less rainfall and less water available for irrigation introduce the need to work in R&D for adaptation and mitigation for these conditions.

Examples of the tendency of reduction in annual precipitation in the last 55 years for one locality of the south of Chile is presented in Figure 3. In this location, the average annual precipitation of the last 10 years (2012–2021) has been 18% lower than the historic average. Furthermore, the precipitation during the main growing season (October to March) between 2012/13 and 2021/22 has been reduced from the historic 332 mm to 253 mm, meaning a decrease of 24% (Figure 4). The shortage of water to crops gets more serious because of the reduction of water available for irrigation in the last years. Perhaps as important as the water available for crops are the temperatures – and not just average ones should be considered; even more important than the average are maximum and minimum absolute temperatures per day that affect considerably the adaptation of species and varieties. In this respect, Figure 5 shows the number of days during the main growing season (October to March) with maximum temperatures above 27°C for Carillanca Research Center. From the *season* 2011/12 onwards on average there was an increase of 22% in this parameter (Figure 5). This aspect will be discussed later in respect of the adaptation of forage grasses.

PLANT BREEDING AT INIA-CHILE

Climate change introduces “environmental” pressure (biotic and abiotic factors) to plant growth and production. Additionally, each day the consumer demands better and differentiated quality products and there is a need to produce in a more sustainable way. That is why worldwide, and in Chile, the development of new genetic combinations is a high priority.

Plant genetic improvement has historically been a strategic guideline of INIA. In fact, it was an important activity of the Ministry of Agriculture even before 1964 and it was reinforced with the founding of the institution; INIA’s plant breeding programs started from the beginning of the institution and they have been its main R&D topic and the main contribution to the agricultural sector. Plant breeding was strengthened with the creation of the genetic resources program (1985) and the building of gene banks (1990), structuring a plant germplasm bank network. Also, in the early 1990s, INIA started the biotechnology program, focusing on various areas, considering both the development of tools, analytical platforms and products, always supported by the understanding of biological processes and how they can be used to face various problems and provide suitable solutions. Some areas of biotech development at INIA to support plant breeding programs (PBPs) have been molecular mark selection (e.g., quality in wheat, seedlessness in table grape, fungi and virus resistance in potato), identification of “genetic architecture” of complex traits, genetic transformation for disease resistance and abiotic stress (salt and drought), gene editing and so on.

In the last four decades, the productive systems of Chile have undergone important changes, evidencing a considerable increase in average yields and industrial quality, not a minor issue considering that 50% of the advances achieved in yield are usually attributed to genetic improvement (Figure 6). It is important to mention that, in the last season, rice yield decreased considerably, mainly due to low temperature at flowering time, late sowing date because of weather conditions and also because of the reduction of water available for irrigation.

Most of the varieties with proprietary registration in Chile have been developed abroad (nearly 90%, Table 1). This proportion is higher in fruit crops and ornamentals, and lower in field crops. Also, it is important to state that the agronomic evaluation in Chile is not a legal requirement for commercialization. Both aspects are important for variety adaptation because it is well known that there is genotype x environment interaction, especially in a scenario of climate change. INIA-Chile is an important player in plant breeding (43% of the national varieties in 2022) with emphasis in field crops (62%) and forages (100%).

Figure 7 shows the number of INIA’s varieties registered today by species or group of species. The varieties generated by INIA occupy a good part of the cultivated area; as an example, the approximate percentage of the national surface that uses INIA varieties is: rice (100%), triticale (90%), oat (95%), durum wheat (95%), bread wheat (60%), sweet lupine (40%), bitter lupine (30%), common bean (80%) and potato (40%).

INIA currently maintains 13 PBPs in different species or groups of species (table grapes, cherry trees, apple trees, wheat, triticale, rice, oats, quinoa, beans, sweet and bitter lupine, potato and forages). These PBPs are strongly linked to the private sector (agroindustry, consortia, seed companies), international centers and farmer organizations, playing a fundamental role in the productive chain for the national and export markets. In its history, INIA has generated more than 260 cultivars of different plant species, contributing considerably to agricultural development.

The PBPs of INIA Chile began to visualize climate change/abiotic stress with more emphasis around 10–15 years ago. Some programs are beginning to consider selection for abiotic stress at an early stage and most of them consider this at the end when the decision is taken for the varieties to go to the market. An interesting example in fruit crops is the sweet cherry breeding program where part of the crosses and selection are done to reduce winter cold requirements; this is with the purpose of producing cherries in new areas with milder winters and also because of the climate change.

In cereals, an example is the rice breeding program (japonica type); the area for rice production in Chile is the southernmost in the world and low temperatures at establishment and flowering time are frequent. Also, rice crop in Chile is traditionally produced under flooded conditions, meaning a high-water footprint. INIA’s rice breeding considers the adaptation to lower temperatures and reduced irrigation.

In potatoes, tuber yield is highly related to available water; when rainfed and irrigated conditions are compared, depending on the rainfall during the crop development, an average reduction between 10% and 35% occurs in the south of Chile (Figure 8; Martínez *et al.* 2021). New varieties have been released (Porvenir and Yaike) with high yield potential both under irrigation and rainfed conditions (Figure 9; Martínez *et al.* 2021).

In the area of forages, INIA developed varieties of alfalfa and annual medics two to three decades ago, but those varieties were not important in the market. Traditionally, the only species with INIA's varieties in the national and export market have been red clover and more recently bromegrass (*Bromus valdivianus*) for the Chilean market. Besides these two species, a new breeding program in perennial ryegrass is in its early stages, and genetic studies in alfalfa are also conducted.

In red clover, INIA has developed three varieties, Quiñequeli-INIA, Redqueli-INIA and Superqueli-INIA, released in 1962, 1997 and 2011, respectively. Figure 10 shows the improvement in forage yield according to the variety in two environments in the same site over four seasons (irrigated) and three years (rainfed). This improvement is mainly due to the better survival of plants of the newest variety and general adaptation to the environment. Further studies regarding the response to water availability have been conducted in the last years, demonstrating significant differences between experimental lines in the water use efficiency (Figure 11).

Bromegrass is a native genus to the south cone of South America. *Bromus valdivianus* (Syn. *Bromus stamineu*s) is an interesting species in the south of Chile because of its persistence as a pasture, high capacity to produce forage in different environments and good animal performance under grazing. Regarding climate change, the species shows better growth during the dry season and can tolerate higher temperatures in the summer compared to perennial ryegrass. INIA began to work with Bromus by 1994 and after 14 years released the first national varieties of the species (Bronco-INIA and Bromino-INIA). Figure 12 shows a summary of the forage production during three seasons in rainfed and irrigated conditions, comparing Bronco-INIA bromegrass and Nui perennial ryegrass. In spite of the irrigation, perennial ryegrass could not grow properly during the summer and this is due to the occurrence of days with maximum temperatures above 27°C (Figure 5), a condition that triggers the "dormancy" of ryegrass and, to a lesser degree, bromegrass. Bromegrass yielded on average of three growing seasons, 235% more than the perennial ryegrass in the summer in rainfed conditions and 207% with irrigation (Figure 12). Also, from the second season onwards the total yield per season was higher in bromegrass compared to perennial ryegrass, demonstrating the importance of national breeding, especially valuating the work with native species and its domestication.

FINAL REMARKS

Plant breeding is essential for adaptation to climate change. For this purpose, it is fundamental to strengthen national breeding programs for local adaptation. Even with the advent of new techniques, "breeding time" requires a medium- to long-term vision and budget.

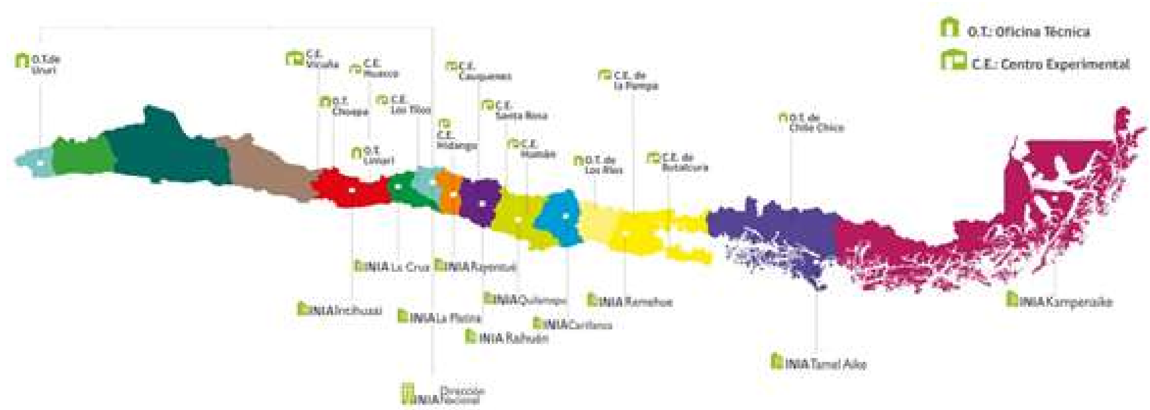

Figure 1. *National coverage of research dependencies of the Institute of Agricultural Research of Chile, INIA-Chile.*

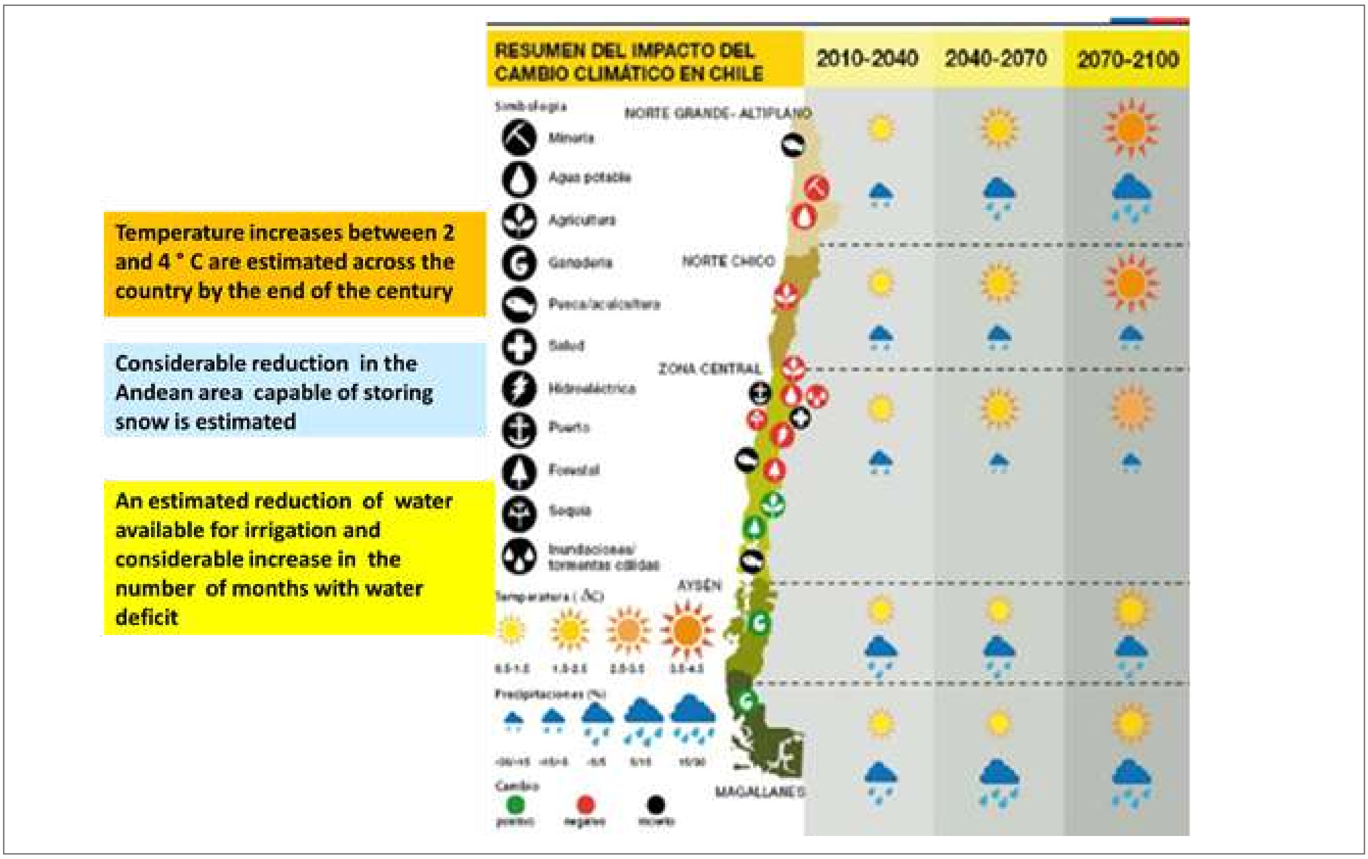

Figure 2. *Predicted climate change in Chile for this century.*

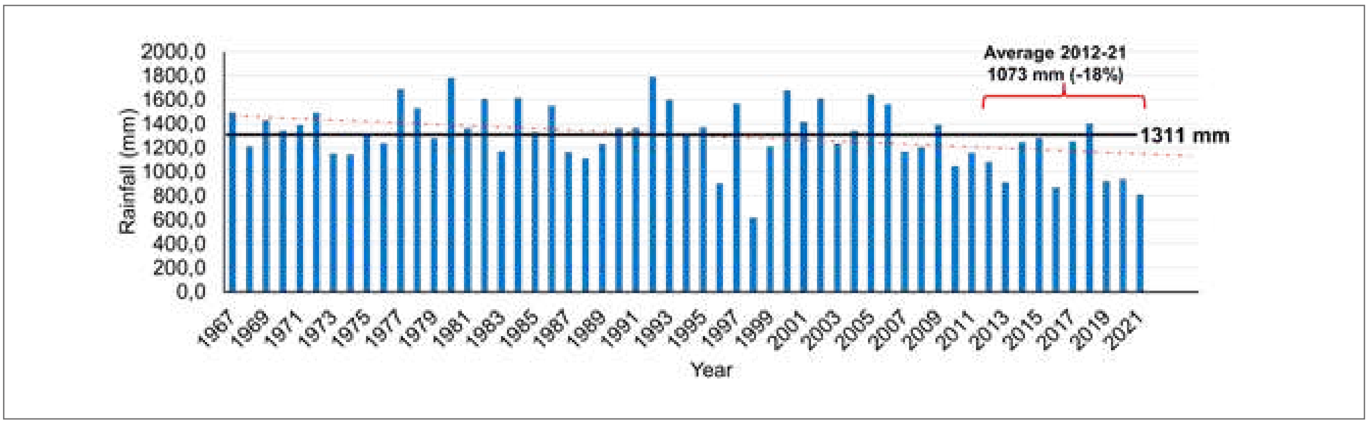

Figure 3. *Annual rainfall at Carillanca research center (38°41'S, 72°25'W) from 1967 onwards.*

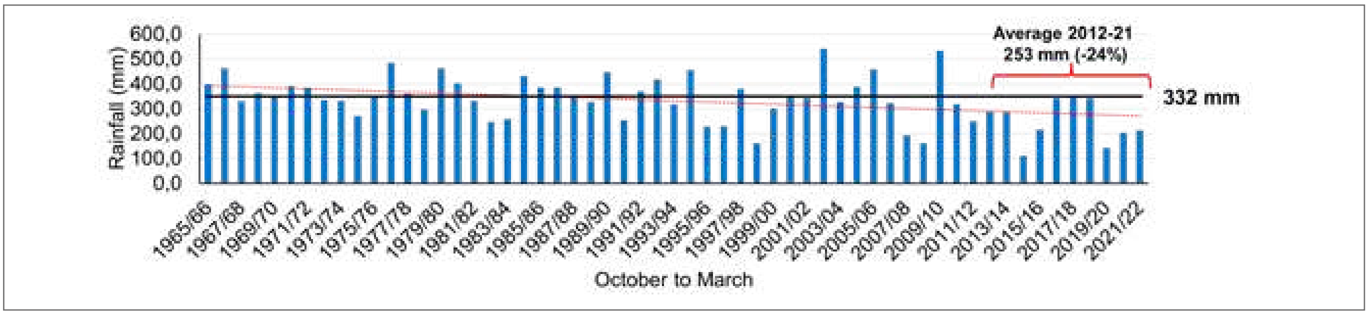

Figure 4. *Rainfall during the main growing season (October to March) from 1965 onwards at Carillanca research center (38°41'S, 72°25'W).*

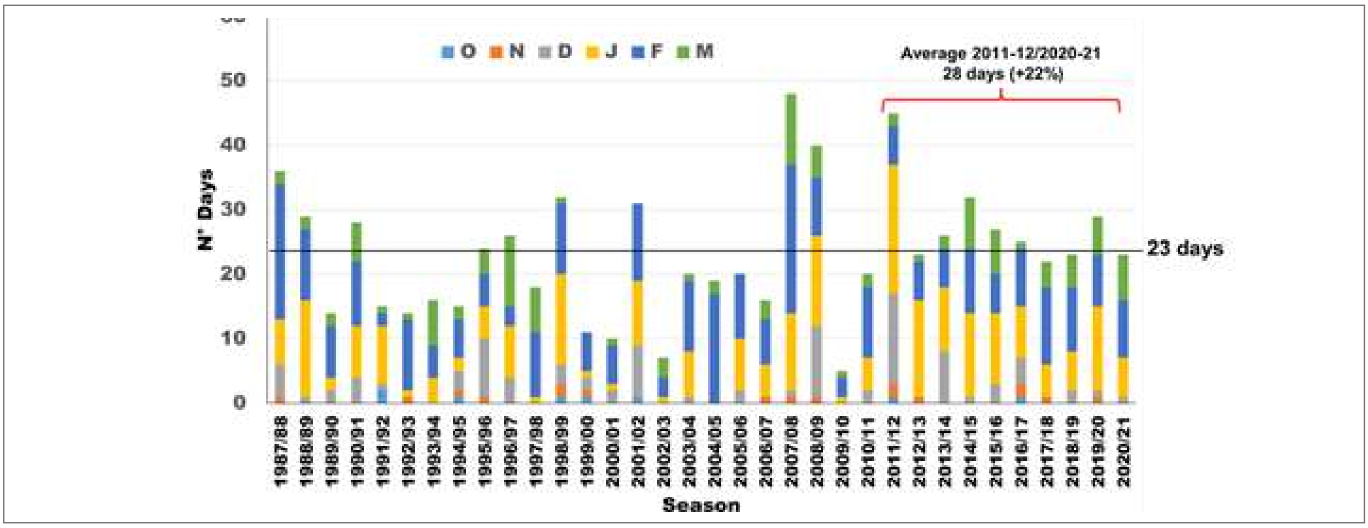

__Figure 5.__ Number of days with maximum temperatures above 27°C during the main growing season (October to March) from 1965 onwards at Carillanca research center (38°41'S, 72°25'W).

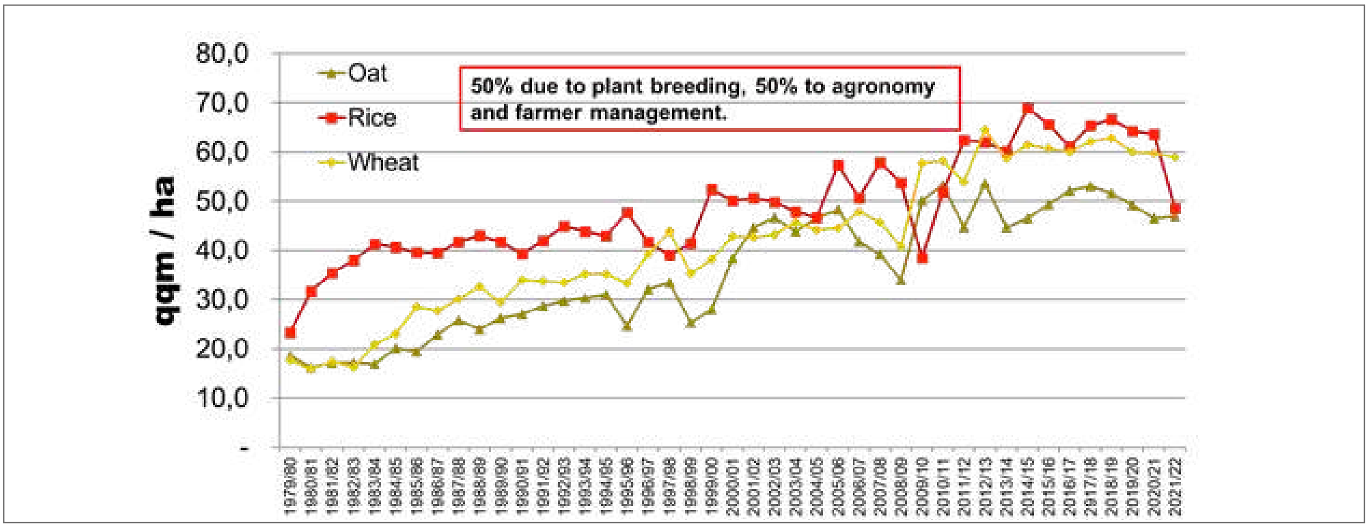

__Figure 6.__ Average national yield of the main cereals in Chile (Source: Adapted by the author from ODEPA 2022).

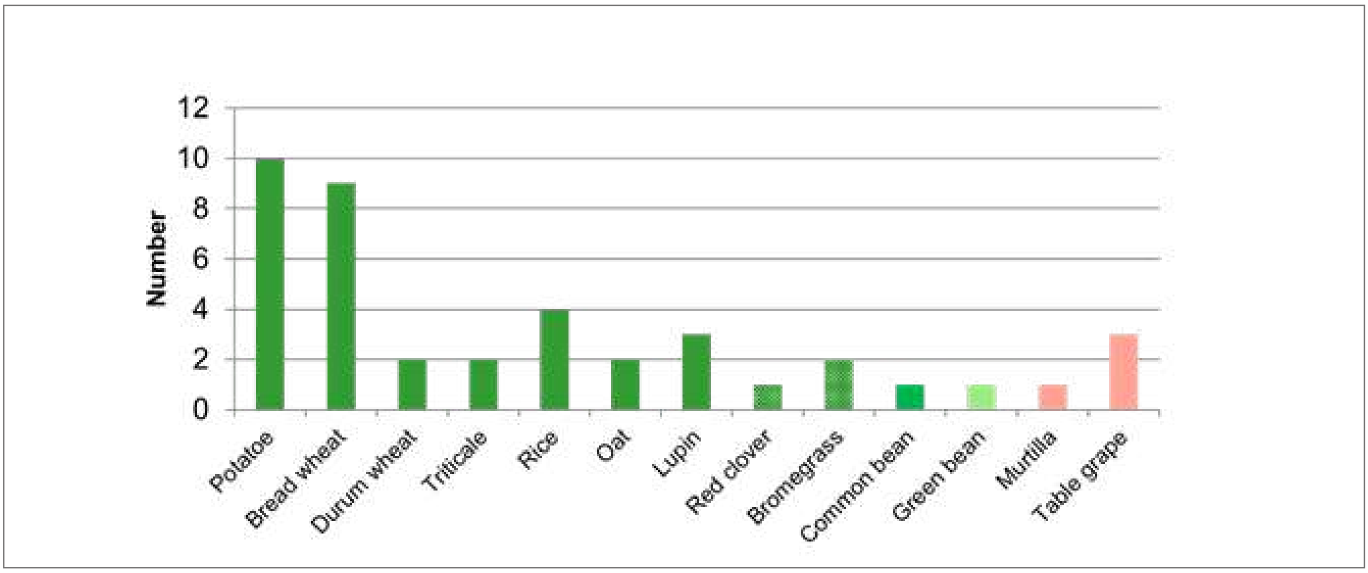

__Figure 7.__ Number of varieties of INIA-Chile by species, July 2022 (Source: Adapted by the author from Servicio Agrícola y Ganadero 2022).

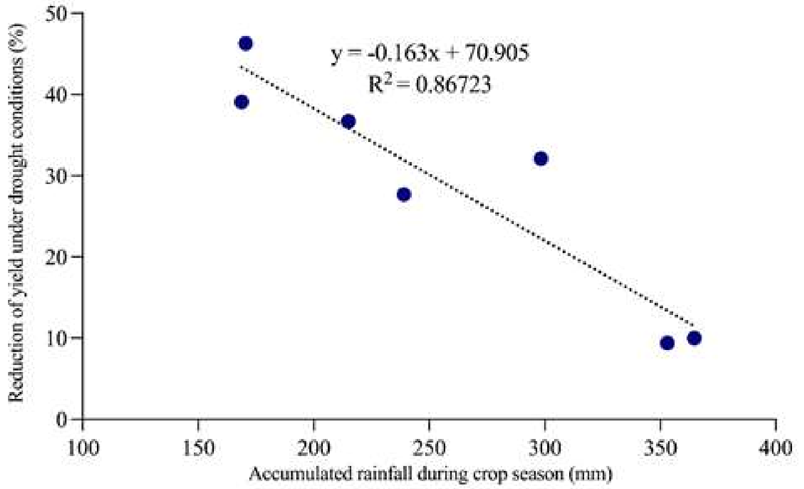

Figure 8. *Percentage of reduction of the yield under rainfed conditions compared to irrigated plots concerning the accumulated precipitation during the growing season between 2012–2013 and 2019–2020 seasons (Source: Martínez et al. 2021).*

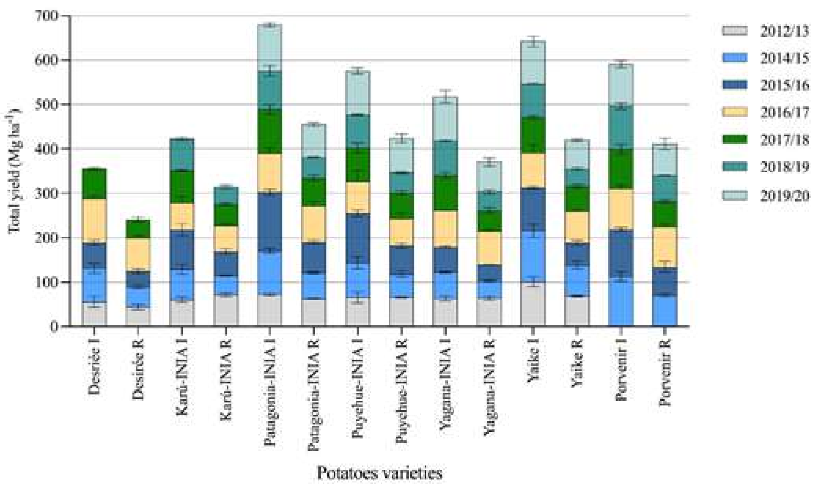

Figure 9. *Temporal tuber yield of seven potato varieties under irrigation and rainfed conditions from 2012–2013 to 2018–2019 seasons (Desiree and Porvenir with five and six seasons, respectively). Error bars indicate standard error. I = irrigation; R = rainfed (Source: Martínez et al. 2021).*

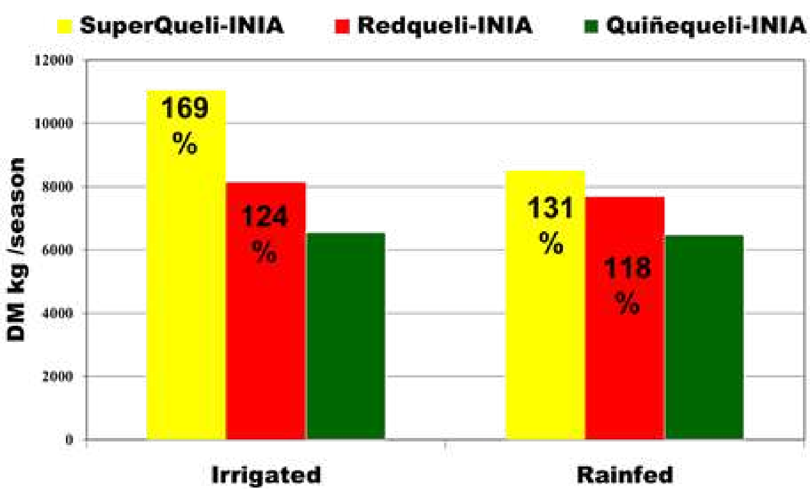

Figure 10. *Average forage yield of INIA's red clover varieties at Carillanca research center (38°41'S, 72°25'W) (Source: Ortega et al. 2014).*

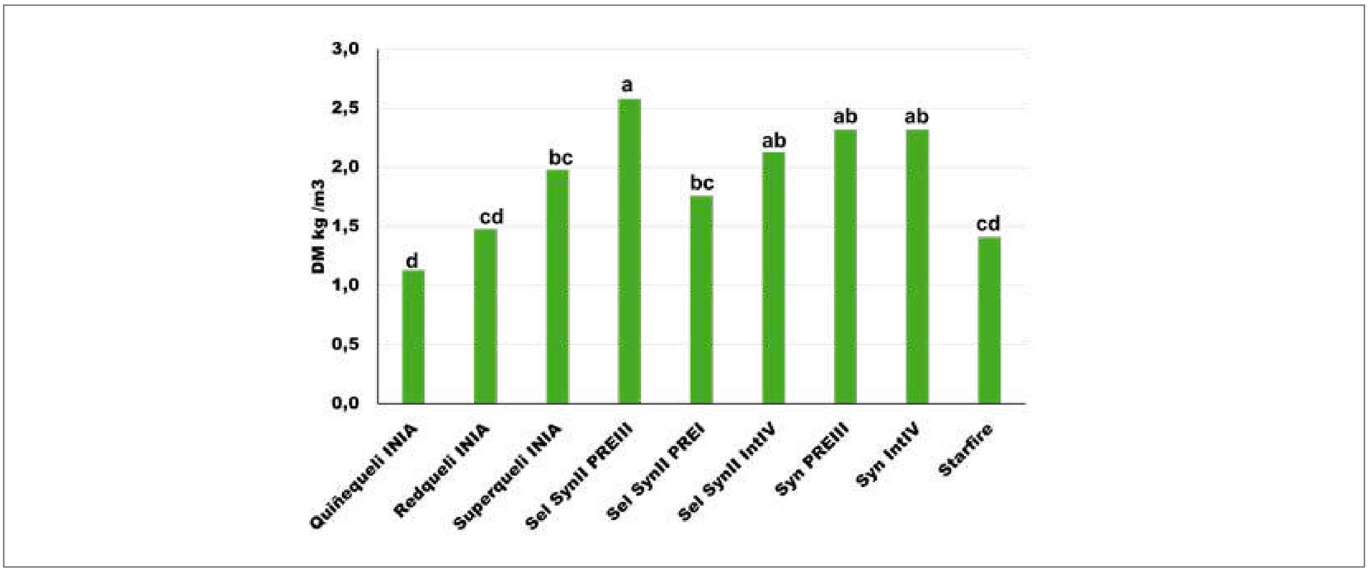

Figure 11. *Average water use efficiency of experimental lines and varieties of red clover over two seasons at Carillanca research center (38°41'S, 72°25'W) (Source: López-Olivari and Ortega-Klose 2020).*

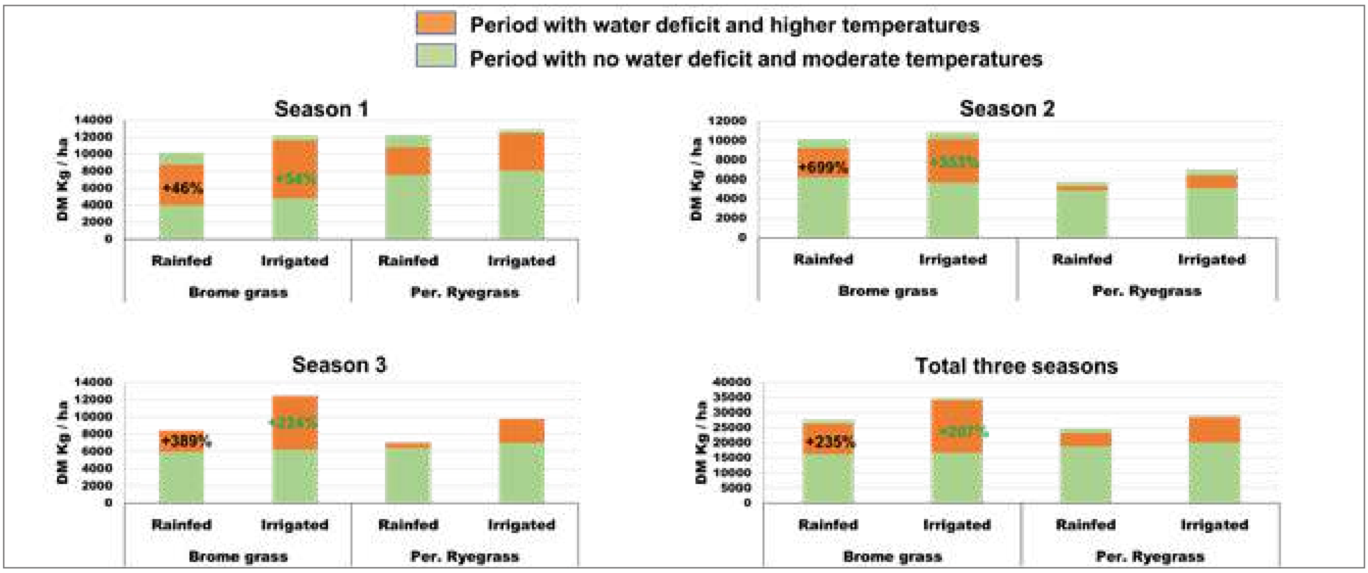

Figure 12. *Performance of selected native bromegrass (Bromus valdivianus) compared to perennial ryegrass over three seasons (Source: Adapted by the author from López-Olivari and Ortega-Klose, 2021).*

Table 1. *Number of varieties in the Chilean property registration (RVP) by group of species, July 2022.*

PLANT GROUP	TOTAL	INTRODUCED	CHILEAN	INIA
FRUIT CROPS	707	672	35	4
FIELD CROPS	125	72	53	33
ORNAMENTAL	45	44	1	0
VEGETABLES	19	18	1	1
FORAGES	11	8	3	3
FORESTRY	10	8	2	0
ORNAMENTAL	45	44	1	0
TOTAL	**917**	**822**	**95**	**41**

Source: Adapted by the author from Servicio Agrícola y Ganadero 2022.

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López-Olivari, R. and Ortega-Klose, F. (2020) Response of red cover to deficit irrigation: dry matter yield, populations, and irrigation water use efficiency in southern Chile. *Irrigation Science* 39: 173–189. DOI: 10.1007/s00271-020-00693-0

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Presentation made at the Seminar

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ADVANCES IN THE DEVELOPMENT OF NEW VARIETIES BETTER ADAPTED TO CLIMATE CHANGE IN CROPS AND FORAGES: A SOUTH AMERICAN PERSPECTIVE

UPOV SEMINAR, OCT.'2022

Dr. Fernando Ortega Klose
fortega@inia.cl

Instituto de Investigaciones Agropecuarias

INIA IS THE MAIN AGRICULTURAL RESEARCH INSTITUTE IN CHILE, WHICH BELONGS TO THE MINISTRY OF AGRICULTURE

- INIA was established in 1964.
- National coverage throughout its 10 regional research centers , experimental centers, technical offices, labs and gene banks.

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GEOGRAPHY AND CLIMATES

- **5.1 million ha.** of arable land in a territory of 75 million ha.
- Population: **17,248,450** (13% rural)

Southern Hemisphere: off-season Agricultural production

Outstanding sanitary conditions: **Fitosanitary Island**

North: Desert West: Pacific Ocean East: Andean Mountain Range South: Southern Ice

Diversity of climates: **diversity of production**

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NUMBER OF VARIETIES IN THE CHILEAN RVP BY ORIGIN (July 2022)

MOST VARIETIES ARE INTRODUCED

AGRONOMIC EVALUATION OF VARIETIES IS NOT COMPULSARY IN CHILE

PLANT GROUP	TOTAL	INRODUCED	CHILEAN	INIA
FRUIT CROPS	707	672	35	4
FIELD CROPS	125	72	53	33
ORNAMENTAL	45	44	1	0
VEGETABLES	19	18	1	1
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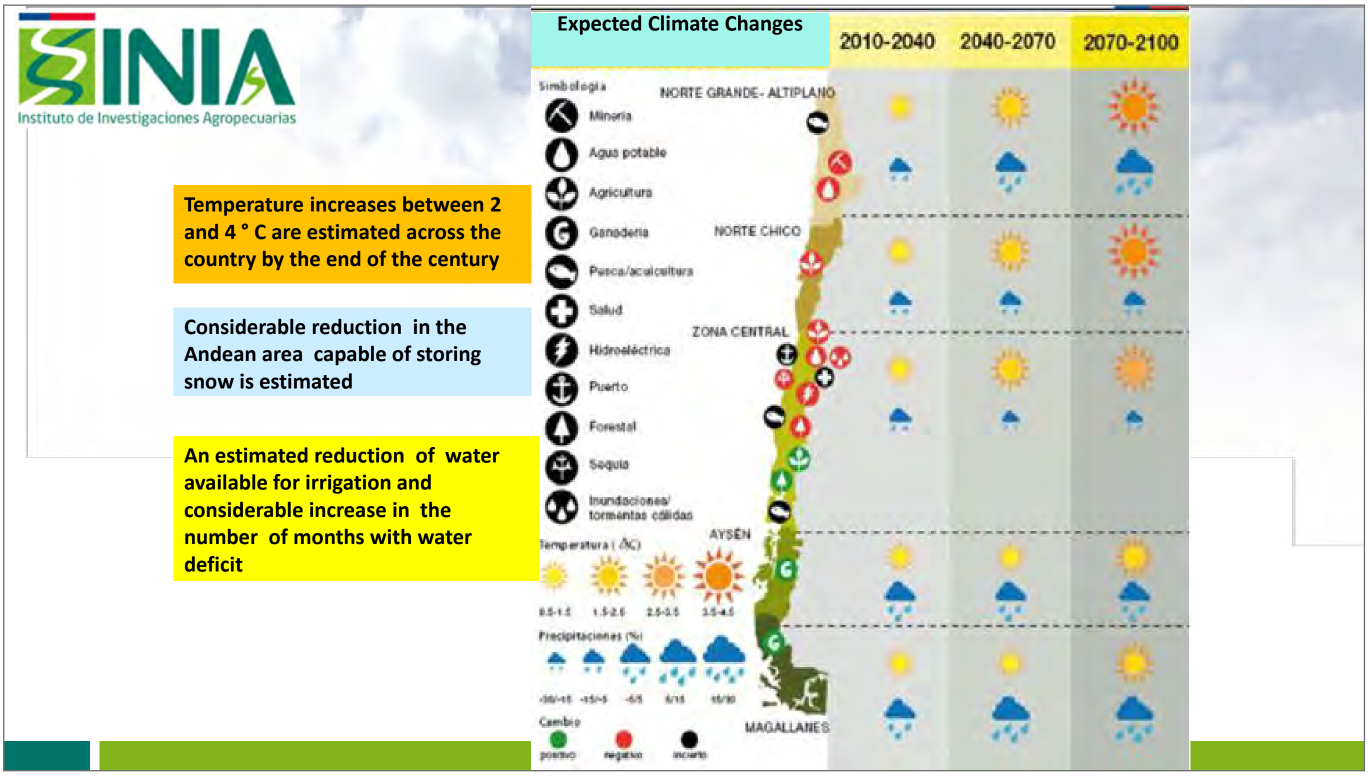
ORNAMENTAL	45	44	1	0
TOTAL	**917**	**822**	**95**	**41**

Source: Adapted from Servicio Agrícola y Ganadero (Chile) information.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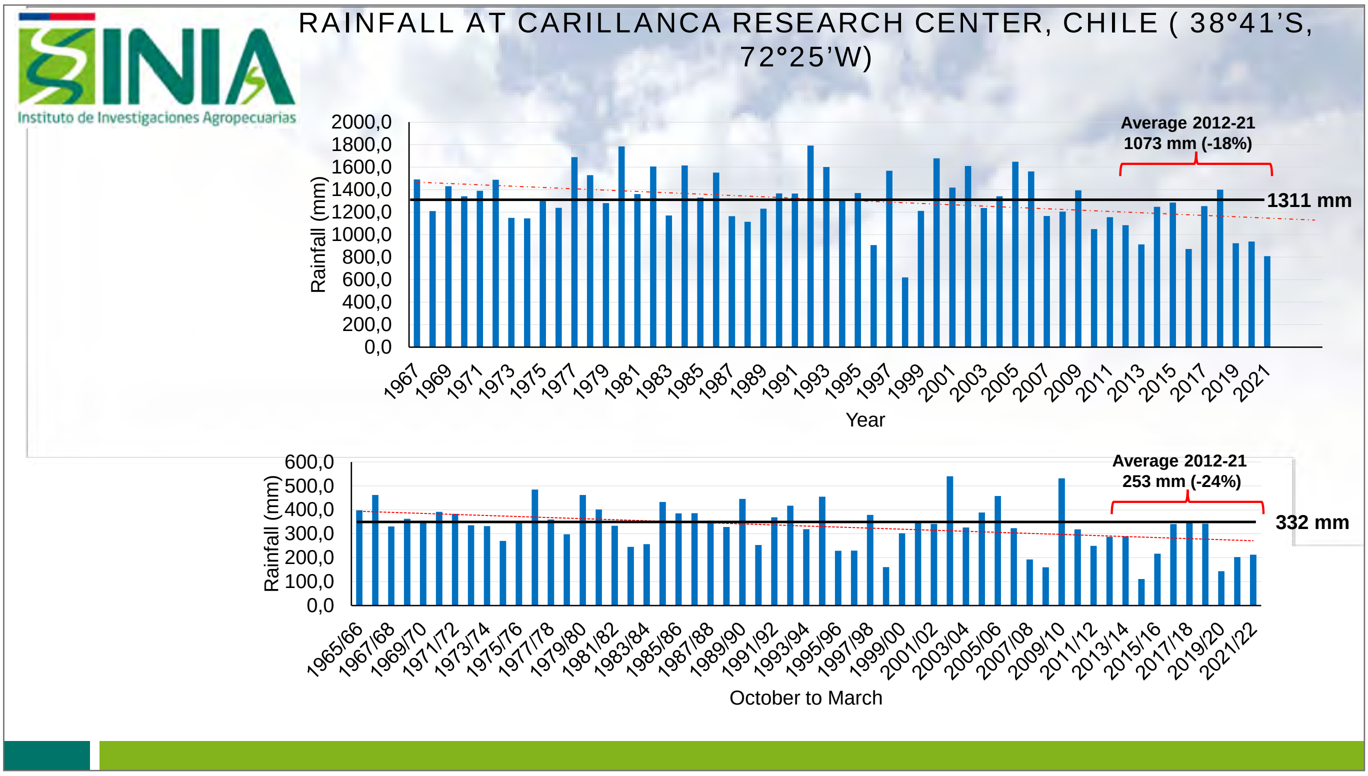
Temperature increases between 2 and 4 ° C are estimated across the country by the end of the century
Considerable reduction in the Andean area capable of storing snow is estimated
An estimated reduction of water available for irrigation and considerable increase in the number of months with water deficit
Expected Climate Changes
2010-2040
2040-2070
2070-2100
Simbología
Minería
Agua potable
Agricultura
Ganadería
Pesca/acuicultura
Salud
Hidroeléctrica
Puerto
Forestal
Sequía
Inundaciones/ tormentas cálidas
Temperatura (ΔC)
0.5-1.5
1.5-2.5
2.5-3.5
3.5-4.5
Precipitaciones (%)
Cambio
positivo
negativo
incierto
NORTE GRANDE- ALTIPLANO
NORTE CHICO
ZONA CENTRAL
AYSEN
MAGALLANES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RAINFALL AT CARILLANCA RESEARCH CENTER, CHILE (38°41'S, 72°25'W)
Average 2012-21
1073 mm (-18%)
1311 mm
Rainfall (mm)
2000,0
1800,0
1600,0
1400,0
1200,0
1000,0
800,0
600,0
400,0
200,0
0,0
1967 1969 1971 1973 1975 1977 1979 1981 1983 1985 1987 1989 1991 1993 1995 1997 1999 2001 2003 2005 2007 2009 2011 2013 2015 2017 2019 2021
Year
Average 2012-21
253 mm (-24%)
332 mm
Rainfall (mm)
600,0
500,0
400,0
300,0
200,0
100,0
0,0
1965/66 1967/68 1969/70 1971/72 1973/74 1975/76 1977/78 1979/80 1981/82 1983/84 1985/86 1987/88 1989/90 1991/92 1993/94 1995/96 1997/98 1999/00 2001/02 2003/04 2005/06 2007/08 2009/10 2011/12 2013/14 2015/16 2017/18 2019/20 2021/22
October to March

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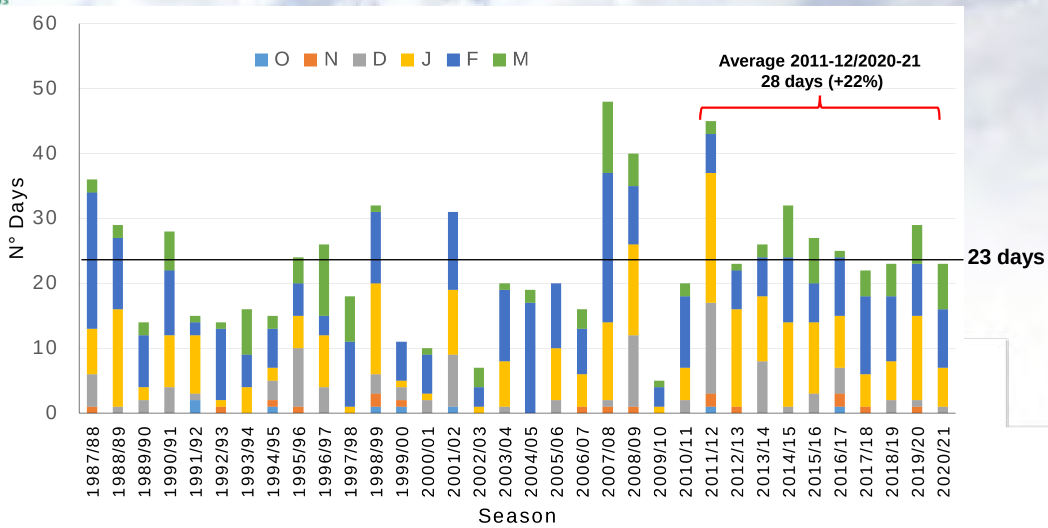
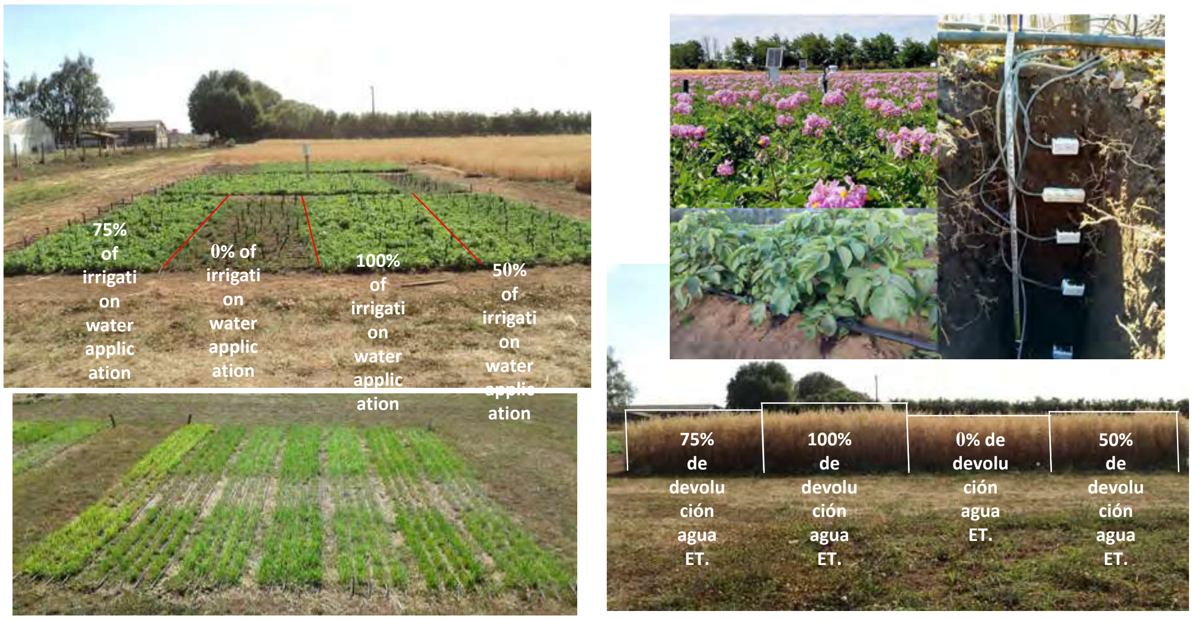
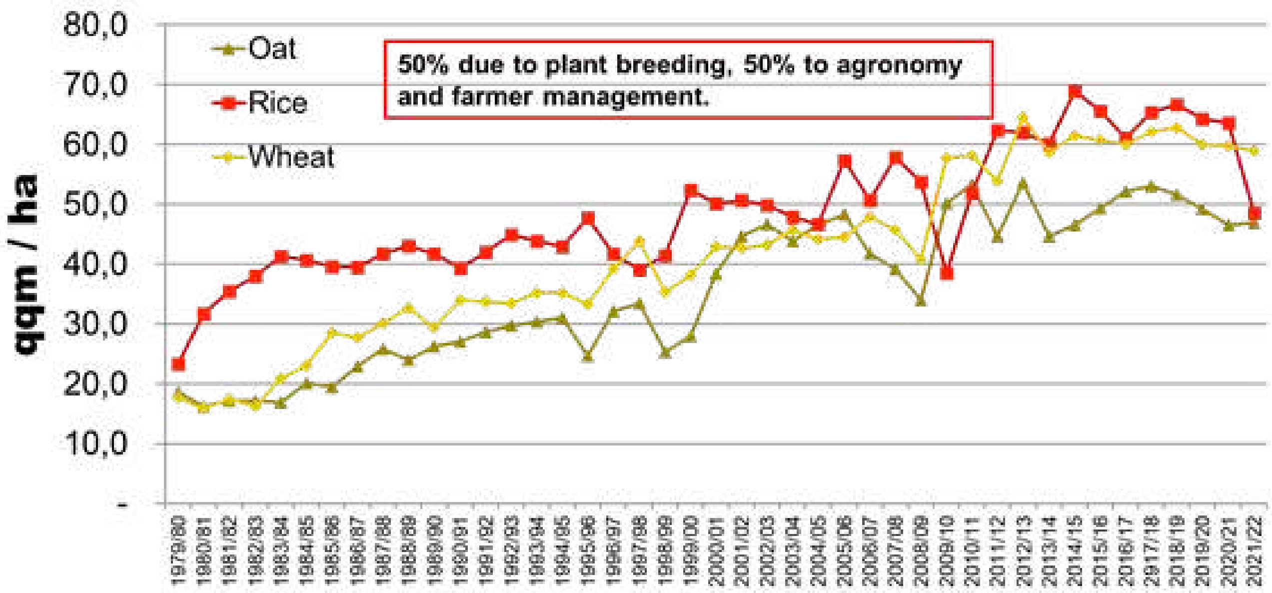
NUMBER OF DAYS WITH MAXIMUM TEMPERATURES ABOVE 27°C. CARILLANCA RESEARCH CENTER, CHILE (38°41'S, 72°25'W)

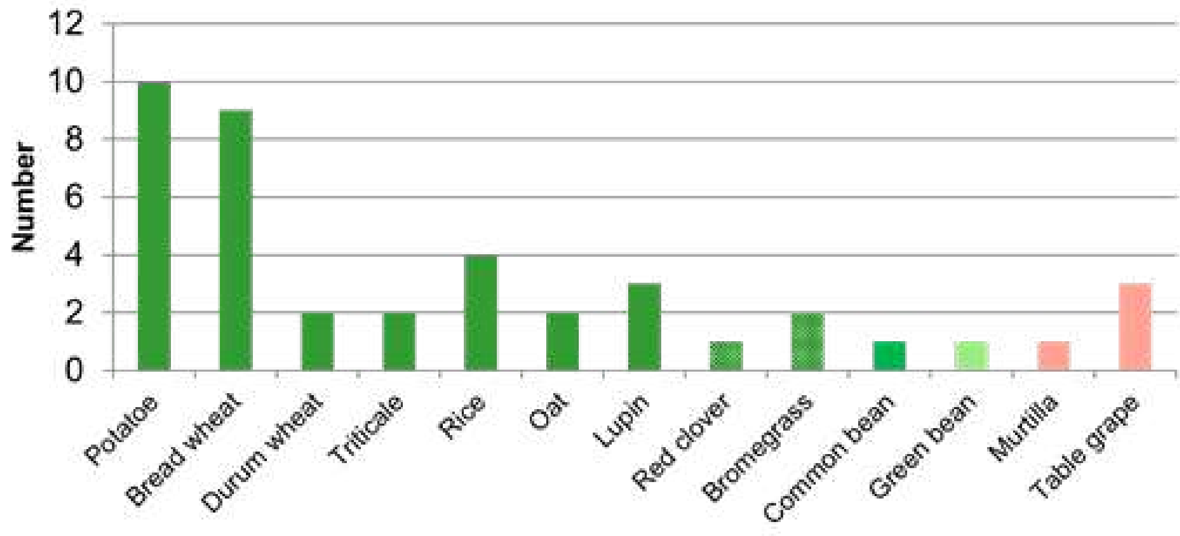


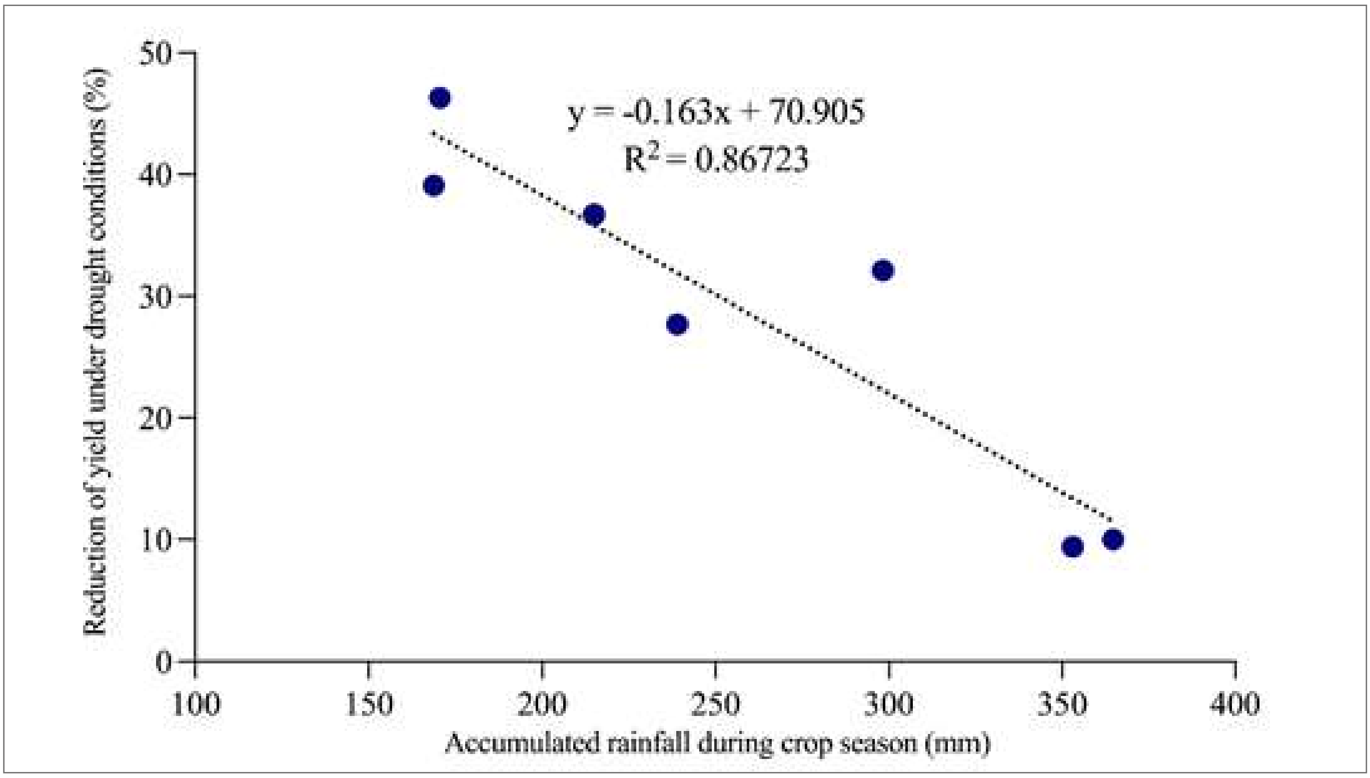
Liderando la agrociencia para un futuro sostenible

SCREENING OF ADVANCED LINES FOR WATER STRESS (WHEAT, OAT, RICE, FORAGES, POTATOES, MURTILLA, QUINOA, LUPIN..)

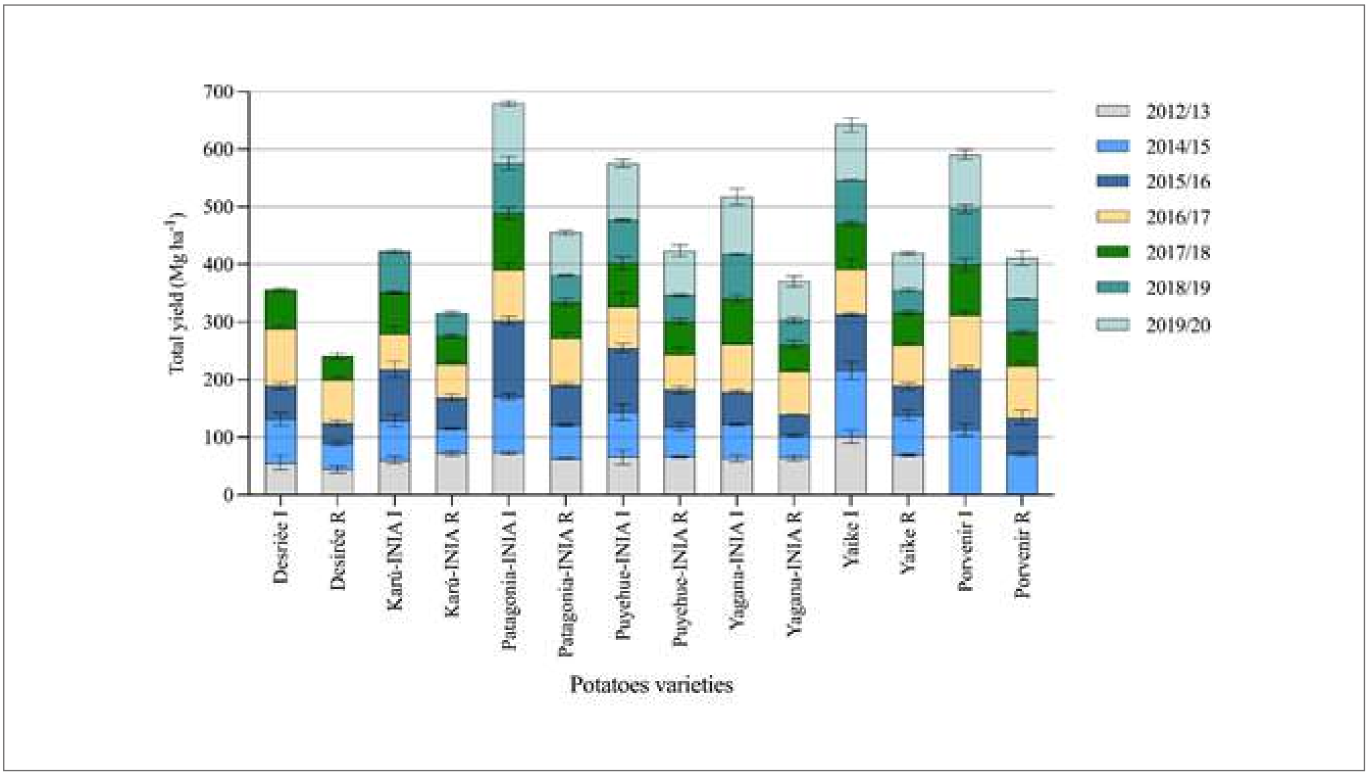



Oat
Rice
Wheat
50% due to plant breeding, 50% to agronomy and farmer management.
qqm / ha
80,0
70,0
60,0
50,0
40,0
30,0
20,0
10,0
-

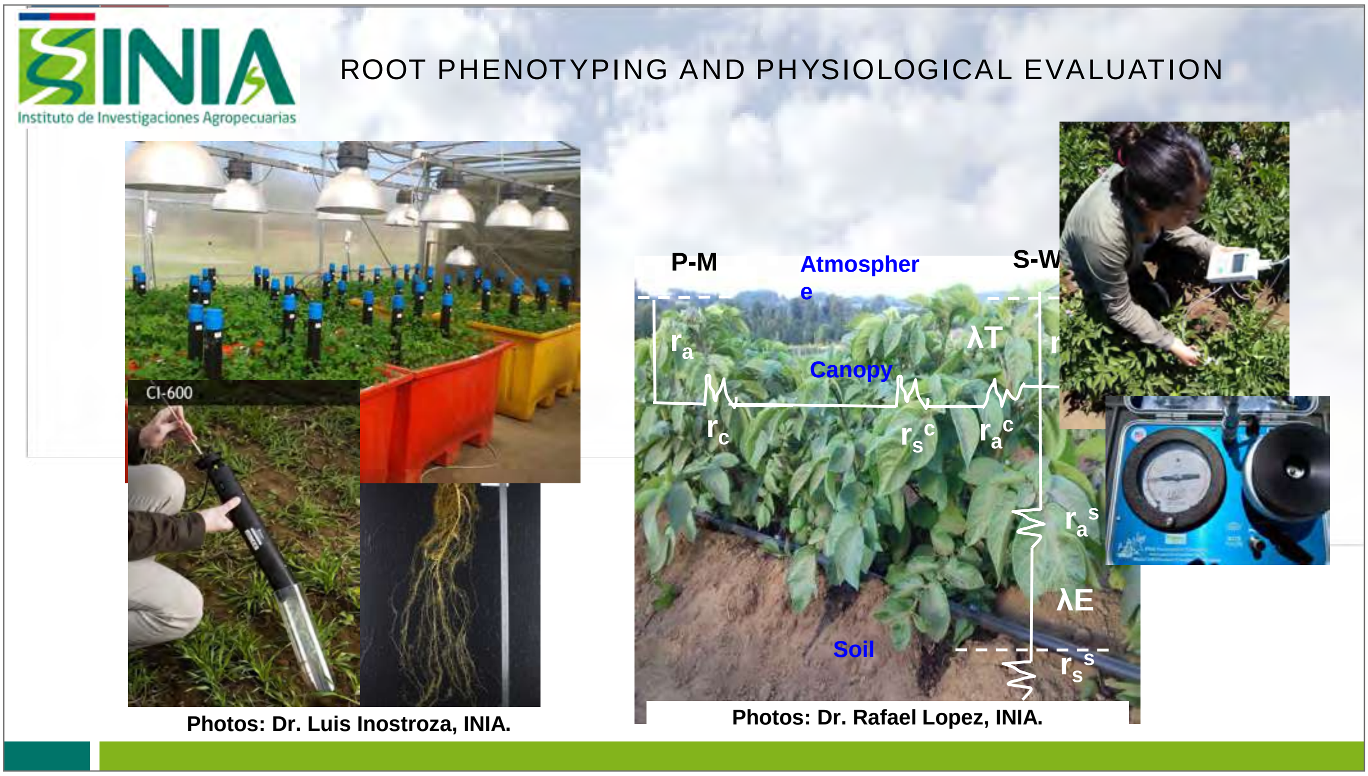

Number
12
10
8
6
4
2
0
Potatoe
Bread wheat
Durum wheat
Triticale
Rice
Oat
Lupin
Red clover
Bromegrass
Common bean
Green bean
Murtilla
Table grape



y = -0.163x + 70.905
R^2 = 0.86723
Reduction of yield under drought conditions (%)
Accumulated rainfall during crop season (mm)



Total yield (Mg ha⁻¹)
2012/13
2014/15
2015/16
2016/17
2017/18
2018/19
2019/20
Desirée I
Desirée R
Karú-INIA I
Karú-INIA R
Patagonia-INIA I
Patagonia-INIA R
Puyehue-INIA I
Puyehue-INIA R
Yagana-INIA I
Yagana-INIA R
Yaike I
Yaike R
Porvenir I
Porvenir R
Potatoes varieties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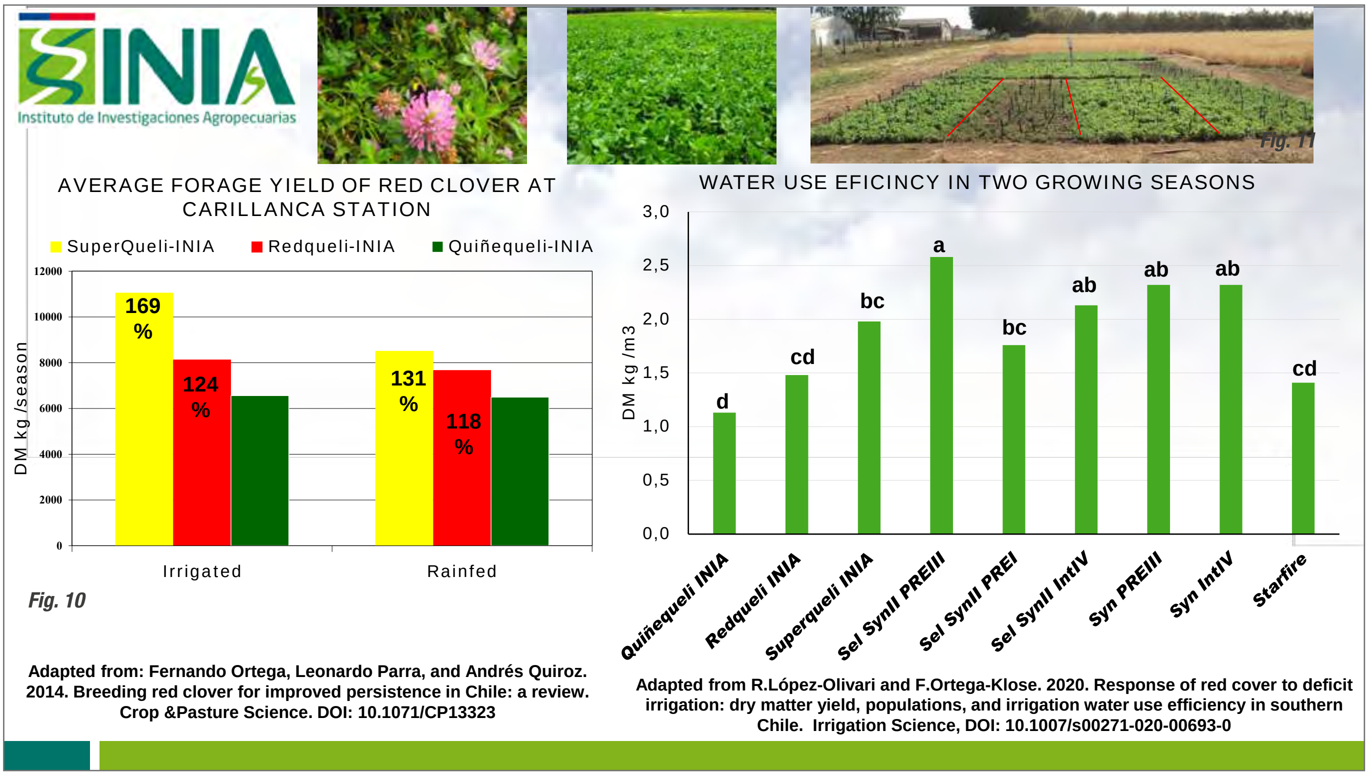
ROOT PHENOTYPING AND PHYSIOLOGICAL EVALUATION
CI-600
P-M
Atmosphere
S-W
Canopy
λT
λE
Soil
Photos: Dr. Luis Inostroza, INIA.
Photos: Dr. Rafael Lopez, INIA.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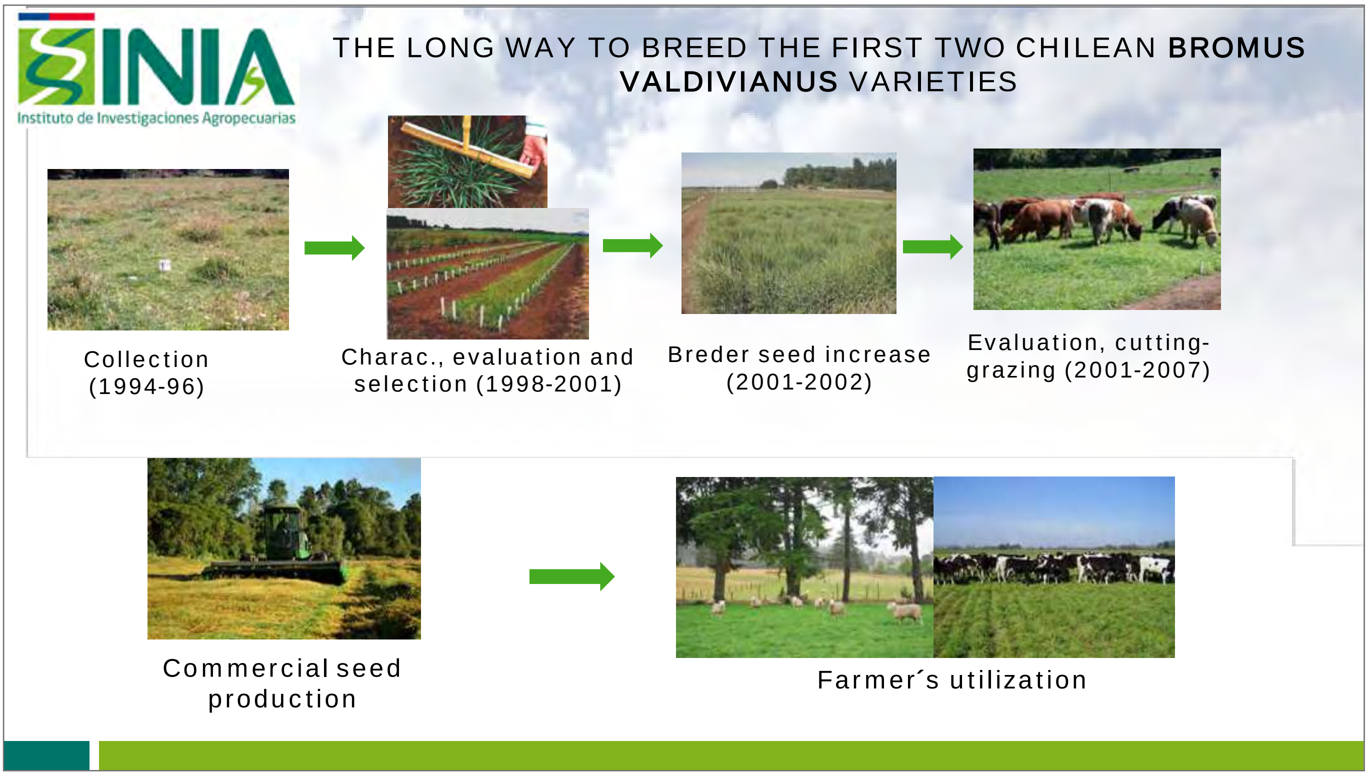
AVERAGE FORAGE YIELD OF RED CLOVER AT CARILLANCA STATION
SuperQueli-INIA
Redqueli-INIA
Quiñequeli-INIA
DM kg /season
169 %
124 %
131 %
118 %
Irrigated
Rainfed
Fig. 10
WATER USE EFICINCY IN TWO GROWING SEASONS
DM kg /m3
Quiñequeli INIA
Redqueli INIA
Superqueli INIA
Sel SynII PREII
Sel SynII PREI
Sel SynII IntIV
Syn PREII
Syn IntIV
Starfire
Fig. 11
Adapted from: Fernando Ortega, Leonardo Parra, and Andrés Quiroz. 2014. Breeding red clover for improved persistence in Chile: a review. Crop &Pasture Science. DOI: 10.1071/CP13323
Adapted from R.López-Olivari and F.Ortega-Klose. 2020. Response of red cover to deficit irrigation: dry matter yield, populations, and irrigation water use efficiency in southern Chile. Irrigation Science, DOI: 10.1007/s00271-020-00693-0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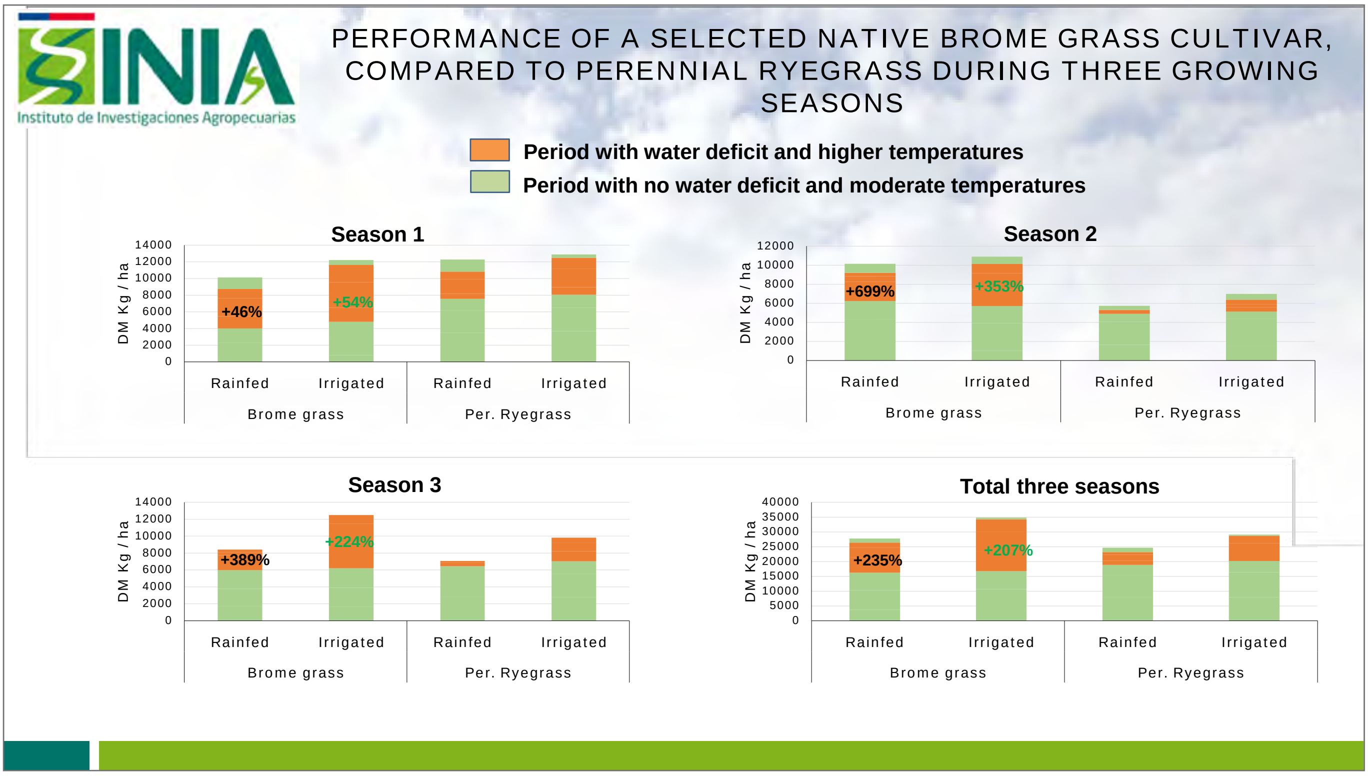
THE LONG WAY TO BREED THE FIRST TWO CHILEAN BROMUS VALDIVIANUS VARIETIES
Collection (1994-96)
Charac., evaluation and selection (1998-2001)
Breder seed increase (2001-2002)
Evaluation, cutting-grazing (2001-2007)
Commercial seed production
Farmer´s utilization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PERFORMANCE OF A SELECTED NATIVE BROME GRASS CULTIVAR, COMPARED TO PERENNIAL RYEGRASS DURING THREE GROWING SEASONS
Period with water deficit and higher temperatures
Period with no water deficit and moderate temperatures
Season 1
DM Kg / ha
14000 12000 10000 8000 6000 4000 2000 0
+46%
+54%
Rainfed Irrigated Rainfed Irrigated
Brome grass Per. Ryegrass
Season 2
DM Kg / ha
12000 10000 8000 6000 4000 2000 0
+699%
+353%
Rainfed Irrigated Rainfed Irrigated
Brome grass Per. Ryegrass
Season 3
DM Kg / ha
14000 12000 10000 8000 6000 4000 2000 0
+389%
+224%
Rainfed Irrigated Rainfed Irrigated
Brome grass Per. Ryegrass
Total three seasons
DM Kg / ha
40000 35000 30000 25000 20000 15000 10000 5000 0
+235%
+207%
Rainfed Irrigated Rainfed Irrigated
Brome grass Per. Ryegrass

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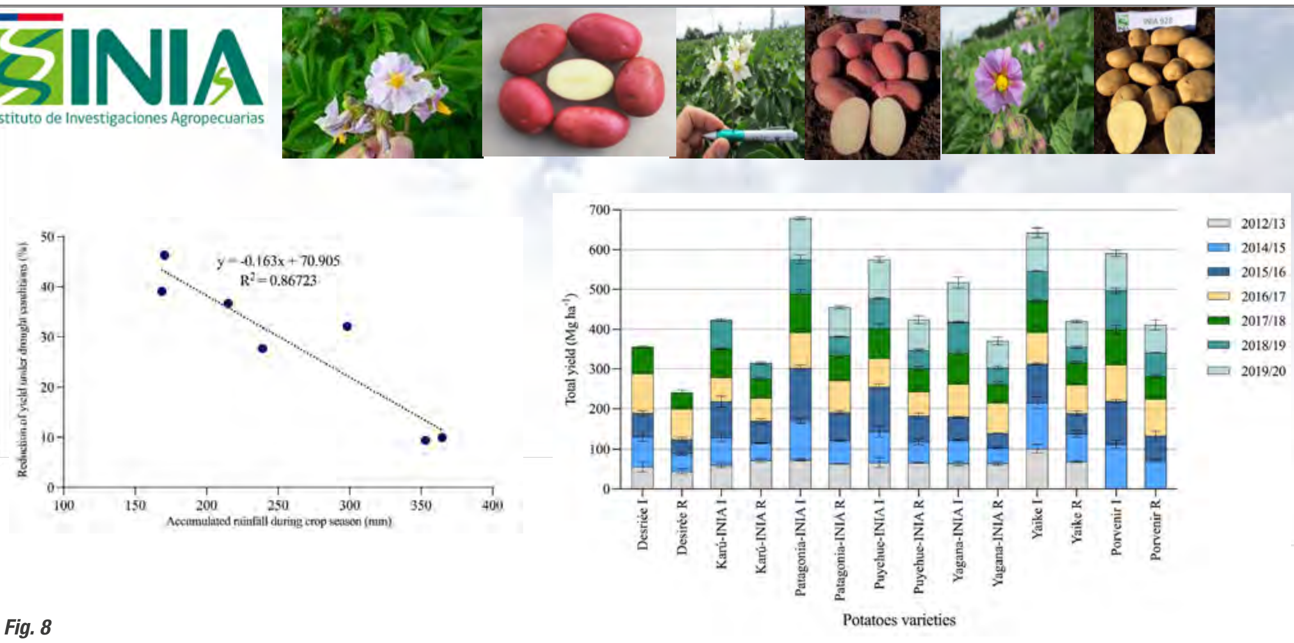

Fig. 8

Martinez et al. 2021. Evaluating the drought tolerance of seven potato varieties on volcanic ash soils in a médium-term trial. Frontiers in Plant Science, DOI: 10.3389/fpls.2021.693060.

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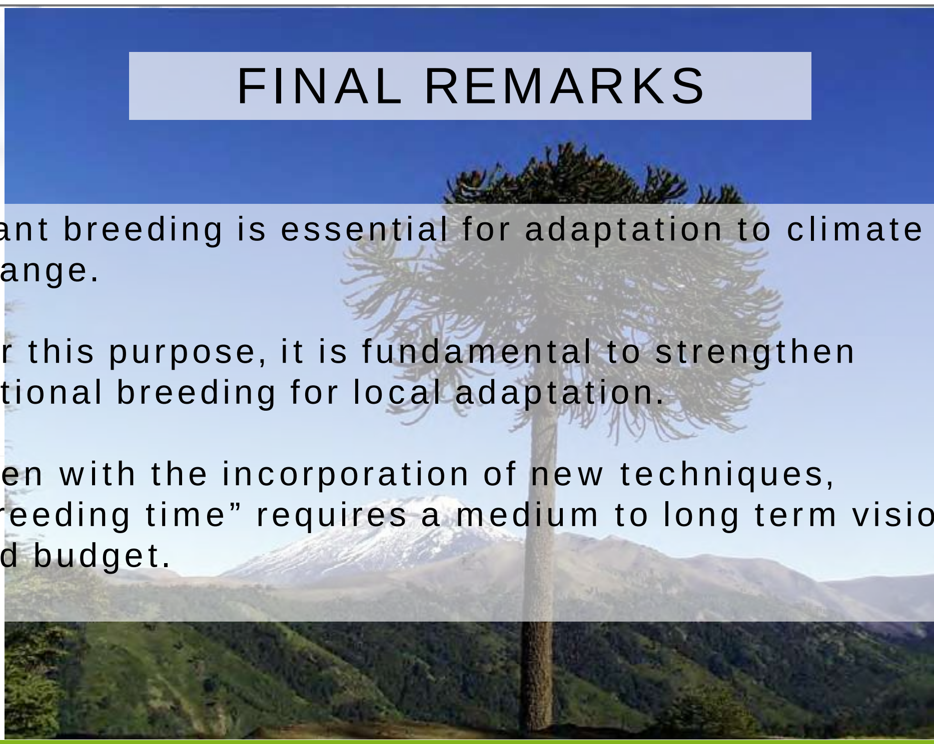


FINAL REMARKS

- Plant breeding is essential for adaptation to climate change.
- For this purpose, it is fundamental to strengthen national breeding for local adaptation.
- Even with the incorporation of new techniques, “breeding time” requires a medium to long term vision and budget.

BREEDING PROGRAM TO MITIGATE CLIMATE CHANGE AND ENVIRONMENTAL PRESSURES ON CROPS

Mr. Dave Bubeck
Research Director, Corteva, United States of America

Thanks to all the organizers for such an ambitious UPOV seminar on the critical subject areas of plant breeding, intellectual property protection of germplasm and leveraging technologies for crop improvement to mitigate for changing environments.

Slide #2

I will begin by setting the context of the roots of the seed product portion of Corteva agriscience company, from heritage Pioneer Hi-Bred International, by recognizing one of the longest corn-breeding efforts in the world with more than century of corn breeding tracing back to Henry A. Wallace. I shared the very first written correspondence between Henry A. Wallace, founder of Pioneer Hi-Bred and eventually Vice President of the United States of America, and the first corn breeder he hired, Raymond Baker. Mr. Baker was asking Mr. Wallace if he would be willing to have some inbred seed to make hybrid crosses, and Mr. Wallace responded positively that he would do that and provided the first instructions of what he would need to do to set up an isolated field to create hybrid seed with 30–40 different females that would be crossed in isolation to a common male parent. That was the first written correspondence that planted the seeds of a long relationship between Henry A. Wallace, Raymond Baker and Pioneer Hi-Bred.

Today I will address the following areas:

1) a brief touch on the impact of public and private sector corn breeding in the US;
2) methods and practices to conduct effective plant breeding programs in the face of changing environments;
3) example and potentials of genome editing technologies.

Slide #3

One way to illustrate the improvements of plant breeding and crop management practices is to visualize the additional crop land area that would be required to produce the US corn crop at the total grain volume derived from the 2021 production year, under the actual yield levels in a given year. The black vertical bars on the chart represent the actual number of acres harvested in a given year, and the grey bars represent the additional acres that would have been required to produce the total amount of corn grain produce in 2021. To point out a single year on this chart, in 1931 average corn grain yield levels averaged 27.8 bu/A. At this level of productivity over 600 million acres acres (over 25% of the entire US land mass) would have been required to produce the 2021 corn crop at 1931 average yield levels. These tremendous yield increases over time demonstrate the improvements in genetics, yield stability across environments and general improvement in farm management practices.

Slide #4 - Some fundamental aspects of successful plant breeding programs endure over time. A germplasm pool, or a set of genetic entities, are required as source materials for breeders. Creating breeding crosses between parents in this germplasm pool marks the beginning of the breeding cycle. Multiple decisions are critical to set up successful outcomes of a breeding program. The ability to evaluate the new breeding outcomes with precision and accuracy, as one conducts testing in a set of predictive environments, and the environments must be predictive or estimable of future environments so that the selection of commercial products will be successful. The outcome of this breeding process creates a refined and hopefully improved upon germplasm pool. In conducting long-term breeding programs, the germplasm pool must contain the genetic variance that enables selection to the targeted environments where the crop will be grown. Provided that sufficient genetic variation exists, it is possible to mitigate climate change pressure over time. At Corteva, we have had data over many decades known as the ERA/Decade studies that indicate that at least for corn breeding in the last 50 years, we have had sufficient variation to select for improved yields in spite of changing environments.

Slide #5

Genetic variation is essential to continue to make genetic gains and crop performance improvement. The expectation and results of any breeding program over time, in selecting the best performance of a few and discarding the majority of genetic recombinants, is a decline in genetic diversity and ultimately variation. Therefore, a breeding strategy should include consideration for how to create additional favorable genetic variation, either from bringing additional germplasm into a breeding program or leveraging some technologies that can create additional variation.

Slide #6

This very long list of corn traits representing needs of growers and end users illustrates the challenges that a plant breeder faces in a multi-trait selection. Genetic gain for any of these traits requires favorable variation, selection environments where the trait expression can be assayed with precision and effective response to long-term selection. Breeding programs and breeders must have patience and adjust breeding goals as the environmental pressures change over time. Leveraging technologies that could provide sufficient trait performance to enable the plant breeder to remove that trait as a selection target would reduce the complexity of their highly quantitative selection challenge.

Slide #7

I want to provide a current example of our efforts to leverage CRISPR/genome editing for the purpose of multi-genic disease control. This effort is conducted through leveraging native maize genes, and can target any base genetic inbred and hybrid that has desired commercial performance for grain yield and other traits.

Slide #8

This native genetic effort for disease control utilizes CRISPR, leveraging a solution for multiple disease traits, and specifically four traits listed in this example: NLB, S. Rust, GLS and Anthracnose stalk rot. Co-location of multiple disease genes per trait provides durability of resistance and potentially enables breeders to put more selection intensity on the rest of the genome, enabling increased selection intensity for the remainder of the genome. *Slide #9*

Slide #9

Genome editing could provide opportunities to go beyond current plant breeding techniques and exceed current ranges of trait variation. Chromosomal rearrangements may increase the potential to change phenotypes and “unlock” existing genetic variation that cannot be leveraged due to lack of recombination (https://www.nature.com/articles/s41477-020-00817-6). Utilizing gene relocation to enable co-location of multiple native traits can unleash major portions of the genome for improved maintenance of genetic diversity and additional favorable trait selection. In the near future, multiple and simultaneous edits across numerous traits may increase the rate of genetic gain beyond what has been historically possible.

Slide #10

Numerous science, technology and engineering accomplishments have contributed to the productivity of crop performance, including off-season/continuous nurseries, molecular markers/DNA sequencing, automated research planting and harvesting equipment, GMO traits, improved analytics, managed environments for research plots, genomic predictions and doubled haploids. What additional technologies will be added over the next 50 years? I believe that the fundamentals of plant breeding, as a multi-disciplinary biological and engineering challenge, will still be essential to feeding a growing global population. I predict that CRISPR/genome editing will reside on the list of accomplishments, or certainly some form of precise technology that drives multiple genomic changes that contribute to crop performance improvement. However, it is imperative that countries establish policies that enable technologies such as genome editing to be utilized.

Slide #11

Key summary points:

1) Continue plant breeding, leveraging all technologies that contribute to crop performance improvement.

2) Genetic variation is essential to achieve breeding goals.

3) Plant breeding requires long-term selection, patience and adjusting breeding goals as the environmental pressures change over time.

4) Genome editing methods have potential for creating additional and needed variation to accomplish future environmental changes.

5) Increased progress to minimize or eliminate biotic and abiotic stresses enables increased heritability and selection efficiency for grain yield improvement.

Presentation made at the Seminar

CORTEVA agriscience

Breeding programs to mitigate climate change and environment pressures on crops

Dave Bubeck, Research Director – Seed Product Development, Corteva Agriscience

UPOV - Seminar on the role of plant breeding and plant variety protection in enabling agriculture to mitigate and adapt to climate change

October 11, 12, 26; 2022

File under seed corn Requests

G. D. Station A.
Ames, Iowa
March 7, 1926

H.A. Wallace
Des Moines
Iowa

Dear Mr. Wallace
At the corn show last Feburary, you said that if I would write to you along in March you might be able to let me have some inbred corn to cross and enter in the Corn Yield contest. So I am writing you in hopes that you will have some to spare.

I am a sophmore Farm, Crops, and Soils student at Ames, so naturally very much interested in corn. Is it best when crossing corn to use the paper sack method, so as to cross on both parents; or just cut the tassels off of one strain? I am going to school at Ames, but would want any corn sent home to Beaconsfield, Iowa. You can either send it C.O.D or let me know what the postage is.

Thanking you in advance, I remain,

Yours Truly
Raymond Baker

March 10, 1926.

Mr. Raymond Baker,
G.D. Station A,
Ames, Iowa.

Dear Mr. Baker:

I think I can send you some inbred strains of corn all right, but before sending them I would like to know just what kind of a plot you have. Do you have a half acre which is at least 500 feet away from any other corn, where there would not be much chance for pollen from other corn coming in on it? If so, I would suggest that you use the detasseling method. I would send you one sort to use as a male parent and thirty or forty other sorts to use as female parents. I would want you to plant about twenty hills each of these different female parents. We would then take four pounds of each of these different combinations and enter them in the Iowa Corn Yield Contest in the spring of 1927. We can enter these combinations in the name of Baker and Wallace if you so desire.

If you take on this project, you will of course have to arrange to plant the corn with some care so you know in which row each of the different strains is planted, and then in July you will have to arrange to pull the tassels out every day, and in late September or early October you will have to harvest the different sorts and label them. It is quite a little job.

Write me further on the matter as to just how you want to go ahead with this proposition. If you happen to be coming down to Des Moines at any time , let me know in advance and drop around to the office.

Sincerely yours,

HAWallace
BM

Beaconsfield, Iowa
July 15, 1926

Mr. H.A. Wallace
DesMoines, Iowa

Dear Mr. Wallace:

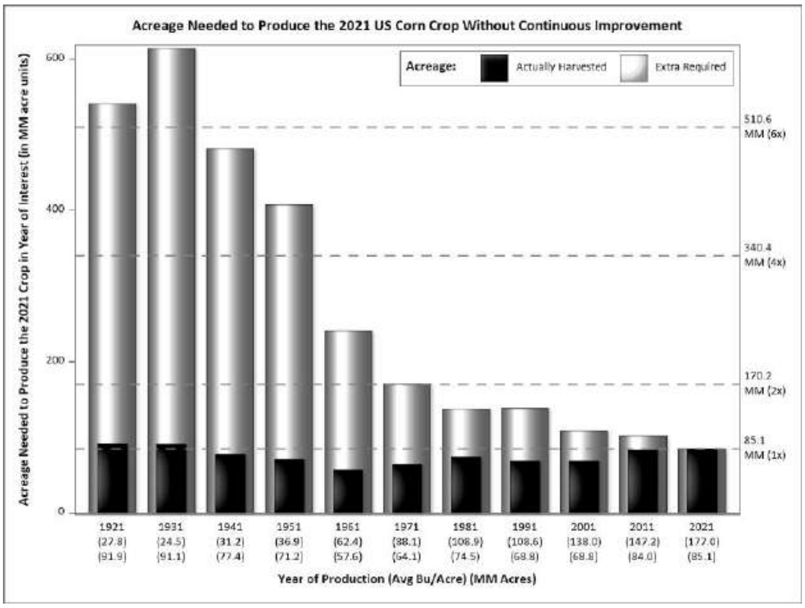
Our corn is doing fine, and I am having a lot of fun pulling out the tassles. I have already pulled out about half the tassels. Some of the mother parents are so tall (over 8 ft) that I need a step-ladder to reach the tassels.

RAYMOND BAKER

CORTEVA agriscience

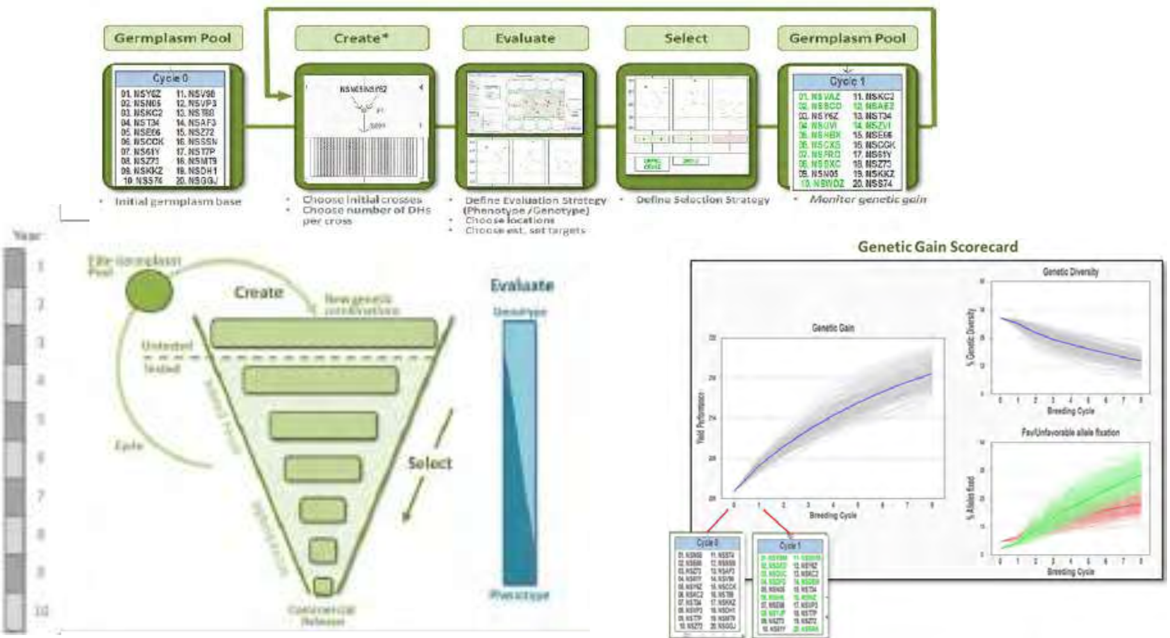
Slide #2

Acreage impact of corn breeding and improved management practices



CORTEVA agriscience

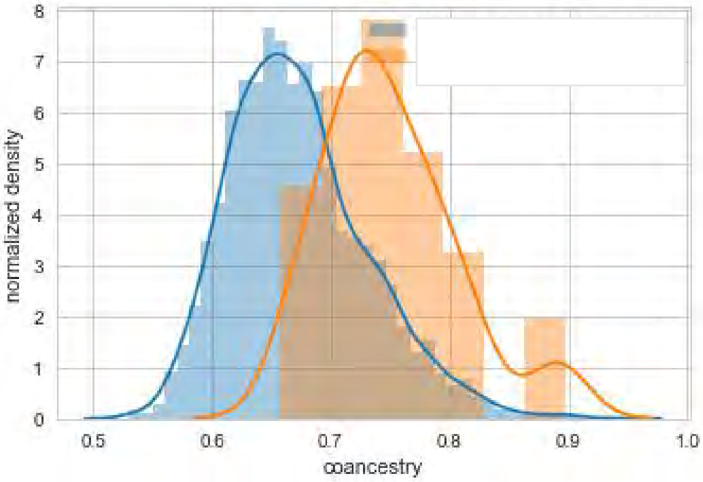
The Breeding Pipeline - Conduct pre-commercial product testing in target environments for multiple years

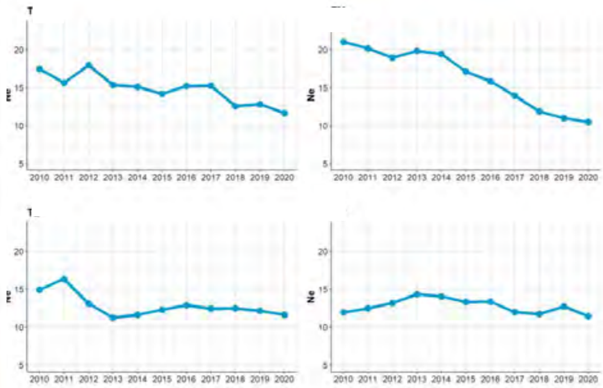


CORTEVA agriscience

Genetic variation – trends over time

- Genetic variation is essential to achieve breeding goals
- Co-ancestry based – pedigree and/or genotype
- Allelic diversity – driven by population sizes in breeding programs





CORTEVA agriscience

Maize Breeding – highly complex trait selection needs

Genetic gain for any of these traits requires favorable variation and response to long-term selection, adding patience and adjusting breeding goals as the environmental pressures change over time

Agronomics

Yield

Test weight
Grain moisture
Grain dry-down
Stalk lodging
Root lodging
Plant height
Ear height
Brittle snap
Drought tolerance
Emergence
Stand establishment
Early growth
Cold tolerance

Pest Resistance

Gray leaf spot
Northern leaf blight
Southern leaf blight
Stewart's wilt
Rusts
Smuts
Anthracnose
Diplodia
Giberella
Fusarium
Diplodia
Bacterial wilt

End-Use Traits

Mycotoxin Production in Grain
Starch, Protein, & Oil
Extractable starch
Total fermentables
Gross energy
Digestible energy
Food-grade Traits
Silage quality traits

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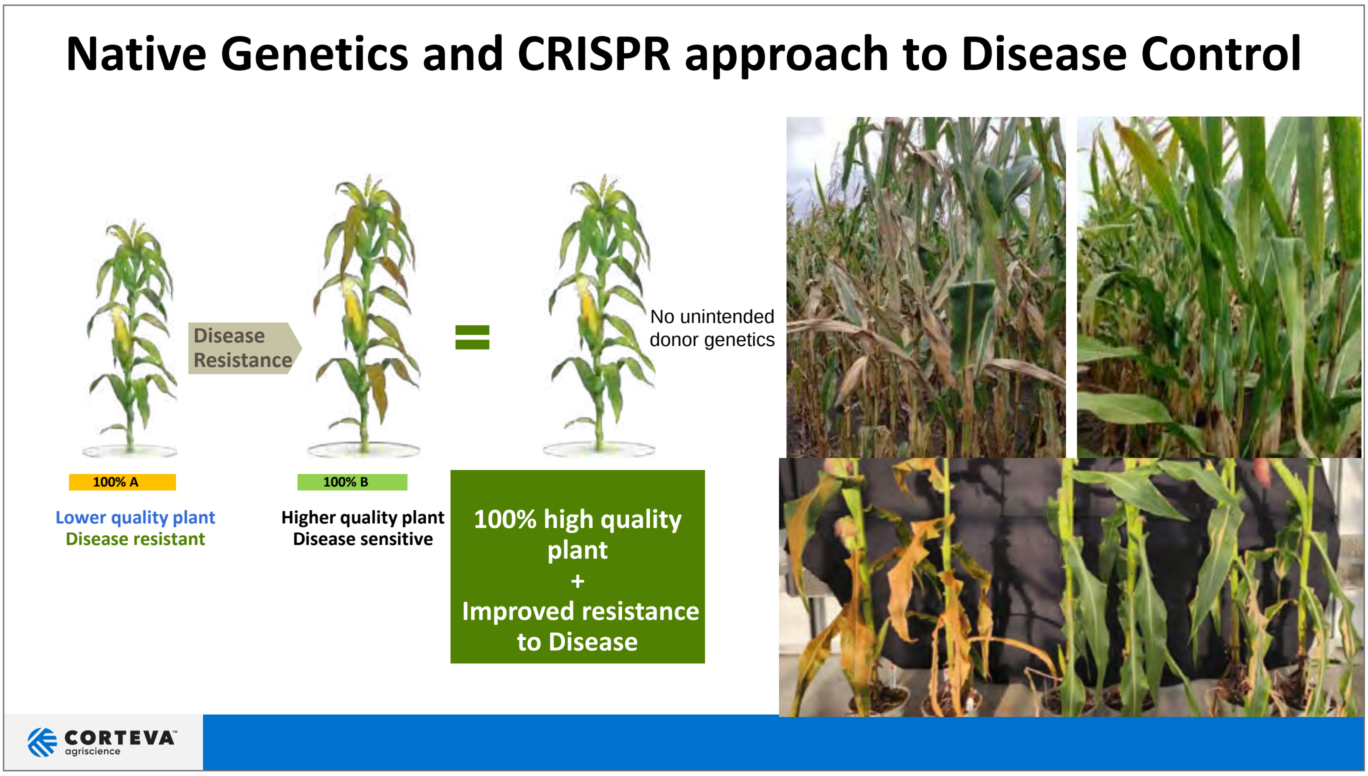
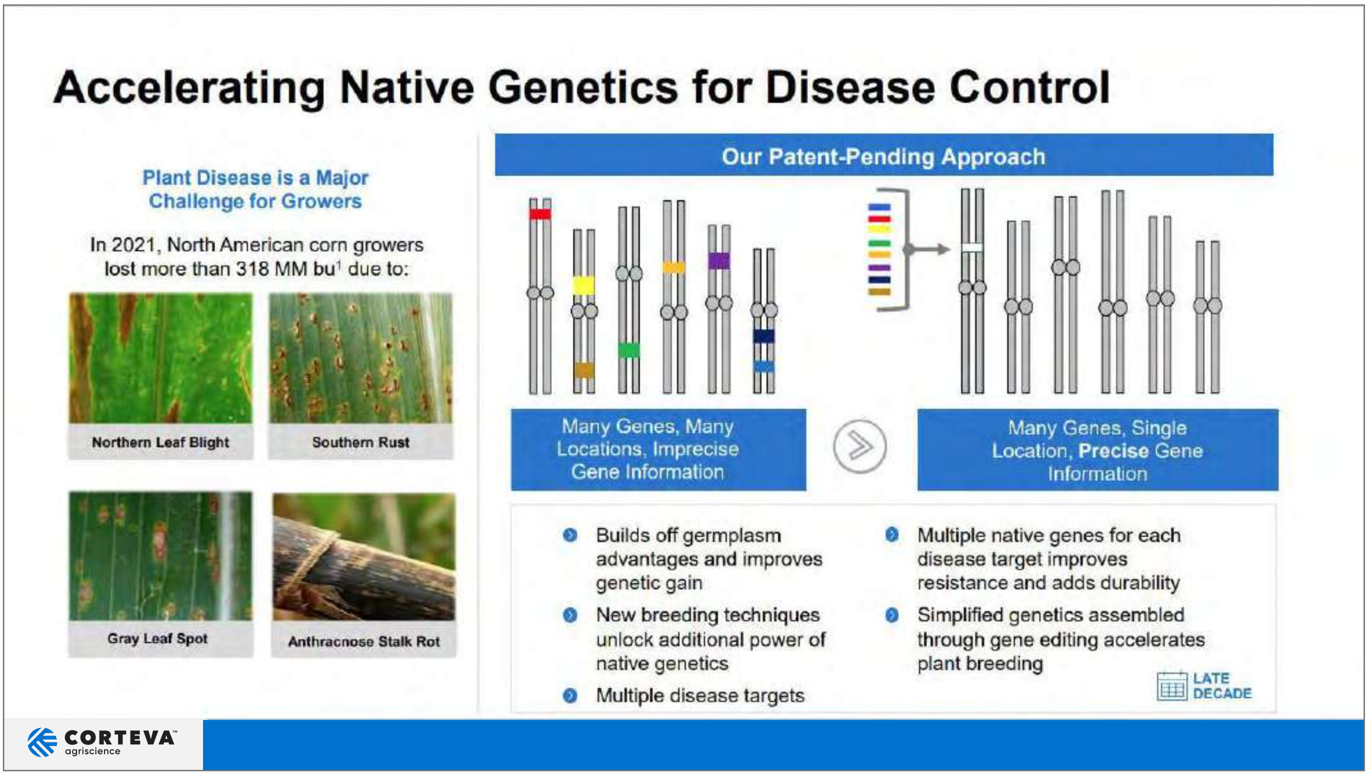

Native Genetics and CRISPR approach to Disease Control
Disease Resistance
No unintended donor genetics
100% A
Lower quality plant
Disease resistant
100% B
Higher quality plant
Disease sensitive
100% high quality plant
+
Improved resistance to Disease
CORTEVA
agriscience


Accelerating Native Genetics for Disease Control
Plant Disease is a Major Challenge for Growers
In 2021, North American corn growers lost more than 318 MM bu[1] due to:
Northern Leaf Blight
Southern Rust
Gray Leaf Spot
Anthracnose Stalk Rot
Our Patent-Pending Approach
Many Genes, Many Locations, Imprecise Gene Information
Many Genes, Single Location, Precise Gene Information
Builds off germplasm advantages and improves genetic gain
New breeding techniques unlock additional power of native genetics
Multiple disease targets
Multiple native genes for each disease target improves resistance and adds durability
Simplified genetics assembled through gene editing accelerates plant breeding
LATE DECADE
CORTEVA
agriscience

Genome editing and future potential – what if we could…go beyond plant breeding techniques and exceed current range of variation

- Chromosomal rearrangements (CR's) and potential to change phenotypes and "unlock" genetic variation (https://www.nature.com/articles/s41477-020-00817-6)
- Effective control of genomic recombination elements
- Enable co-location of native traits, unleashing major portions of the genome for improved maintenance of genetic diversity and additional favorable trait selection
- Multiple and simultaneous edits across numerous traits

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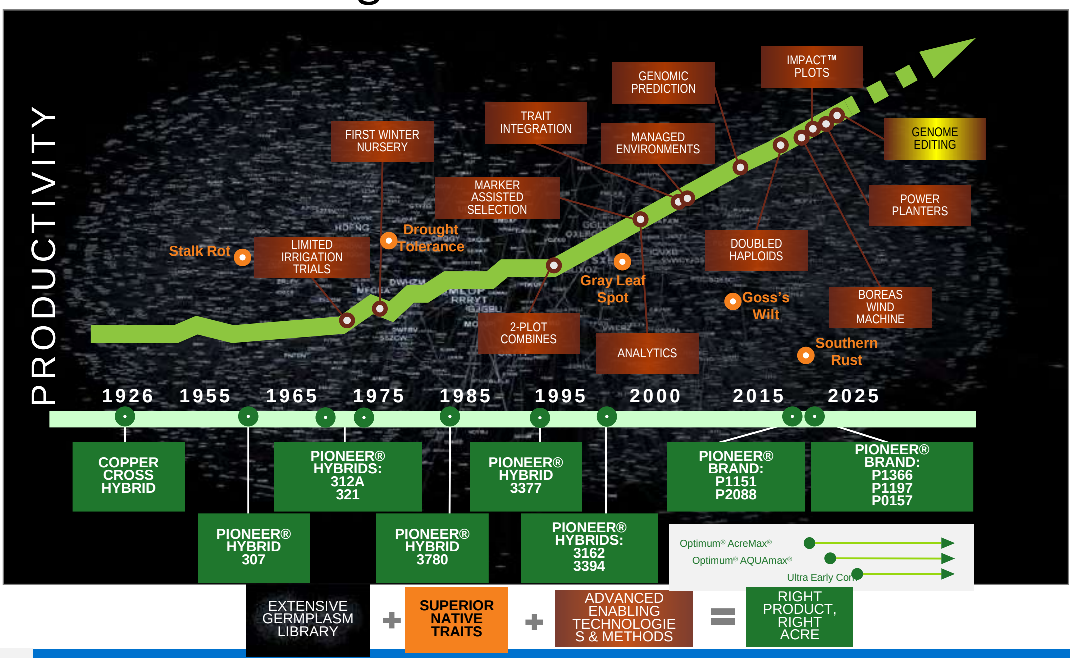
Will Genome Editing reside on this chart in 2070?



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Key Points

- Conduct plant breeding and pre-commercial product testing in the target environments for multiple years
- Genetic variation is essential to achieve breeding goals and mitigate climate change
  - Account for inevitable diversity decline over time
  - Leverage science and technology to create new favorable variation
- Plant breeding requires long-term selection, patience and adjusting breeding goals as the environmental pressures change over time
- Genome editing methods have potential for creating additional and needed variation to accomplish future environmental needs to feed a growing population
- Increased progress to minimize or eliminate biotic and abiotic stresses enables increased heritability and selection efficiency for grain yield improvement

CORTEVA agriscience

Thank you!

CORTEVA agriscience

12

QUESTIONS

TORO UGALDE Manuel (Mr.), Vice-Chair of the Administrative and Legal Committee, UPOV (moderator)

We have time for one question.

HUERTA Yolanda (Ms.), Legal Counsel and Director of Training and Assistance, UPOV

There is a question from Mr. Frederico Longhini from Lyon.

LONGHINI Federico (M.), Élève ingénieur agronome, ISARA-Lyon (Institut supérieur d'agriculture Rhône-Alpes), Lyon, France

First of all, I would like to thank you for having organized this webinar, and thank you for giving me the floor. I would like to address my question to Fernando Ortego Klose from Chile. I take advantage of the presence of the delegate from Argentina. And what about the link between Public-Private Partnerships (PPPs) in the Nordic countries? As far as markets are concerned and the southern coast of America, is there some kind of coordination for the protection of plant varieties? Thank you very much.

ORTEGA KLOSE Fernando (Mr.), Forage Plant Breeder, Chilean Agricultural Research Institute (INIA), Carillanca regional center, Chile (speaker)

Thank you, Frederico, for that question. Currently, we are engaged in exchanges with certain programs, for example, with regard to cereals and also with regard to rice, we have some cooperation programs. There is no cooperation on the other species, however. We have not yet been able to develop common agencies.

This did occur when we had the Mercado Común del Sur (Southern Common Market) (MERCOSUR) Network, which allowed us to have close cooperation between Chile and Argentina where we had in-depth exchanges. There are no other collaboration exchanges for the time being. Of course, we have technological exchanges but not in terms of plant varieties.

TORO UGALDE Manuel (Mr.), Vice-Chair of the Administrative and Legal Committee, UPOV (moderator)

Would anyone else like to ask a question? Can we take it that this chapter of our webinar is over?

THEMATIC SESSION 5:

Role of plant variety protection in the development of new varieties to mitigate and adapt to climate change

Moderator: Ms. Kitisri Sukhapinda, Patent Attorney, Office of Policy and Affairs (OPIA), United States Patent and Trademark Office (USPTO), United States of America

The role of PBR in plant breeding efforts to address climate change mitigation and adaptation. Example of Canada, including public sector breeding
Mr. Anthony Parker, Commissioner, Plant Breeders' Rights Office,
Canadian Food Inspection Agency (CFIA), Canada

Plant breeding and plant variety protection: a catalyst for developing climate smart crop varieties in Sub-Saharan Africa
Mr. Hans Adu-Dapaah, Expert, Crops Research Institute,
Council for Scientific and Industrial Research Institute (CSIR), Ghana

Plant breeding and plant variety protection for variety adaptation to the Japanese climate
Mr. Yasunori Ebihara, Director of Plant Variety Office, Intellectual Property Division, Export and International Affairs Bureau, Ministry of Agriculture, Forestry and Fisheries (MAFF), Japan

The role of plant variety protection in promoting development of crop varieties that adapt to, and mitigate, climate change. Example of Kenya
Mr. Simon Mucheru Maina, Head, Seed Certification and Plant Variety Protection,
Kenya Plant Health Inspectorate Service (KEPHIS)

Impact of the Community Plant Variety Rights system on the European Union economy and the environment
Mr. Francesco Mattina, President, Community Plant Variety Office (CPVO) and Mr. Nathan Wajsman, Chief Economist of the European Intelletual Property Office (EUIPO)

Questions (panel discussion)

Concluding remarks
Mr. Marien Valstar, President of the Council, UPOV

THE ROLE OF PLANT BREEDERS' RIGHTS IN PLANT BREEDING EFFORTS TO ADDRESS CLIMATE CHANGE MITIGATION AND ADAPTATION. EXAMPLE OF CANADA, INCLUDING PUBLIC SECTOR BREEDING

Mr. Anthony Parker
Commissioner, Plant Breeders' Rights Office, Canadian Food Inspection Agency (CFIA), Canada

This paper will discuss the role of Plant Breeders' Rights (PBR) in plant breeding efforts to address climate change, along with some examples from the Canadian context.

In Canada we have been observing the impacts of climate change for quite some time. Certainly, since the middle of the last century, we have been seeing an overall 1.7°C increase in temperatures. The warming is particularly exacerbated in the Canadian north with the thawing of permafrost and once permanently frozen areas. It is accelerating at a quicker speed, 2.3°C, and continues to move forward at an increased pace.

This is impacting our agricultural systems. The growing season is getting longer. The number of frost-free days has increased, so we are now seeing the migration of certain crops northward. We are able grow crops such as corn and soybean on expanded acres. The growing season used to be a limiting factor and that is no longer the case, and these crops are starting to displace some of our more traditional crops, cereals and canola.

We are also observing reduced precipitation later in the growing season; when this is coupled with higher temperatures, increased heat stress, it has a negative impact on yields. We are seeing more frequent spring flooding, more summer droughts, more extreme weather events. They are already happening right now, and they are going to increase over time. Additionally, a warmer climate brings new pests and diseases that previously did not thrive in our Canadian environment due to our cold winters, and these are now becoming more problematic.

I believe this picture in Figure 1 says it all, and this is not unique to Canada but is a common problem that every part of the world is now experiencing. The new normal is that nothing is normal anymore. The picture on the left was taken in the midst of the growing season in Canada's premier agricultural area, the Prairie Provinces, where 90% of all our agriculture activities are happening. It shows a farmer standing in a field of malting barley, with excellent growing conditions. At the time, they were estimating 100 bushels per acre, high quality malting barley perfect for brewing beer. What this picture does not show is that winter came earlier, much earlier than usual, essentially decimating the crop, resulting in lower quality, and downgrading the crop from malting barley to feed grade barley. So what looked like a perfect crop was affected by climate change and dramatic unpredicted weather. Move ahead one year to July 2020, the picture on the right shows the farmer in the same field, again growing barley, but in unprecedented drought conditions. Instead of 100 bushel per acre malting barley, this variety under extreme drought conditions yielded less than 10 bushels per acre.

In Figure 2, we move to May 2022, in Western Canada, and by this time all crops should be planted in the ground and starting to emerge. This is the picture of unprecedented flooding, with day after day after day of rain, preventing farmers from moving equipment onto their land and planting their crops. The good news is that the fields did eventually dry up, but planting was at least one month later than on average. What this illustrates, moving into the future, is that farmers need choices, they need options. They need a diversity of crop types, a diversity of different varieties within these crop types. In this particular case, when a farmer is initially thinking about planting a late season crop such as corn, once they are delayed in seeding, they look for earlier maturing varieties. They contact their seed company and look for different options. This is the first line of defense. If corn is no longer a viable option, the farmer must look for other shorter season options: soybeans, canola and, finally, cereals. Can the farmer find something that will work in a condensed growing season?

Of course, Canada is obviously not immune to climate change, and we are seeing agricultural disasters due to climate change all over the world, be it the recent floods in Pakistan, Afghanistan, or the drought conditions in the southwest of the US. It has now become ubiquitous and commonplace.

I wish to share with you one particular research project, linked to climate change adaptation, that we stumbled across the summertime that can demonstrate the interrelationship between PBR protection and developing new plant varieties. When our PBR Office was conducting our Distinctness, Uniformity and Stability (DUS) examinations in Western Canada, we noticed a massive robot vehicle combing back and forth over the field plots. We spoke to the researcher, an employee at a public research station, Agriculture and Agri-Food Canada (AAFC). AAFC is Canada's largest breeder of wheat varieties, and they were using digital imagery to assess all the wheat varieties they had bred over the past 120 years, examining them for their different phenotype characteristics. The digital imaging was revealing differences in plant canopy temperatures between different varieties, as well as differences in respiration rates and plant dehydration. Looking back in time, they are able to correlate periods of time where our Canadian prairies were under drought conditions, to varieties which were inadvertently being bred for drought tolerance. These older drought-tolerant varieties can be used as breeding material for introgression into more high performing varieties. So how does this connect to UPOV-based plant breed's rights? In this particular case, all varieties that are bred by this public research institution do seek PBR protection. For example: Article 14 of the 1991 Act of UPOV articulates the exclusive breeder's rights. AAFC exercises these exclusive rights for each one of its protected varieties, which secures the investments that were made by taxpayers and farmers directly into this breeding program. So the revenue they receive from sales, licensing and royalties are reinvested back not just into breeding but also into research activities to create a self-sustaining funding environment.

Furthermore, Article 15 (1) (II), the "researcher's exemption", allows and supports ongoing research and scientific publication and the dissemination of knowledge about the qualities of these specific varieties. The AAFC research about digital imaging will continue for a few years, then will likely be published in a scientific journal. That information will be available to others so they can make determinations if any of these varieties have useful characteristics for drought tolerance.

In addition, Article 15 (1) (III) is a further restriction on the breeder's rights, called the "breeder's exemption". This ensures that all PBR-protected varieties are available for breeding purposes. So it has a great public policy and public interest benefits; even though you may have intellectual property protection on a specific variety, that variety can now be used by others to introgress to other breeding programs, including those of competitors.

Therefore, if a variety has great characteristics concerning drought tolerance, those now can be moved into different breeding programs, and it does not matter whether it is public or private. Finally, we know that with forms of intellectual property protection, such as patents and plant breeders' rights, the exclusive monopoly that the inventor or the breeder has is finite. Article 19 puts time limits on the monopoly, but we know in reality, that monopoly is often surrendered muc h earlier than the term assigned.

In this particular instance with AAFC, the moment their varieties are unprotected, they are considered public domain and they deposit them in the International Treaty on Plant Genetic Resources for Food and Agriculture (ITPGRFA) Multilateral System, so they become available for others to use without restriction. I hope this demonstrates that critical link of using plant breeders' rights to support continuous efforts, breeding efforts, around addressing climate change.

I know in Canada, every single decision, either public or private, around pursuing breeding efforts to address climate change always has a component associated with IP protection. How do you protect that IP? How do you have the appropriate balances?

Some concluding thoughts from my perspective, supporting breeding efforts to address climate change mitigation and adaptation is a collective initiative. It requires input from farmers, breeders, both public and private, and policy makers. All actors play a critical role in ensuring that we have the appropriate levels and supports in place for breeding efforts to address climate change. From our perspective this PBR-based UPOV system already provides a framework to support these goals. It ensures that we have a proper balance between incentives and rewards for innovators, but equally, on the other hand, sufficient restrictions in place on the breeders' rights by way of exemptions that ensure that we have access to knowledge and scientific information on the use of protected varieties. In addition, we have the important exception to use protected varieties for breeding purposes.

Presentation made at the Seminar

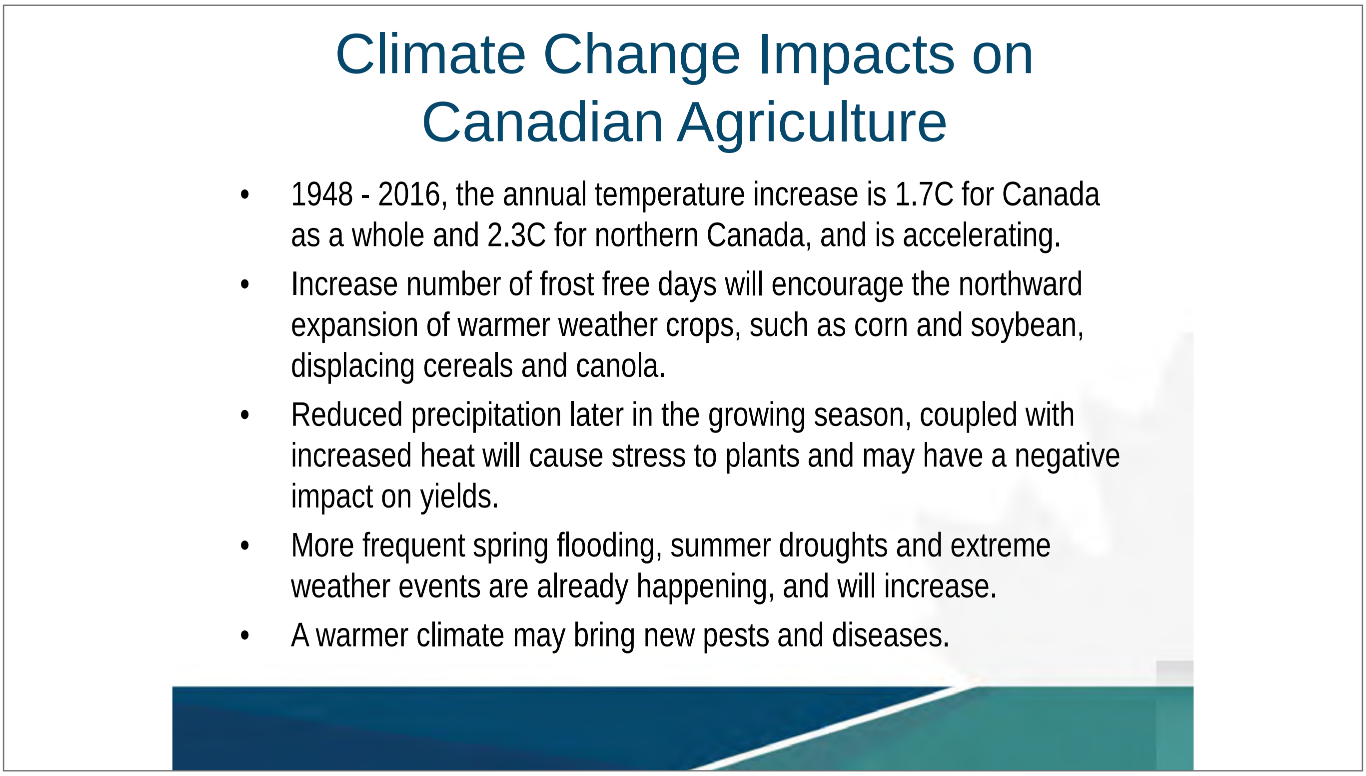

Figure 1: **Photo courtesy of CBC News – Shows AB farmer Richard Owen in the same field – In 2020, 100 bu/ac malting barley variety, in 2021 yielded less than 10bu/ac under extreme drought conditions*

Figure 2: **Photo courtesy of the Western Producer – Shows farmer's fields on May 15, 2022 in MB – a time that should be the peak of planting season,. Seeding delayed by over 1 month.*

Public Research

Example: Digital Imaging Technology and Plant Phenotyping of Wheat Varieties

- Research conducting plant phenotyping in publically bred wheat varieties released by Agriculture and Agri-Food Canada (public sector) since 1904 'Marquis' wheat.
- Many varieties bred during periods of drought in the Canadian Prairies: 1919-21, 1929-37, 1961, 1986-88, 1999-2005, 2021.
- Digital imagery reveals differences in plant canopy temperatures between varieties.
- Differences identified between varieties in respiration rates and plant dehydration.
- Historic drought tolerant varieties can be used as breeding material for introgression into modern high performing varieties

Linking to UPOV-based PBR

- All wheat varieties released by AAFC are PBR protected. Art 14. of UPOV secures the investments made by taxpayers and farmers. Royalties from sales and licensing are re-invested back into breeding and research, creating a self-sustaining funding environment.
- Art 15 (1) (ii) "researcher's exemption" supports ongoing research, and scientific publication, dissemination of knowledge about the qualities/attributes of specific varieties.
- Art 15 (1) (iii) "breeder's exemption" ensures that all PBR protected varieties are available for breeding purposes. Breeder's have information on varieties that are drought tolerant, and can access those varieties to introgress into their breeding program.
- Art 19, the breeder's right is finite. Unprotected varieties are "public domain", AAFC varieties deposited in ITPGRFA – MLS system.

Concluding Thoughts

- Supporting breeding efforts to address climate change mitigation and adaptation requires collective action, including; farmers, breeders (public and private), and policy makers. All actors play a critical role.
- UPOV-based PBR provides a framework to support these goals, ensuring the proper balance between incentives and rewards, and restrictions on the breeder's right by way of "exemptions", that ensure access to knowledge and the use of protected varieties for breeding purposes.

Thank you!

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PLANT BREEDING AND PLANT VARIETY PROTECTION: A CATALYST FOR DEVELOPING CLIMATE SMART CROP VARIETIES IN SUB-SAHARAN AFRICA

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ABSTRACT

Climate change and high population growth (projected to be t2wo billion in 2050) pose a threat to food and nutrition security in sub-Saharan Africa. Agricultural productivity in sub-Saharan Africa is low compared to the rest of the world due to biotic and abiotic stresses. Developing new varieties of crop plants is the most important strategy for adaptation and mitigation of agriculture to climate change. A number of improved crop varieties have been developed and released by the public and private breeding institutions in sub-Saharan Africa. These improved varieties with resistance/tolerance to biotic and abiotic stresses, enhanced nutritional qualities, nutrient-use efficiency and early maturity are commercialized without any royalties to the breeders or institutions who developed them. To enhance breeders' capacity and motivate them to respond to emerging climate challenges, it is essential that varieties developed by breeders are protected. Plant Variety Protection (PVP) under UPOV Convention 1991 provides a legal framework that gives exclusive rights to the breeders who develop the improved varieties. The paper outlines challenges militating against agricultural productivity in sub-Saharan Africa, breeders' response to these challenges, and provides some success stories of these improved varieties. It explains the concept of PVP as well as outlining how it can serve as catalyst for developing climate smart varieties to address climate change issues coupled with the benefits of PVP to the breeders in sub-Saharan Africa. It also deliberates on how PVP implementation in Kenya is enhancing the development of improved varieties. The paper established that if PVP is implemented well in sub-Saharan Africa, it would encourage investors to fund breeding activities on a sustainable basis, and urge the African Breeders' Association to champion the cause of PVP activities, to their benefit as well as other end-users.

KEYWORDS: climate change adaptation, developing countries, gene banks, genetic resources, policy

INTRODUCTION

Agriculture is one of the major sources of livelihood in sub-Saharan Africa, engaging on the average 60% of the working population. Aside from the labor force, Africa has over 60% of the world's unexploited arable land[1]. In spite of the vast resources, a quarter of Africa's population suffers from hunger and malnourishment. Agricultural productivity in sub-Africa is low compared to other parts of the world (Figure 1).

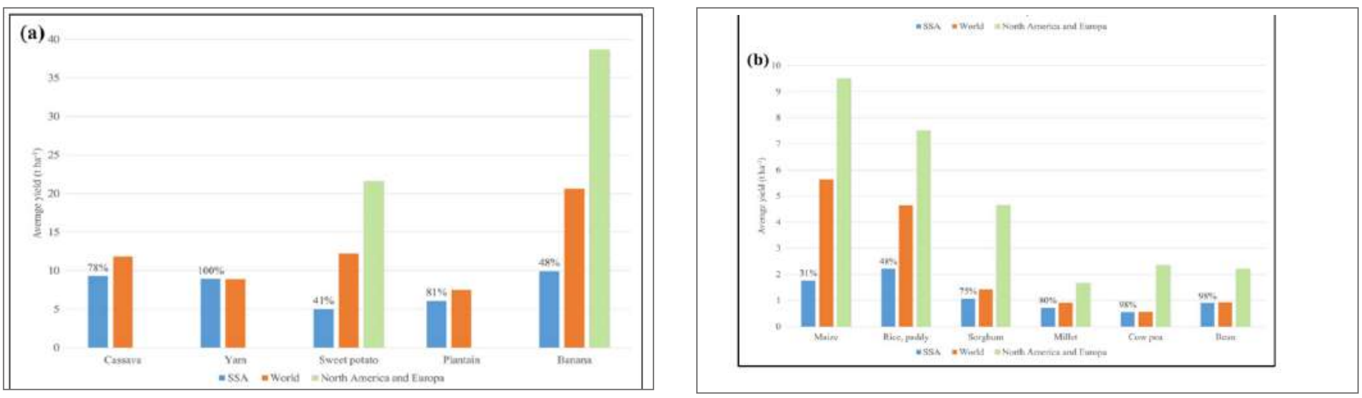

Figure 1. *(a) and (b) average yields (t/ha) of the 10 selected staple crops, for SSA, the world, and North America/Europe. SSA: sub-Saharan Africa (FAOSTAT, 2016).*

This may be attributed to rapid decline in soil fertility, increased complexity of pests and diseases, post-harvest losses and short shelf life of produce, inherent low yield of landraces, lack of labor during peak seasons, illegal mining activities destroying agricultural lands and water bodies, coupled with the adverse effects of climate change. Climate change and high population growth pose a threat to food security in West Africa, where economies are highly dependent on agriculture (CCAFS 2017). Global warming is predicted to exceed 2°C by the close of the century (Raffery *et al.* 2017) with crop productivity projected to fall by 5–10% per degree of warming. In sub-Saharan Africa, climate scenarios predict a temperature rise of up to 1.2 and 3.2°C by 2035 and 2100, respectively (Zougmoré *et al.* 2016). Temperatures in most areas have already exceeded the threshold for the growth and productivity of most of our food crops (Almazroui *et al.* 2017; Bucchignani *et al.* 2018). Smith and Myers (2018) stated that an increase in climate variability is affecting a number of food insecure communities and increasing atmospheric concentrations may affect the nutrient content of some staple crops, with consequences for food and nutrition security particularly in sub-Saharan Africa. Rainfall amounts and patterns have changed with shifts in the start of the rainy seasons, especially in the dryland areas (Berg and Sheffield 2018; Chadwick *et al.* 2016) resulting in low yields. The welfare of the people in sub-Saharan Africa is thus greatly threatened.

According to FAO (2019), Africa imported roughly US$81 billion worth of food in 2019. With an estimated population of 2 billion by 2050, food production in Africa will have to double, using limited resources. This is a wakeup call for African countries to improve crop productivity by embracing productivity-enhancing climate smart technologies and innovations. Climate smart agriculture (CSA) is defined by FAO (2010) as as agriculture that sustainably increases productivity, resilience (adaptation), reduces greenhouse gas (mitigation) and enhances achievement of national food security and development goals. The key pillars of CSA, according to Lippert *et al.* (2014) are adaptation, mitigation and food and nutrition security. Even though sub-Saharan Africa contributes less than 5% of Global Greenhouse Gas (GHG) emissions, the region is vulnerable to the negative effects of climate change because Africa's development prospects are linked due to over reliance on rainfall (Tol 2018). Climate smart agricultural technologies include breeding climate smart crops, efficient resource management, integrated renewable energy technologies for farming systems, resource conservation technologies, land use management, cropping season variation, efficient pest and disease management, forecasting and use of Geographical Information System (GIS) mapping.

To achieve food and nutrition security in sub-Saharan Africa by 2050, crop productivity has to be doubled or tripled, using limited resources. The need for increased productivity per unit area (intensification) cannot be overemphasized. Smart breeding to develop resilient crop varieties has a role to play. Over the years, the national agricultural research systems (NARS) in sub-Saharan Africa have developed and released a number of improved crop varieties using conventional breeding and biotechnological methods. Breeding initiatives by institutions in the various NARS and private breeding ventures in SSA have not yielded the expected dividends to the owners and breeders of these varieties. Plant varieties are living entities that could be produced unchanged by anyone, implying once a variety is released, it can be multiplied and commercialized without authorization from the breeder. This is a disincentive to the sustainable development of improved crop varieties to mitigate the effects of climate change. The absence of legal framework to protect the interest of breeders has resulted in people failing to recognize the investments and efforts of the breeders who developed these improved varieties. The purpose of PVP is to establish a legal framework to protect the rights of breeders of new varieties of plants or plant groupings. Plant Variety Protection seeks to promote the development of new varieties of plants with resistance and tolerance to biotic and abiotic stresses respectively.

Quality seed and other planting materials are the pillars of improved crop productivity. The promotion and adoption of PVP in sub-Saharan Africa would protect the emerging seed companies and public institutions involved in breeding as well as encourage innovation to address biotic and abiotic challenges emanating from climate change. This paper explores how breeders in sub-Saharan Africa are responding to climate challenges through innovative use of plant genetic resources. It further demonstrates some success stories of breeders in sub-Saharan Africa using conventional and biotechnological approaches and the need for smart breeding to fast-track the breeding process. In addition, it explains PVP and its importance as a catalyst for developing climate smart crop varieties to address climate challenges.

OVERVIEW OF VARIETY DEVELOPMENT AND RELEASE IN SUB-SAHARAN AFRICA

Variety development process involves:

(a) Pre-breeding activities, comprising the following: (i) preliminary studies to set breeding objectives (farmer survey, PRA and questionnaire administration and analysis); (ii) germplasm collection and introduction, on-station evaluation, selection of potential parents or germplasm to initiate the breeding process.

(b) Breeding activities include: establishment of crossing blocks, inbred line development (5–6 cycles of inbreeding/selfing per parental line), identification of potential inbred line parents for hybrid development (combining ability studies). Establishment of evaluation trials on-station and out-station in multiple locations, coupled with disease and pest assessment in hotspots. On-farm evaluation of selected genotypes from on-station multi-location trials. Sensory evaluation, physicochemical and economic analysis of potential varieties to justify their agronomic and economic superiority over existing varieties.

(c) Release and registration: Establishment of verification trials on-station, assessment by national variety release and registration committee (at both vegetative and reproductive phases of crop growth) coupled with presentation by the breeder on the progressive findings from the evaluations over the years. Recommendation to National Seed Council for release of varieties and subsequent registration in the national variety catalogue.

(d) Post-release activities: Seed increase of released varieties for dissemination.
Seed production commences from breeder seed, followed by foundation seed production and lastly certified seed production, generally done by private organizations. Dissemination activities include establishment of demonstration fields and publicity of the released varieties. Maintenance of released varieties to ensure continuous availability of germplasm (both cold room storage and field establishments) is also paramount. The sum total of the above activities would cost about US$30,000 per variety per year. A number of breeding institutions in sub-Saharan Africa depend on external donor support projects to develop and release improved crop varieties. This is not sustainable, especially with the advent of Covid-19, and the Russia-Ukraine war. Now most donors are concentrating on their respective countries. Budgetary support to public breeding institutions in sub-Saharan Africa is woefully inadequate, and in some cases governments pay only the salaries of breeders. Plant Variety Protection, which provides a legal framework to protect the breeders of new varieties of plants, may provide an incentive to entice private investors to invest in the breeding industry. This would assure breeders of a return on their investments and by so doing guarantee the development of new and improved varieties in sub-Saharan Africa on a sustainable basis to address climate challenges. Over the years, plant breeding has evolved based on new scientific knowledge coupled with the development of efficient tools/strategies to complement the development of new improved varieties to address emerging challenges due to climate change and climate variability. These challenges could be addressed if all the tools and strategies available to breeders are harnessed and utilized to enhance the development of climate smart crops bred to adapt to harsh and extreme weather conditions. Smart breeding is an integration of conventional breeding strategies with advanced molecular, genomic and phenomic tools to breed resilient crop varieties efficiently and effectively. The varieties should possess enhanced yield potentials and resistance to biotic and abiotic stresses with consumer-preferred traits. According to Eleblu *et al.* (2021), the array of tools and strategies available to the breeders include genetic resources conserved in situ, ex situ or in vitro; gene banks, diverse panels in national and international research centers, Bi-parental, Recombinant Inbred Lines (RILS), Nested Association Mapping, Multi-Parent Advanced Generation Inter-cross (MAGIC) as well as training populations. The next array of tools available to breeders are those that could be used to characterize, evaluate, detect, select and recommend for release to farmers and other end-users. The first-generation breeding tools include domestication/selection, hybridization, as well as vegetative propagation techniques. The second-generation breeding tools include in vitro propagation techniques, organogenesis and embryo rescue, anther culture, somaclonal variation, in situ conservation, in vivo dissection and analysis. The third-generation breeding tools include molecular biology tools, QTL mapping, marker-assisted breeding, sequencing, targeting induced local lesions in genomes. The fourth-generation breeding tools are next generation sequencing, genome aided breeding, epigenetics, transcriptomics, gene expression regulation, metabolics, proteomics, gene editing and comparative genomics. It is worthy to note that the third and fourth generation breeding tools outlined above add speed and precision to the myriad of breeding tools currently available to fast track the development of improved climate smart crops for adaptation and mitigation to climate change. The need to evaluate each climate change scenario with the view to deciding on appropriate strategies to use based on available tools and resources cannot be over-emphasized.

SOME SUCCESS STORIES OF PLANT BREEDING ACTIVITIES IN SUB-SAHARAN AFRICA

A number of improved crop varieties have been developed and released by both public sector breeding institutions and private sector seed companies in sub-Saharan Africa using both conventional and biotechnological methods. These improved varieties are resistant/tolerant to biotic and abiotic stresses with consumer-preferred attributes. Drought/heat-tolerant maize, cowpea, sorghum, millet, tomato, groundnut, cassava, beans, rice, etc. with enhanced levels of pro-vitamin A, lysine and tryptophan, iron and zinc have been developed to mitigate the effects malnutrition in sub-Saharan Africa. Nutrient use efficient (nitrogen and phosphorous) crop varieties of maize, rice, cowpea, etc. have also been developed. Aflatoxin-tolerant maize, groundnut and other crop varieties as well pests and diseases resistant crops have been developed by breeders in sub-Saharan Africa. Others include vegetables such as tomato, pepper and cocoyam. Below are some selected examples of improved varieties to buttress the good work done by some breeders in sub-Saharan Africa. An improved groundnut variety resistant to the devastating nature of groundnut rosette virus (Figure 2), improved cowpea variety resistant to bacteria blight and anthracnose, improved drought-tolerant maize and rice varieties compared to farmers' varieties developed by breeders in Ghana, first ever open-pollinated pepper and tomato varieties with good yields, high brix and tolerance to early and late blight are presented below.

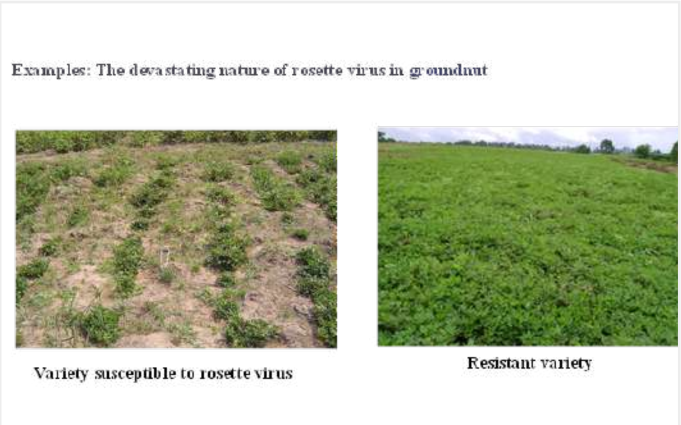

Figure 2. The devastating nature of rosette virus in groundnut.

Figure 3. Improved cowpea variety compared with farmers' variety.

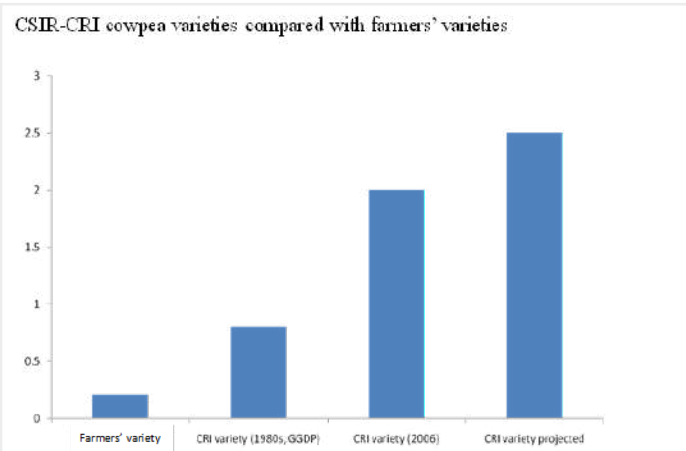

Figure 4. CSIR-CRI cowpea varieties compared with farmers' varieties.

Figure 5. CSIR-CRI developed high-yielding drought-tolerant maize variety.

Figure 6. Effect of flooding.

Figure 7. CRI-Kwabena Kwabena tomato variety released by CSIR-CRI, Ghana.

Figure 8. KOPIA tomato variety released by CSIR-CRI, Ghana.

Figure 9. "Taro" varieties released by CSIR-CRI, Ghana.

PEPPER VARIETIES RELEASED IN GHANA

The first released varieties of pepper in Ghana are "Shito Adope" and "Maakontose" by CSIR-CRI. "Shito Adope" is very hot and has short growth habit but is very prolific (high yielding), yielding as much as 30t/ha. "Maakontose", on the other hand, is mild or, better put, it as not hot at all and so it can be used to substitute tomato in homes where there are no tomatoes (i.e. it can perform similar role as tomato), and also gives 35t/ha, far more than farmers' yield, of 8.3 t/ha.

PRIVATE SECTOR PARTICIPATION IN PLANT VARIETY DEVELOPMENT AND SEED DELIVERY

The major objective of any business venture is to make a profit and the seed industry is no exception. Before entering the plant variety development and seed industry business in sub-Saharan Africa, one needs to consider the following:

- State clearly the objectives for entering into plant variety development and seed delivery enterprise.
- Understand the process of developing improved plant varieties, engage a competent breeder, or collaborate with relevant institutions having technical capacity.
- Know the seed delivery system you would want to operate.
- Develop a bankable business plan to access funding.
- Acquire infrastructure and other assets for quality seed production.

- Know the seed laws in sub-Saharan African countries and associated regulations that deal with improved seed.
- Identify a reliable market for the produce-improved seed of the released varieties.
- Know the theory and practice of basic seed production techniques, conditioning and marketing.
- Know about the PVP Acts in the respective countries and their accompanying regulations.
- Know the variety of release and registration processes in the respective countries.
- Plant variety development and seed delivery is dynamic, so be prepared to network in-country and within sub-Saharan Africa (Adu-Dapaah 2021).

PLANT VARIETY PROTECTION SYSTEM

- The adoption of the Agreement on Trade Related Aspects of Intellectual Property Rights (TRIPS) required that contracting parties protect plant varieties either by patents or by an effective *sui generis* system of protection or by a hybrid of these two systems (Article 27.3b). Patents and plant breeders' rights (PBR) are separate intellectual property rights with different conditions of protection scope and exceptions. Breeders can use PBR or patents to the extent that such systems are available in the territory concerned. Most countries in sub-Saharan Africa are using an effective sui generis system of protection.
- Plant Variety Protection is a form of intellectual property right that seeks to grant plant breeders exclusive right to the varieties they develop. It aims at ensuring that new varieties become available, breeders have access to foreign varieties, genetic diversity is sustainably used, export trade is supported by developing varieties that meet international standard and breeders have value for the varieties they develop.

Sub-Saharan Africa has two regional bodies operating plant breeders' right systems based on the UPOV Convention 1991. These are:

(i) African Intellectual Property Organisation (OAPI), covering the territory of its 17 member states (Benin, Burkina Faso, Cameroon, Central African Republic, Chad, Comoros, Congo, Cote d'Ivoire, Equatorial Guinea, Gabon, Guinea, Guinea Bissau, Mali, Mauritania, Niger, Senegal, Togo). OAPI is a member of the UPOV Convention, 1991.

(ii) African Regional Intellectual Property Organisation (ARIPO) is one of the intergovernmental organizations that have initiated the procedure for acceding to the UPOV Convention. The member states of ARIPO (19) are Botswana, Gambia, Ghana, Kenya, Lesotho, Liberia, Malawi, Mozambique, Namibia, Rwanda, Sao Tome & Principe, Sierra Leone, Somalia, Sudan, Swaziland, Uganda, United Republic of Tanzania, Zambia, Zimbabwe.

BENEFITS OF A REGIONAL PVP SYSTEM

For the national authorities and examination offices: Less administrative work for national authorities, close

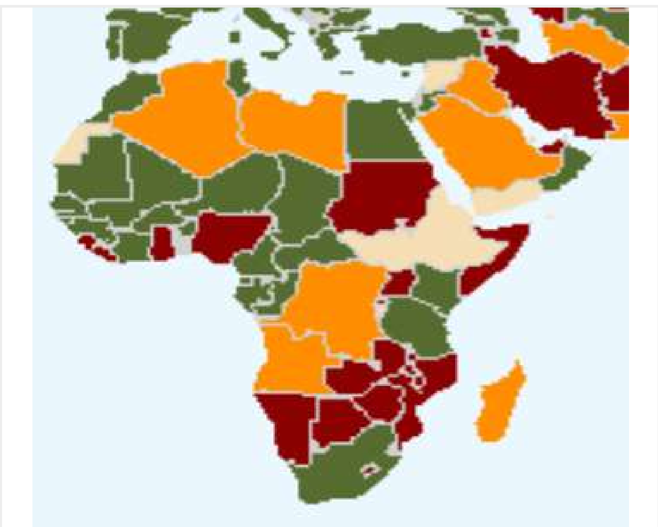

Figure 10. *A map showing UPOV member countries in sub-Saharan Africa.*

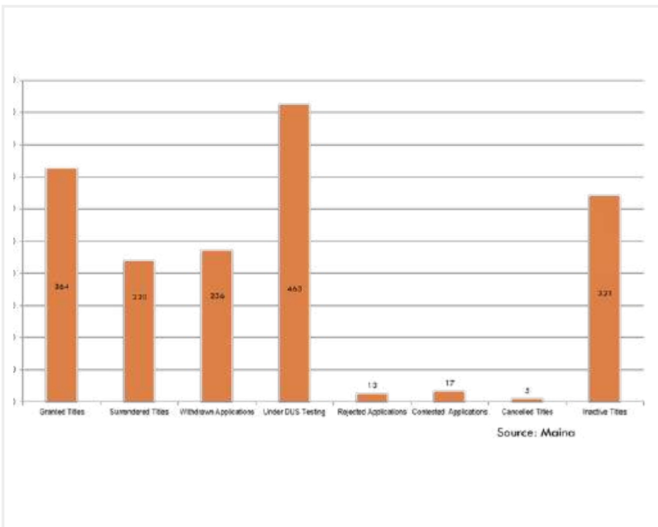

Figure 11 *PVP implementation in Kenya*

cooperation on a technical level, efficiency gains through cooperation, harmonization of practices and financial income for conducting DUS examinations on behalf of ARIPO/OAPI.

Benefits for sub-Saharan Africa: Strong voice within the international community, strong counterparts for stakeholders, high budgetary solvency and sustainability, cooperation in DUS testing and exchange of DUS test reports in sub-Sahara African and among UPOV countries.

WHO CAN APPLY FOR PLANT VARIETY PROTECTION?

Article I (IV) of the UPOV Convention defines a breeder as the person who bred or discovered and developed a variety; the person who is the employer of the aforementioned person or who has commissioned the latter's work where the laws of the relevant contracting party so provides; the successor in title of the first or second aforementioned person, as the case may be. It is important to note that the concept of a person embraces both physical persons and legal persons (i.e., companies). The breeder might be, for example, an amateur gardener, a farmer, a scientist, a plant breeding institute or an enterprise specializing in plant breeding.

Conditions for granting a breeder's right
Article 5 states the conditions to fulfil before protection is granted. The breeder's right shall be granted where the variety is: (I) new, (II) distinct, (III) uniform and (IV) stable. The variety to be protected must have a designated denomination in accordance with the provisions of Article 20.

Scope of breeders' rights
The UPOV Convention (see Article 14 (link to UPOV Convention)) specifies the acts in respect of the propagating material (e.g., seed, bulbs, tubers, cuttings, etc.) of a protected variety, which require the prior authorization of the breeder. Those acts are the following: production or reproduction (multiplication), conditioning for the purpose of propagation, offering for sale, selling or other marketing, exporting, importing and stocking for any of the above purposes.

Exceptions to the plant breeder's rights are: acts done privately and for non-commercial purposes; acts done for experimental purposes and acts done for breeding other varieties, and, except where the provisions of Article 14(5) apply, acts referred to in Article 14(1) to (4) in respect of such other varieties.

Measures regulating commerce
Article 18 of the UPOV Convention requires that the plant breeder's right shall be independent of any measure taken by a contracting party to regulate within its territory; the production certification and marketing of material of varieties or the importing or exporting of such material. PVP recognizes that there should be a particular type of level of market regulation dealt with by an appropriate, dedicated and independent mechanism different from PVP.

DURATION OF PLANT BREEDERS' RIGHTS

- The duration of the plant breeder's rights as regards varieties of trees and vines, expires 25 years after the grant of the breeder's right.
- The protection of all genera and species expires 20 years after they have been granted.

The UPOV Report on the Impact of Plant Variety Protection[2] demonstrated that in order to enjoy the full benefits of plant variety protection, both implementation of the UPOV Convention and membership of UPOV are important. The introduction of the UPOV system of plant variety protection and UPOV membership were found to be associated with increased breeding activities, greater availability of improved varieties, increased number of new varieties, diversification of types of breeders (e.g., private breeders, researchers), increased number of foreign new varieties, encouragement of the development of a new industry competitiveness on foreign markets and improved access to foreign plant varieties and the enhancement of domestic breeding programs.

The UPOV system of Plant Variety Protection can be a catalyst for the development of climate smart crop varieties to mitigate the adverse effects of climate change due to the following benefits:

- Encourages the breeding of new varieties – enabling farmers to respond to the environmental and economic challenges confronting agriculture.

- Provides farmers and growers with access to the best local and global varieties.
- Enables a variety choice to be combined with information and delivery of good quality planting material.
- Offers a tool for capturing value through farmers and breeders.
- Facilitates 'win-win' cooperation between farmers and breeders.
- Provides business opportunities for small farmers and growers.
- Has the potential to be even more effective through improvements in implementation.
- Provides an incentive for farmers and growers to become breeders.
- Enables any farmer or grower to use the best available protected varieties for breeding work.
- Offers an effective and transparent system that is easily accessible for small and medium-sized enterprises.
- Enables farmers and growers to develop local, national and international businesses.
- Empowers farmers and growers in the production chain.[3]

Specific benefits of plant breeders' rights to the breeder include the following:

- Breeders' investments and efforts would be recognized through payment of royalties for the sustainability of the breeding process.
- Breeders have access to valuable foreign germplasm to be used in their breeding programs (breeders' exemption).
- Enables transfer of technology and effective utilization of genetic resources.
- Promotes the growth of the seed industry and create demand for improved varieties to mitigate the adverse effects of climate change.
- Fosters partnerships between public and private breeding.
- Provides incentive to stimulate new breeding initiative.
- Barriers to trade in varieties will be removed, thereby increasing both domestic and international market scope.

It is worthy of note that the formation and launching of African Plant Breeders' Association in 2019 with branches in countries in sub-Saharan Africa is a positive development for the sensitization and promotion of PVP in Africa. Other end users such as farmers would benefit from PVP through the provision of improved varieties with improved yields, resistance/tolerance to pests and diseases, tolerance to drought, heat, flooding, nutrient use efficient crop varieties, variety diversity, input efficiency, improved crop quality, new markets and ultimately increased profitability as well as improved livelihoods. Consumers would also benefit from efficient implementation of PVP through reduction in food cost, varieties with enhanced nutritional quality, efficient land use, improved taste and storage quality as well as diversity of products.

CASE STUDY ON PVP IMPLEMENTATION IN KENYA

PVP Implementation in Kenya

1,661 applications for PVP received by October 2018, local (Kenyan) = 31.21% applications, foreign = 68.79% applications. Local applicants are from public institutions = 80.55%, private institutions = 19.4%.

Impact of PVP in Kenya

Employment creation: estimated at over 500,000 people (including over 100,000 flower farm employees) dependent on the horticulture industry. Increase in introduction of crop varieties as a result of enhanced variety description – the latter made possible by: (I) readily available UPOV test guidelines for most agricultural crops; (II) personnel trained by UPOV on the development of national test guidelines; (III) collaborations and cooperation between the breeders and the testing authorities on variety description. (IV) Increased interest in Kenya by foreign breeders (Breeders outside Kenya submit their varieties in the national protection system);(V) International breeders have incorporated their companies domestically to produce and market their varieties; (VI) Capacity building, funding, germplasm exchange and commercialization of varieties enhanced.[4]

CONCLUSIONS

The PVP system is a positive development that seeks to address the interests of plant breeders and other stakeholders along the seed value chain. The benefits of the Act cuts across several sectors of the economies of sub-Saharan African countries and will promote national development. The PVP has an enormous potential to improve productivity and the seed system, protect genetic diversity, and empower farmers to access new markets and attract private sector investments in plant breeding. Aggressive and targeted sensitization of the key provisions should be pursued by countries in sub-Saharan Africa, with members of the African Plant Breeders' Association at the forefront. Development of Institutional IP Polices by the NARS conducting research in plant science should be pursued by NARS in sub-Saharan Africa. Sustainable funding for variety development and the release of new and improved varieties to meet the needs of all actors along the respect crop value chains cannot be over-emphasized.

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Presentation made at the Seminar

PLANT VARIETY PROTECTION: A CATALYST FOR DEVELOPING CLIMATE SMART CROP VARIETIES IN SUB-SAHARAN AFRICA

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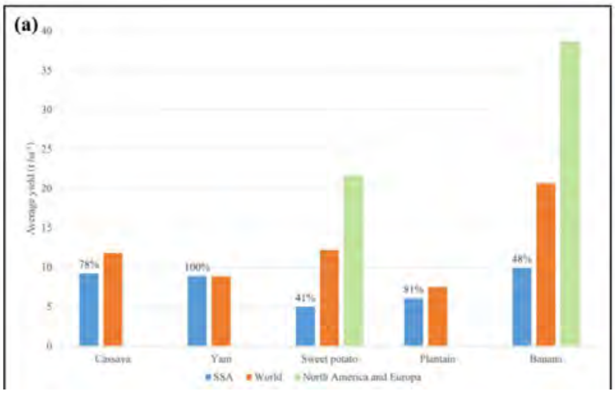
Introduction

- As Africa's population continues to grow(projected to be 2b by 2050) and arable land and other resources become scarce, there is the need to increase agricultural productivity (i.e. increase yields and quality using less input).

Introduction

Agricultural productivity in Africa is low compared to other parts of the world



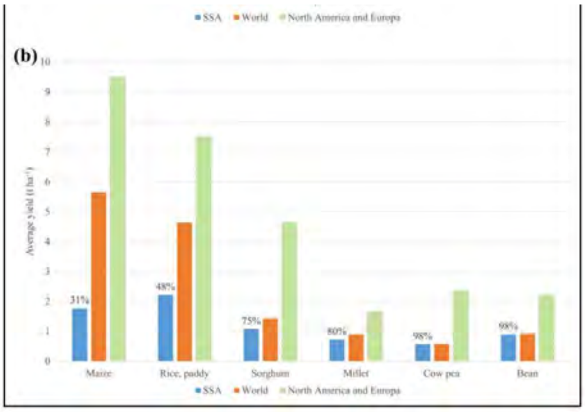


Figure 1(a) and (b) average yields (t/ha) of the 10 selected staple crops, for SSA, the world, and north America/ Europe. FAOSTAT, 2016. SSA: sub-Saharan Africa.

Challenges to agricultural production in Africa

- Rapid declining soil fertility (especially nitrogen)
- Increased complexity of pests and diseases of crops.
- Postharvest losses and short shelf- life of produce

- Inherent low yields of crops
- Lack of labour
- Bush fires leading to
- Loss of biodiversity

- Ecological concerns
- Illegal mining activities destroying agricultural lands and water bodies and distorting ecologies
- Loss of biological diversity
- Land constraints

Achieving food & nutrition security in 2050

- Africa imported roughly $81b of food in 2019. The continent's food demand will double in the next decade.
- Crop production will have to double/triple by 2050, using limited resources (land, water, nitrogen etc.)
- Need to increase productivity per unit area (intensification)
- Smart breeding has a role to play to achieve food and nutrition security.

- Over the years the national agricultural research systems(NARS) in SSA have developed and released a number of improved crop varieties.
- Most of these varieties are being commercialised without any return on investment to the breeders who developed them.
- Funding for sustainable development of climate smart crop varieties is difficult to come by in SSA.
- PVP, when well implemented may be a catalyst for sustainable development of CSCV, since it will attract investors.

- Pre-breeding: germplasm assembly, characterisation, evaluation, selection of potential parents for breeding
- Breeding: cross, evaluate, select, evaluate multiple sites, release
- Release & registration: Assessment and release by NVRRC at vegetative and maturity stages
- Post release: seed increase, disseminate, maintenance breeding

- Smart breeding is an integration of conventional breeding strategies with advanced molecular, genomic and phenomic tools to efficiently and effectively breed resilient crop varieties.
- The varieties should possess enhanced yield potential, resistant to biotic and abiotic stresses with consumer- preferred traits.
- There are array of tools and resources available to the breeder.
- These tools and resources include the following:

- Genetic resources conserved in situ,or in vitro; gene banks, core and representative collections, diverse panels in research centers, bi-parental, recombinant inbred lines, nested association mapping, advanced generation inter-cross(MAGIC), &

training populations.

As well as those that can be used to characterise, evaluate, select and release to end-users.

The first generation breeding tools include domestication/selection, hybridization, as well as vegetative propagation techniques

- The 2nd generation breeding tools include: in vitro propagation techniques, organogenesis &embryo rescue, anther culture, somaclonal variation, in situ conservation and in vivo dissection and analysis.

- The 3rd generation B/Ts : molecular biology tools, QTL mapping, marker assisted breeding, sequencing, targeting induced

local lesions in genomes.

The 4^{th} generation B/Ts: next generation sequencing, genome aided breeding, epigenomics, transcriptomics, gene expression regulation

- Metabolomics, proteomics, gene editing & comparative genomics.
- The third & fourth generation tools outlined above add speed and precision to the array of tools currently available to fast track the development of improved climate smart crops.
- The need to evaluate each climate change scenario with the view to decide appropriate strategies to use based on available tools and resources cannot be over-emphasised.

Achievements

Examples: The devastating nature of rosette virus in groundnut

Variety susceptible to rosette virus

Resistant variety

Achievements

CSIR-CRI developed high-yielding drought tolerant maize variety

Etubi Hybrid

Local Var

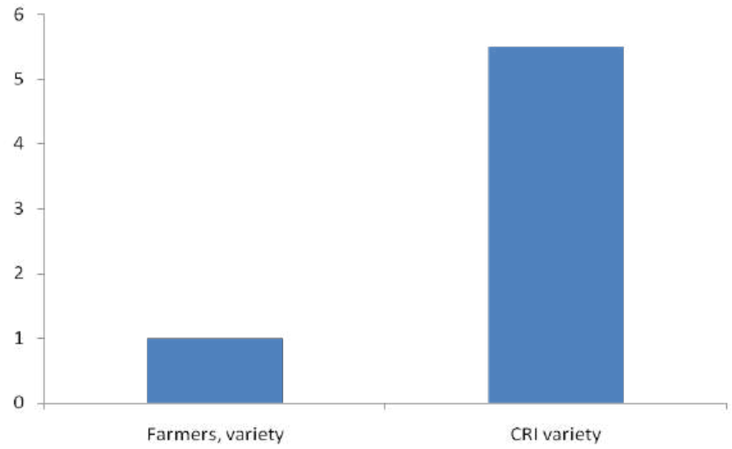
Etubi Hybrid

Achievements

Effect of flooding

Achievements

CSIR-CRI rice varieties compared with farmers varieties



PLANT VARIETY PROTECTION SYSTEM

- The adoption of agreement on Trade Related Aspects of Intellectual Property Rights (TRIPS) required that contracting parties protect plant varieties either by **patents or by an effective *sui generis* system of protection or by a hybrid of these two systems. (**Article 27),3b) Patents and plant breeders rights are separate intellectual property rights with different conditions of protection scope and exceptions.

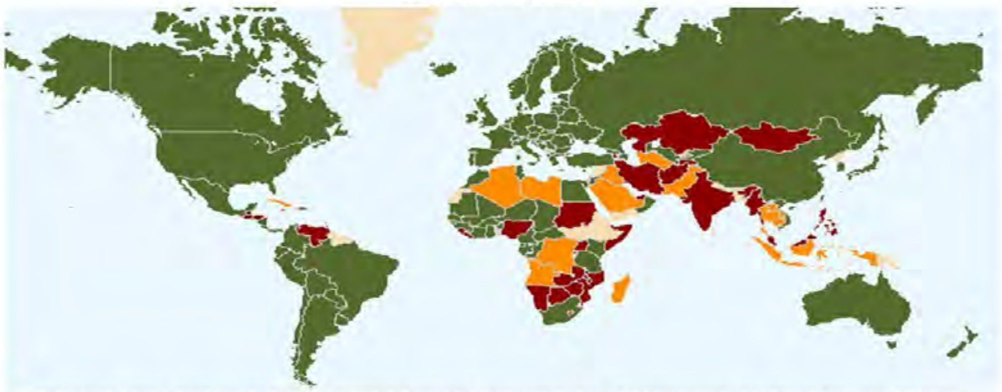
What is a Plant Breeder's Right?

- Plant Breeders' Right is a form of intellectual property right that seeks to grant plant breeders exclusive right to the varieties they develop.

- Plant Breeders Right aims at making sure that:
  - New varieties become available to society
  - Breeders have access to foreign varieties
  - Genetic diversity will be used sustainably
  - Export trade is supported

UPOV STATUS

on November 3, 2021



The boundaries shown on this map do not imply the expression of any opinion whatsoever on the part of UPOV concerning the legal status of any country or territory

- Members of UPOV (78) (covering 97 States)
- Initiating States (19) and Organization (1)
- States (22) and Organization (1) in contact with the UPOV Office

UPOV

SCOPE OF BREEDER'S RIGHT

- Those acts are the following:
- Production or reproduction (multiplication)
- Conditioning for the purpose of propagation
- Offering for sale
- Selling or other marketing
- Exporting
- Importing
- Stocking for any of the above purposes

EXCEPTIONS TO THE PLANT BREEDER'S RIGHT

- The UPOV Convention establishes compulsory and optional exceptions.
- **Compulsory exceptions**
- UPOV members must provide for these exceptions. The compulsory exceptions are established in Article 15(1):
- Acts done privately and for non-commercial purposes;
- Acts done for experimental purposes and
- Acts done for the purpose of breeding other varieties, and, except where the provisions of Article 14(5) apply, acts referred to in Article 14(1) to (4) in respect of such other varieties
- **Optional exceptions**
- Farm safe seed

BENEFITS UPOV SYSTEM OF PLANT VARIETY PROTECTION

- Encourages the breeding of new varieties – enabling farmers to respond to the environmental and economic challenges confronting agriculture.
- Provides farmers and growers with access to the best local and global varieties
- Enables variety choice to be combined with information and delivery of good quality planting material
- Offers a tool for capturing value through farmers and breeders

BENEFITS CONT'D

- Enables any farmer or grower to use the best available, protected varieties for breeding work
- Offers an effective and transparent system that is easily accessible for small and medium –sized enterprises
- Enables farmers and growers to develop local, national and international businesses
- Empowers farmers and growers in the production chain

CASE STUDY

- PVP Implementation in Kenya
- Status of Plant Variety Protection
- A total of 1639 applications for PVP received by April 2018
- Local (Kenyan) = 31.21% applications
- Foreign = 68.79% applications
- Local applicants are from:
- Public institutions = 80.55%
- Private institutions =19.45 %

Impact of PVP in Kenya

- Employment creation: estimated at over 500,000 people (including over 100,000 flower farm employees) depend on the horticulture industry.

- Increase in introduction of crop varieties as a result of enhanced variety description- the latter made possible by: (i) readily available UPOV test guidelines for most agricultural crops (ii) Trained personnel by UPOV on development of national test guidelines (iii) Collaborations and cooperation between the breeders and the testing authorities on variety description.

CONCLUSION

- The PVP system is a positive development which seeks to address the interests of plant breeders and other stakeholders along the seed value chain.
- The benefits of PVP cuts across several sectors of the economies of sub-Saharan African countries and will promote national development.
- The PVP has an enormous potential to improve productivity, the seed system, protect genetic diversity, and empower farmers to access new markets and attract private sector investments in plant breeding.

CONCLUSION

- The formation of African Plant Breeders Association in 2019 with branches in most African countries is a positive development for PVP implementation in SSA.

PLANT BREEDING AND PLANT VARIETY PROTECTION FOR VARIETY ADAPTATION TO THE JAPANESE CLIMATE

Mr. Yasunori EBIHARA,
Director of Plant Variety Office, Intellectual Property Division, Export and International Affairs Bureau, Ministry of Agriculture, Forestry and Fisheries (MAFF), Japan

IMPACTS OF CLIMATE CHANGE ON AGRICULTURAL PRODUCTS

Climate change has a variety of adverse effects, including rising temperatures, increased extreme rainfall and rising sea levels. Among these effects, rising temperatures have particularly severe impact on agricultural production. It is predicted that high temperatures cause poor growth of cereals and skin coloration disorder, which lead to the change in suitable area for cultivation. For example, within 40 years, the southern part of Japan will be no longer suitable for apple growing, and the cultivation area for apple is expected to move further north. The same situation is predicted in other agricultural products.

Global warming is also affecting quality of our staple food, rice. High temperature decreases the amount of starch deposited in a mature grain and the grain goes white, which means the quality of rice is significantly diminished. Such poor growth problems are becoming more common.

In addition, heat causes disorder in coloring and fruit-setting in fruit trees. Marketability is significantly reduced by insufficient or delayed red coloring when apples are exposed to extreme heat. Fruit growth defects as well as poor coloring are also reported for grapes.

NEW PLANT VARIETIES TO ADAPT TO CLIMATE CHANGE

Varieties tolerable for heat stress are being developed in Japan. For example, new varieties of rice have been developed which show little disorder under heat conditions. The rice variety “Niji no Kirameki” contains less immature grain compared to the traditional popular variety “Koshihikari”. Such heat-tolerant varieties are appreciated by farmers. New fruit varieties characterized with good coloration even in heat conditions have been developed. The new impatiens variety “SunPatients” is tolerant under strong sunlight and heat.

New breeding techniques such as genome editing are used to develop pre-harvest sprouting- tolerant wheat. The wheat is expected to prevent significant decline in yield and quality when rainfall occurs.

Recognizing new plant varieties is the key to adapting to global warming. Japan is developing a “Smart breeding system” that integrates big data on phenotype-genotype and new breeding techniques to facilitate the development of new plant varieties. Varieties adapted to climate change are our assets, and foster international competitiveness in the agricultural sector, while the Plant Variety Protection (PVP) system is the basis of encouraging development of new plant varieties.

STRATEGY OF PLANT VARIETY PROTECTION

It took as many as 33 years to develop the new Japanese grape variety “Shine Muscat”, and 13 researchers have been engaged on this project in the last 18 years. Thanks to its good quality, the market price is twice as high as the other grape varieties’ prices, contributing to an increase in farmers’ income. However, when this variety was released, the breeder did not acquire the plant breeders’ rights (PBR) abroad. As a result, “Shine Muscat” has spread widely, without protection, in Asia against the breeder’s intention. This means that farmers in Japan are losing out in the export market for the original “Shine Muscat”. Stakeholders in Japan recognize the importance of the PVP system and need to strengthen the system as well as to accelerate plant breeding.

The Ministry of Agriculture, Forestry and Fisheries developed “MAFF’s Intellectual Property Strategy 2025” in 2021. The strategy provides the direction of Japan’s IP Policy clearly. The following three initiatives address the unintended outflow of protected varieties:

- amendment of Plant Variety Protection and Seed Act to strengthen the PVP system;
- raising awareness and support for the protection of Japanese varieties overseas
- enhancement of cooperation in PVP in Asia.

With regard to cooperation, Japan has promoted PVP cooperation together with UPOV and the East Asia Plant Variety Protection Forum (EAPVP Forum). Japan has committed to contribute to build “e-PVP Asia”, which is a cooperation platform aiming to provide services to enhance the efficiency of the filing and administration of breeders’ rights’ applications and grants in e-PVP Asia participating countries, and to enhance cooperation in Distinctness, Uniformity and Stability (DUS) examination between participating countries. Thus, “e-PVP Asia” will assist both breeders and PVP authorities of UPOV members in Asia. Japan believes that e-PVP Asia will strengthen the PVP system in Asia and provide greater opportunities for farmers to benefit from new plant varieties.

Presentation made at the Seminar

Plant breeding and PVP for variety adaptation to the Japanese climate

Yasunori Ebihara
Plant Variety Protection Office, Intellectual Property Division
Export and International Affairs Bureau
MAFF of Japan

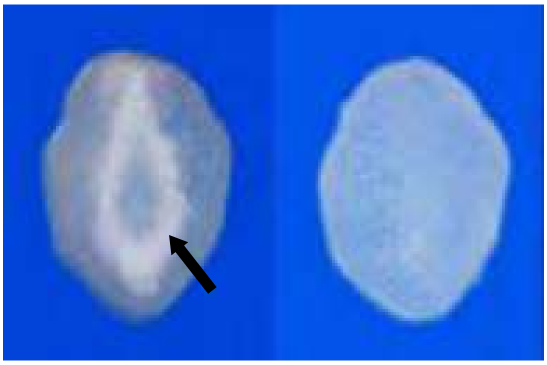
12 Oct 2022

Introduction

- As Africa's population continues to grow(projected to be 2b by 2050) and arable land and other resources become scarce, there is the need to increase agricultural productivity (i.e. increase yields and quality using less input).

Impacts of Climate Change on agricultural products

Rice



Immature starch formation in grain due to high temperatures.

Apple

Poor or delayed coloring of fruit due to high temperature

Deterioration of fruit quality reported in other fruits (grapes, peaches, etc.)

3

New plant varieties are key to adapt to Climate Changes

Rice

High temperature tolerant variety with few immature grains

NIJINOKIRAMEKI (protected new variety) | KOSHIHIKARI (existing variety)

Grapes

New varieties with good coloration even at high temperatures

Grosz Krone
(PVP applied)

Apples

New varieties with good coloration even at high temperatures

BENIMINORI | KINSHU | TSUGARU
New varieties with good coloration | (existing variety)

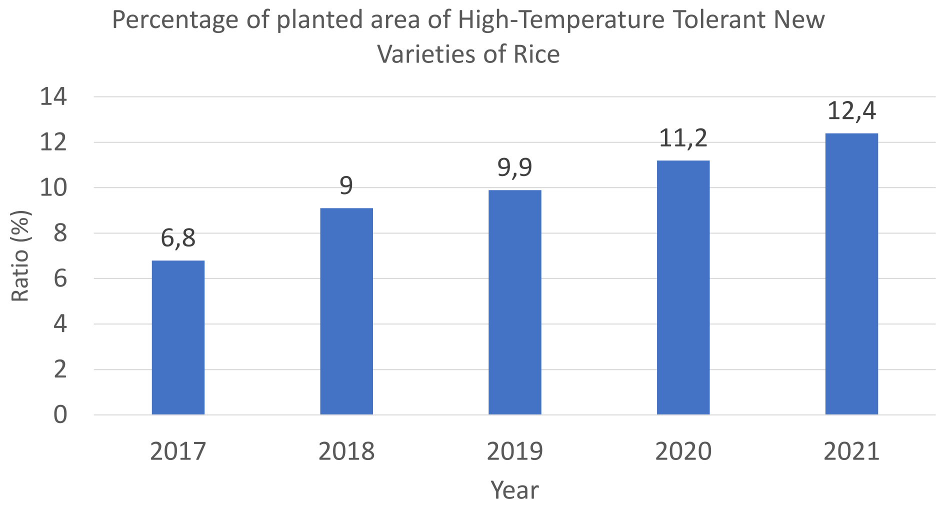
Impatiens

・Growing well in wide range conditions, even at high temperature

SunPatiens

4

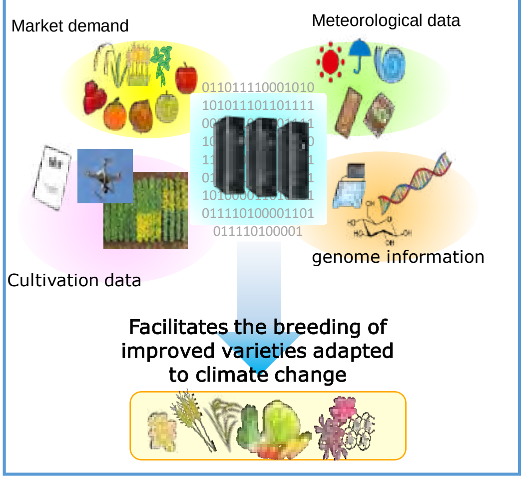
Growing needs for new varieties to adapt climate change



Innovation to facilitate breeding of new varieties to adapt to Climate Change

“Smart breeding system" in combination with AI and new breeding technologies will enable more efficient and faster breeding by big data on phenotype-genotype information.

Developing the “Smart breeding system"



Genome Editing Technologies

- Pre-harvest sprouting tolerant wheat variety

It was bred by Okayama university and National Agriculture and food Research Organization.

6

Case Unintended outflow of plant varieties developed in Japan

Shine Muscat

- Bred in Japan
- Registered in 2006
- Period of breeding is 33 years !!
- It has a strong sweetness, excellent taste, and can be eaten with the skin, so it is traded with high price.
- It is high expected as a main product of export.

Japan Brand!!!

As the background of this case, two factors are identified:

1. Because domestic seed/seedling market was large enough to sustain breeding activities, Japanese breeders haven't tended to acquire PBRs for their new varieties outside Japan.
   → Duration of Novelty was already over, and breeders could not apply for their variety to overseas
2. Under the Japan's PVP Act before its amendment, once a protected seedling is released to the market, PBR of that seedling is exhausted on export.

Consequently,,,,

30 times more area under cultivation abroad (53,000 ha) than in Japan (1,840 ha)

Production, Trade, or Marketing of "Shine Muscat" has been widely spread in Asia, and which is not the intention/strategy of the breeder of "Shine Muscat" .
→ This situation caused not only a loss of Japan's export market, but also damage of Japan's Brand

7

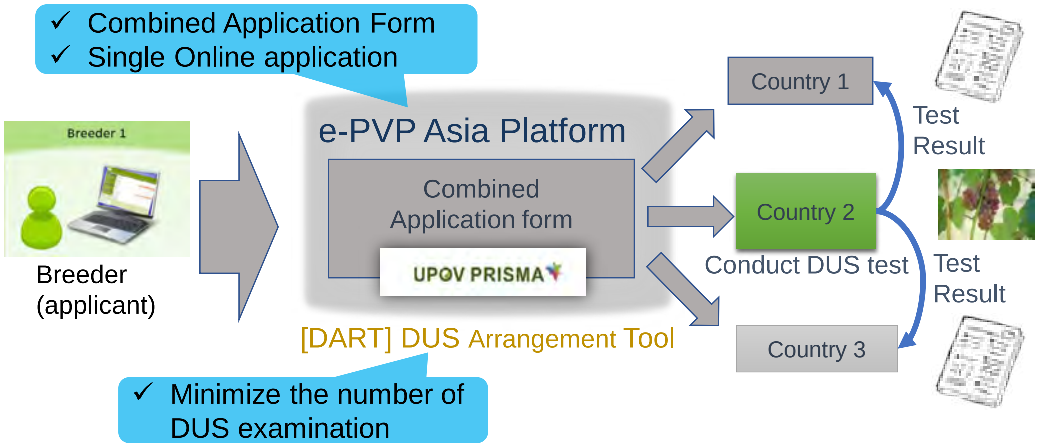
Strategy of Plant Variety Protection - IP Strategies 2025

- Unintended outflow of new plant varieties to the foreign countries
- Lack of awareness of importance of PVP

Amendment of the PVP Act in JP	Encourage breeders to apply foreign countries	Enhancement of cooperation with PVP Office in foreign countries
➢ Designation of export destination country by right holders when filing application ➢ Any acts in respect of the propagating material of protected varieties shall require the authorization of right holders (except with "Compulsory exemption")	➢ Government provides support and raising awareness of the protection of new plant varieties in foreign countries to enforce the breeders' right (Injunction, compensation claims)	➢ Efficient application in Asian countries ➢ Enhanced DUS cooperation to minimize the number of DUS examination in participating counties

8

"e-PVP Asia"



- Current participating countries: JP, VN
  Provisional participating countries: BN, MM, MY
  Observers: other EAPVP Forum members
- Resource partner: UPOV Office
- To be launched in early 2023.

9

Cooperation with the Asian partners

11th East Asia Plant Variety Protection Forum

JICA Training Course

10

Thank you for your attention!

QUESTIONS

SUKHAPINDA Kitisri (Ms), Patent Attorney, Office of Policy and Affairs (OPIA), United States Patent and Trademark Office (USPTO), United States of America (moderator)

At this time, I want to open the floor for some questions. We only have very few minutes left, so please raise your hand, the green hand and we can, you know, ask you to state your question.

HUERTA Yolanda (Ms.), Legal Counsel and Director of Training and Assistance, UPOV

Kitisri there was a question by Professor Morten.

LILLEMO Morten (Mr.), Professor, Norwegian University of Life Sciences Faculty of Biosciences, Norway (speaker)

Yes. I have a short question for the presentation from Canada for Anthony Parker. Is this UPOV convention also used by private breeding companies in Canada, or do they use plant variety patents?

PARKER Anthony (Mr.), Commissioner, Plant Breeders' Rights Office, Canadian Food Inspection Agency (CFIA), Canada (speaker)

Thank you for that question Professor. In Canada, UPOV based plant breeders rights are utilized by both, the public and the private sector. It really is crop dependent on the proportion of utilization in cereals. It tends to be dominated more by the public sector entities, specifically due to a lack of a good system for collection on farm saved seed.

However, in other crops such as soybean and corn and canola plant variety protection is used almost exclusively by the private sector. We do have an interesting situation in Canada that other countries also experience, higher life forms are not patentable subject matter in Canada but subunits such as specific genes are. Generally the private sector uses patent protection on things like genetically modified traits.

SUKHAPINDA Kitisri (Ms), Patent Attorney, Office of Policy and Affairs (OPIA), United States Patent and Trademark Office (USPTO), United States of America (moderator)

All right. Thank you for the question and for the answer. Do we have other questions? We have some time for one more question.

HUERTA Yolanda (Ms.), Legal Counsel and Director of Training and Assistance, UPOV

Laura Villamayor has requested for the floor.

SUKHAPINDA Kitisri (Ms.), Patent Attorney, Office of Policy and Affairs (OPIA), United States Patent and Trademark Office (USPTO), United States of America (moderator)

All right, go ahead Laura.

VILLAMAYOR María Laura (Sra.), Coordinadora de Relaciones Institucionales e Interjurisdiccionales, Instituto Nacional de Semillas (INASE), Secretaría de Agricultura, Ganadería, Pesca y Alimentación, Buenos Aires, Argentina

Good morning. I would like to ask question also for Anthony. You mentioned if I understand you rightly that you are using optical markers, because we are trying also to validate optical markers for identifying varieties. So in which species are you trying this new technology for validating varieties optical markers because we are using them for soybean and for wheat and I would like to know if you have any experience about this, and you can tell us. Thank you, Anthony. Thank you for your great presentation.

PARKER Anthony (Mr.), Commissioner, Plant Breeders' Rights Office, Canadian Food Inspection Agency (CFIA), Canada (speaker)

Thank you, Laura. Yes, indeed the specific research project that we were discussing was the use of optical markers by a public institution for assessing wheat varieties. At this point in time, we have not actually moved that into our program for evaluating DUS. So this is just simply a research project that was specifically targeting the characteristics of wheat lines that were developed over the course of 120 years trying to identify useful characteristics for climate change.

So we have not used them in our office yet but we remain open-minded like many UPOV member countries to the potential of not just biomolecular markers, but perhaps new techniques for assessing phenotypes to establish distinctness uniformity and stability. But regrettably, our office is not at that point in time. So certainly if Argentina has done work in that area or any others, we would love to know about it and be informed by it. Thank you.

VILLAMAYOR María Laura (Sra.), Coordinadora de Relaciones Institucionales e Interjurisdiccionales, Instituto Nacional de Semillas (INASE), Secretaría de Agricultura, Ganadería, Pesca y Alimentación, Buenos Aires, Argentina

Yes, indeed we are working in our laboratories in the National Institute Laboratories just for validating this technique, so we can share our experience and maybe we can share it with the other members of UPOV also. Thank you very much.

THE ROLE OF PLANT VARIETY PROTECTION IN PROMOTING THE DEVELOPMENT OF CROP VARIETIES THAT ADAPT TO, AND MITIGATE, CLIMATE CHANGE. THE EXAMPLE OF KENYA

Mr. Simon Mucheru Maina
Kenya Plant Health Inspectorate Service, Kenya

INTRODUCTION

Agriculture is the mainstay of the Kenyan economy, where it contributes approximately 33% of the Gross Domestic Product. It employs more than 40% of the total population and 70% of the rural population. The agriculture sector accounts for 65% of export earnings, and provides livelihoods for more than 80% of the Kenyan population, contributing to improving nutrition through the production of safe, diverse and nutrient dense foods (Government of Kenya 2011; FAO 2010).

The main food crops in Kenya are maize, wheat, rice, potatoes, green grams and beans. Maize is the principal staple food of Kenya, and it is grown in 90% of all Kenyan farms, while the common bean is the most important legume crop (AFA 2021). Drought-resilient crops such as sorghum, cowpea and pigeon pea are becoming increasingly important because of climate change.

Agriculture in Kenya is mainly rainfed. This presents a challenge since only 20% of the land receives reliable rainfall, while the rest of the country is arid or semi-arid. Population pressure in the highly productive areas, and the resultant conversion of agricultural land into human settlements, coupled with soil degradation due to unsustainable use, have led to reduced productivity. It is becoming increasingly important for farmers to venture into the drier environments for crop production. The situation is worsened by climate change.

Climate change has resulted in increased temperatures and changes in seasonal trends and patterns. In recent years, Kenya has witnessed extended dry periods and rainfall outside the normal seasons. Floods have also been witnessed. With the changing climatic conditions, the country has witnessed the emergence and spread of new pests and diseases such as Maize Lethal Necrosis, Fall Armyworm among others. All these factors have resulted in threats to food security. It is therefore very important for breeders to develop varieties that are resilient to harsh agro-ecological conditions.

PLANT VARIETY PROTECTION IN KENYA

For the last 25 years, the Government of Kenya has embarked on promoting plant breeding through implementation of a system of plant variety protection. Under this system, breeders of new plant varieties obtain rights, which ensure that any person wishing to commercialize their varieties obtains a license and pays royalties against sale of the variety. In this way, the breeder can recover their cost of investment, thereby motivating them to develop new crop varieties.

The office administering plant variety protection was established in 1997 and has functioned under the Kenya Plant Health Inspectorate Service (KEPHIS) since 1998. The legal framework for plant variety protection is provided for in the Seeds and Plant Varieties Act (Cap 326) of the laws of Kenya. Kenya also implements the UPOV Convention, having joined membership in 1999 under the 1978 Convention. Currently, Kenya implements the 1991 UPOV Convention following accession to this Convention in May 2016. Kenya grants plant breeders' rights for all plant genera and species.

Establishment of a plant variety protection office and subsequent membership to UPOV conferred the following advantages: readily available UPOV test guidelines for most of the agricultural crops; trained personnel through cooperation with UPOV and its members on the development of national test guidelines; collaboration and cooperation between breeders and the testing authority on variety descriptions. This has resulted in improved capacity for variety testing.

KEPHIS has engaged in sensitization of breeders to develop new varieties and benefit from the plant variety protection system. This has resulted in the increased introduction of new crop varieties.

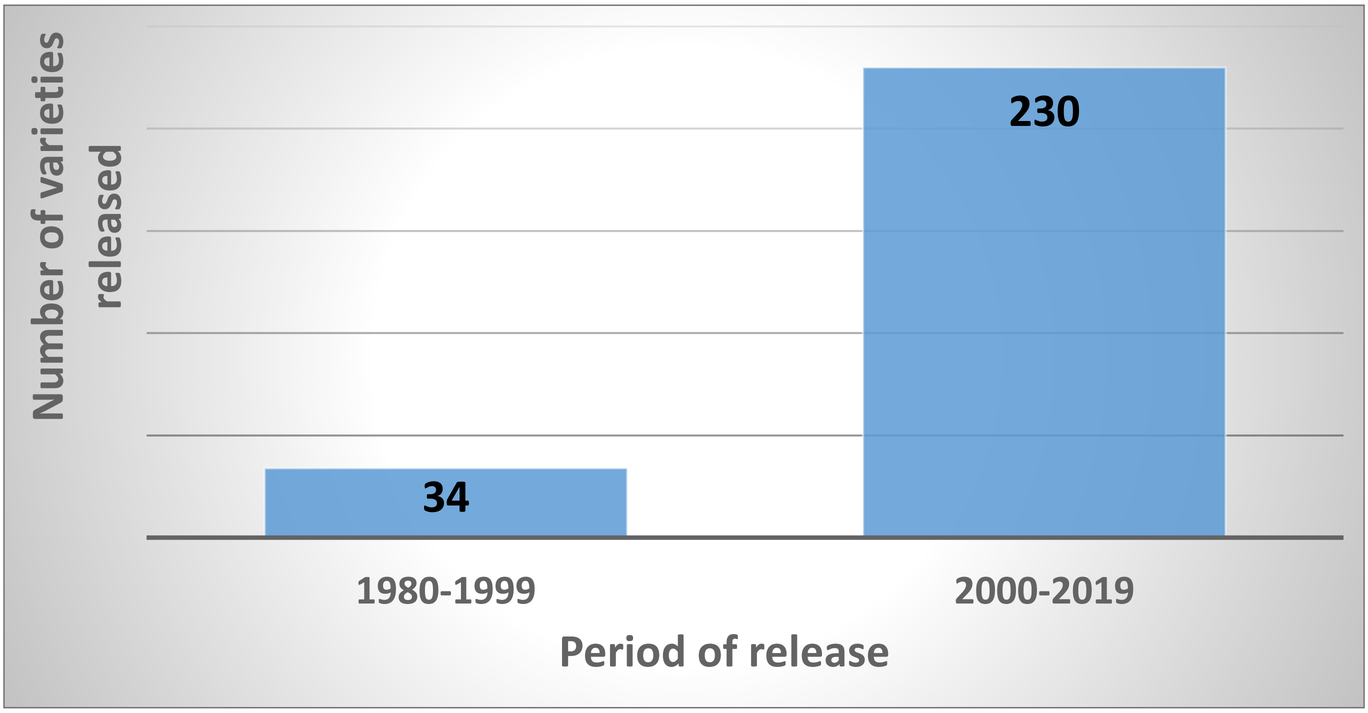


Figure 1. *Comparison of drought-tolerant varieties released during the periods 1980–1999 and 2000–2019 (Source: KEPHIS).*

Breeders have embarked on the development of drought-tolerant varieties of maize, sweet potato, cassava, sorghum, pigeon peas, amaranth and rangeland grasses, among others. Implementation of a plant variety protection system has resulted in close to a sevenfold increase in the number of drought-tolerant varieties released for commercialization. In the last three years alone, a total of 41 climate-smart varieties were released. There are also efforts to release pest- and disease-tolerant varieties to counter emerging pests as a result of climate change. Sixteen varieties tolerant to Maize Lethal Necrosis have been released, while varieties of Fall Armyworm-tolerant maize are under evaluation.

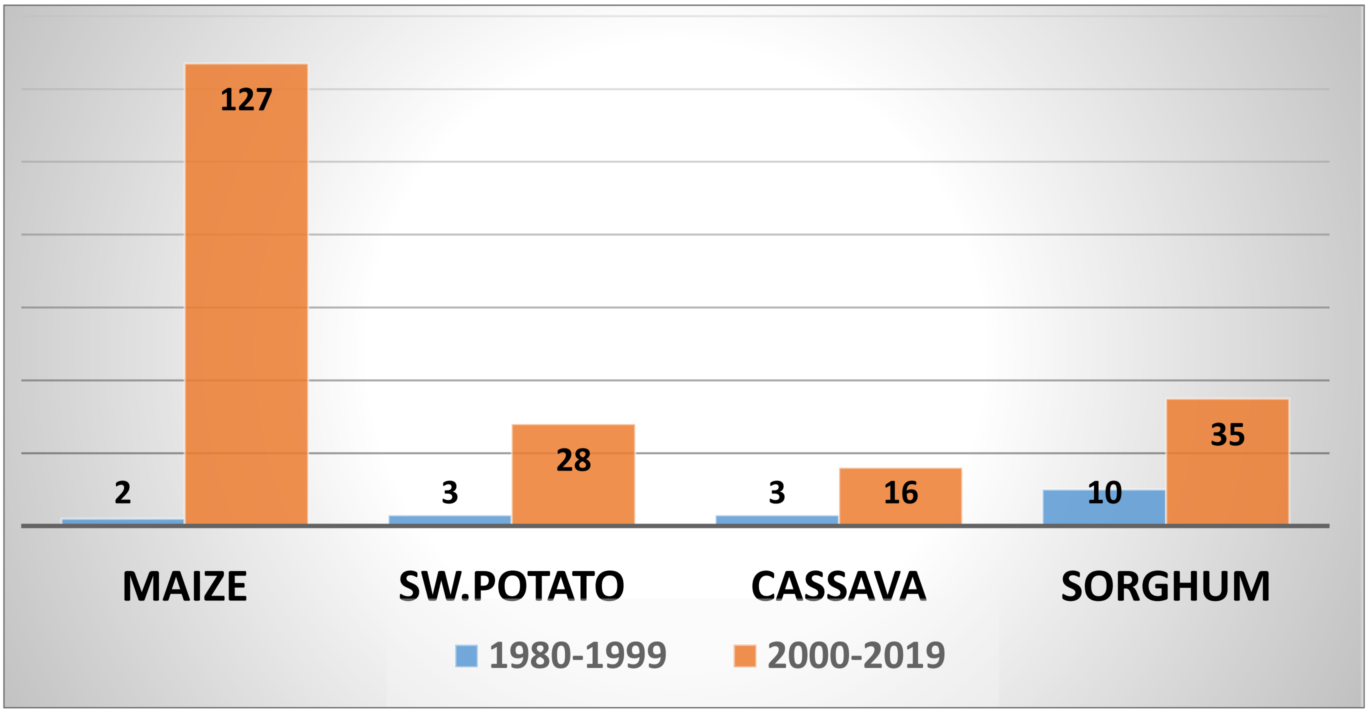


Figure 2. *Comparison of drought-tolerant varieties of specific crops released during the periods 1980–1999 and 2000–2019 (Source: KEPHIS).*

Initially, most of the breeding was undertaken by public breeders, but, with the implementation of plant variety protection, private seed companies are engaged in breeding.

As a result of climate change, breeders have responded by developing varieties of new types of species. In the last ten years, new varieties of amaranth and rangeland grasses have been developed. The rangeland grasses in particular will have an impact on livestock production in the drier parts of the country.

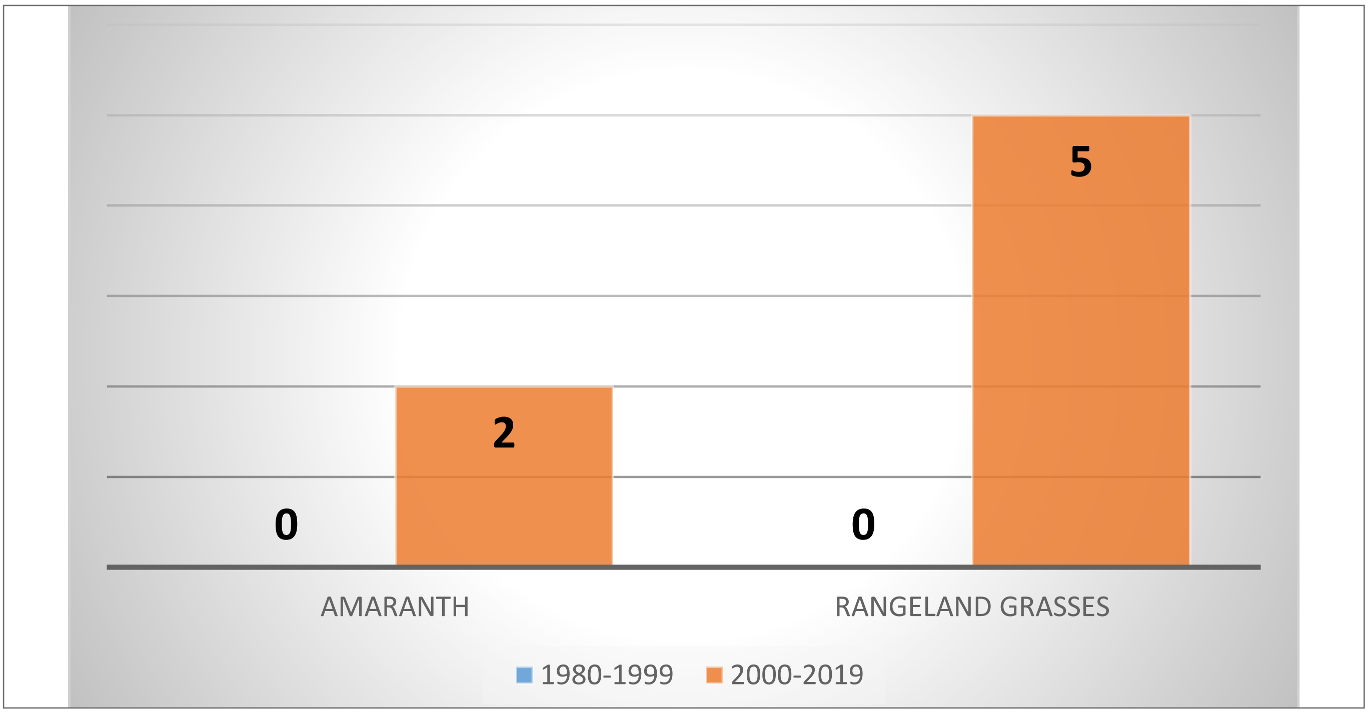


Figure 3. *Introduction of drought-tolerant varieties of amaranth and rangeland grasses (Source: KEPHIS).*

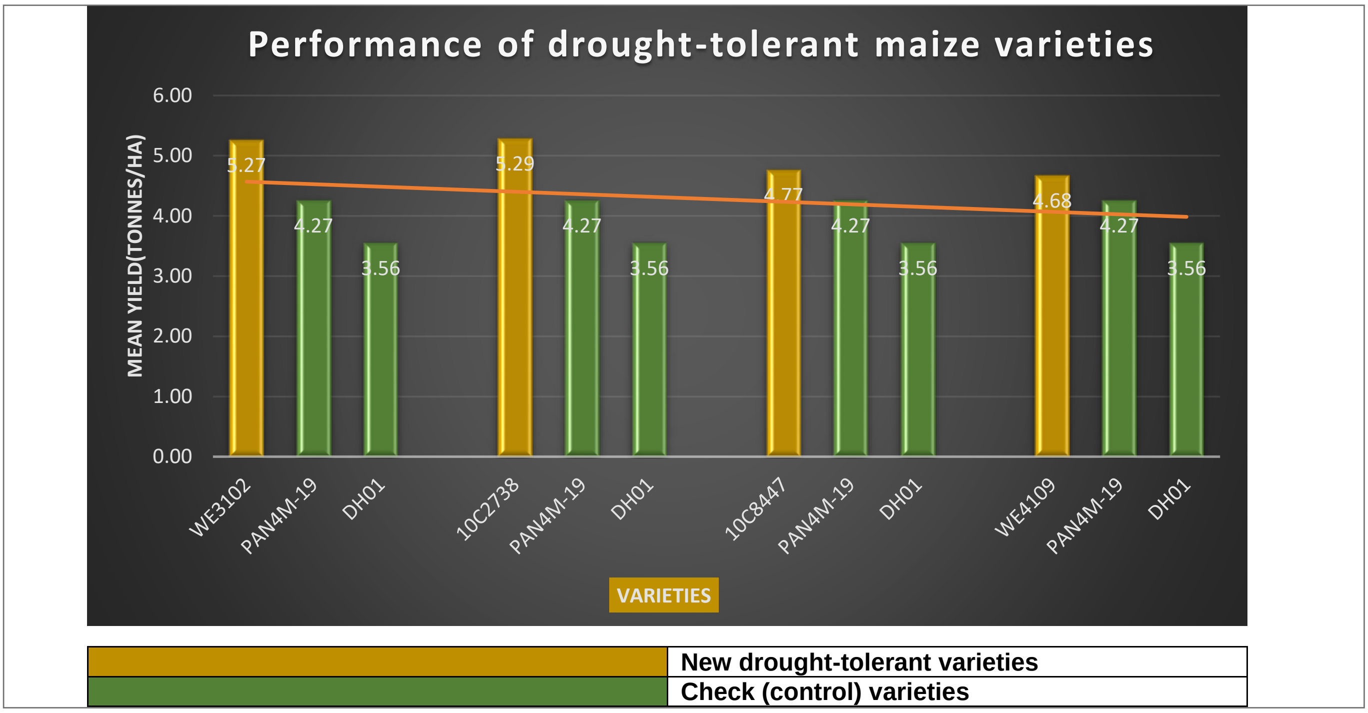


Figure 4. *Increased production through breeding of better yielding drought-tolerant varieties (Source: KEPHIS).*

There is considerable development of climate-resilient varieties following the introduction of plant variety protection in Kenya. This has come as a result of breeders having assurance on return of investment following the development of new varieties; enhanced capacity for testing of new varieties; and collaboration and cooperation between the breeders and the testing authority on variety testing.

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Presentation made at the Seminar

THE ROLE OF PVP IN PROMOTING DEVELOPMENT OF CROP VARIETIES THAT ADAPT TO, AND MITIGATE, CLIMATE CHANGE – EXAMPLE OF KENYA"

Simon M. Maina
Head, Seed Certification and Plant Variety Protection
KEPHIS

Introduction

- The Kenyan economy is largely dependent on agriculture for raw materials, food security, employment and general livelihoods.
- Climate change has resulted in increased temperatures, changes in seasonal trends and patterns.
- In recent years, Kenya has witnessed extended dry periods and rainfall outside the normal seasons.
- With the changing climatic conditions, the country has witnessed emergence of new pests and diseases such as maize Lethal Necrosis (MLN), Fall Army Worm (FAW) among others.
- It is therefore very important for breeders to develop varieties that are resilient to harsh agro-ecological conditions.

Plant Variety Protection in Kenya

- The office to administer the PVP was established in 1997 and has functioned under KEPHIS since 1998
- Kenya acceded to UPOV under the 1978 Convention in **13th May 1999**
- The Seeds and Plant Varieties Act was amended in **2012** to incorporate aspects of the 1991 Act of the UPOV.
- In **May 2016**, Kenya acceded to the 1991 Act of the UPOV Convention.
- Kenya grants PBRs for all plant genera and species

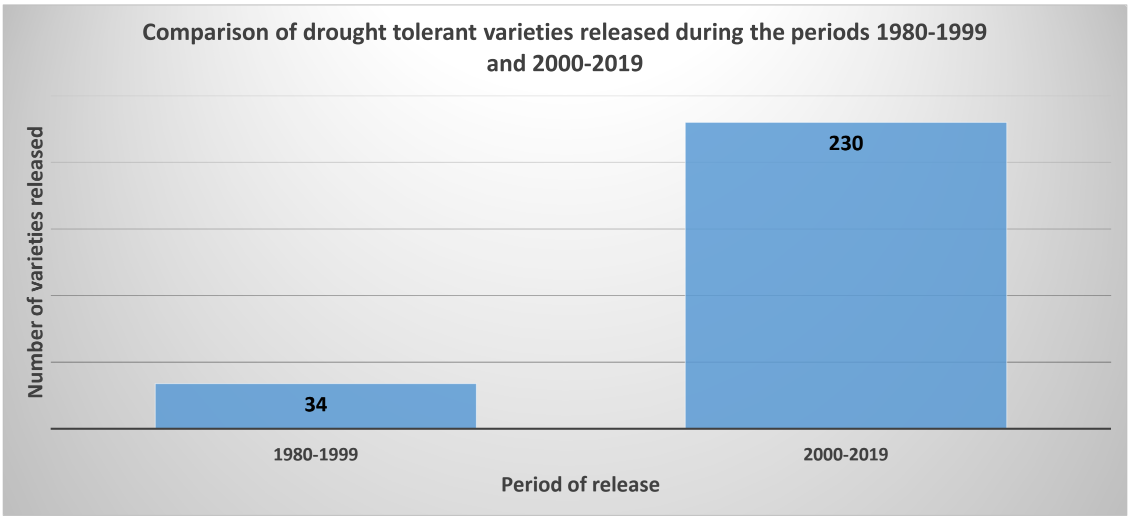
Plant Variety Protection in Kenya

- Establishment of a PVP office and subsequent membership to UPOV, conferred the following advantages:
  - Readily available UPOV test guidelines for most of the Agricultural crops
  - Trained personnel through cooperation with UPOV and UPOV members on development of national test guidelines.
  - Collaboration and co operation between the breeders and the testing authority on variety description.
- KEPHIS engaged in sensitization of breeders to develop new varieties and benefit from the PVP system.
- This led to increased introduction of crop varieties

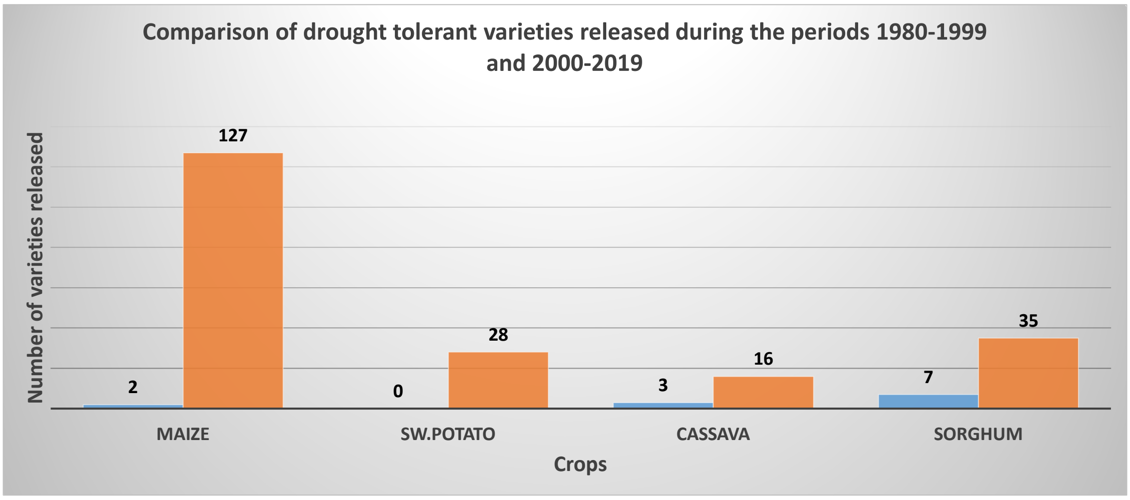
Development of Climate Smart Varieties

- During the last 10 years, breeders have embarked on development of drought tolerant varieties of maize, sweetpotato, cassava, sorghum, pigeon peas, amaranth, rangeland grasses among others.
- There are also efforts to release pest and disease tolerant varieties to counter emerging pests as a result of climate change.
- Sixteen (16) varieties tolerant to Maize Lethal Necrosis Disease (MLND) have been released,
- Varieties of Fall Army Worm (FAW) tolerant maize are under evaluation.

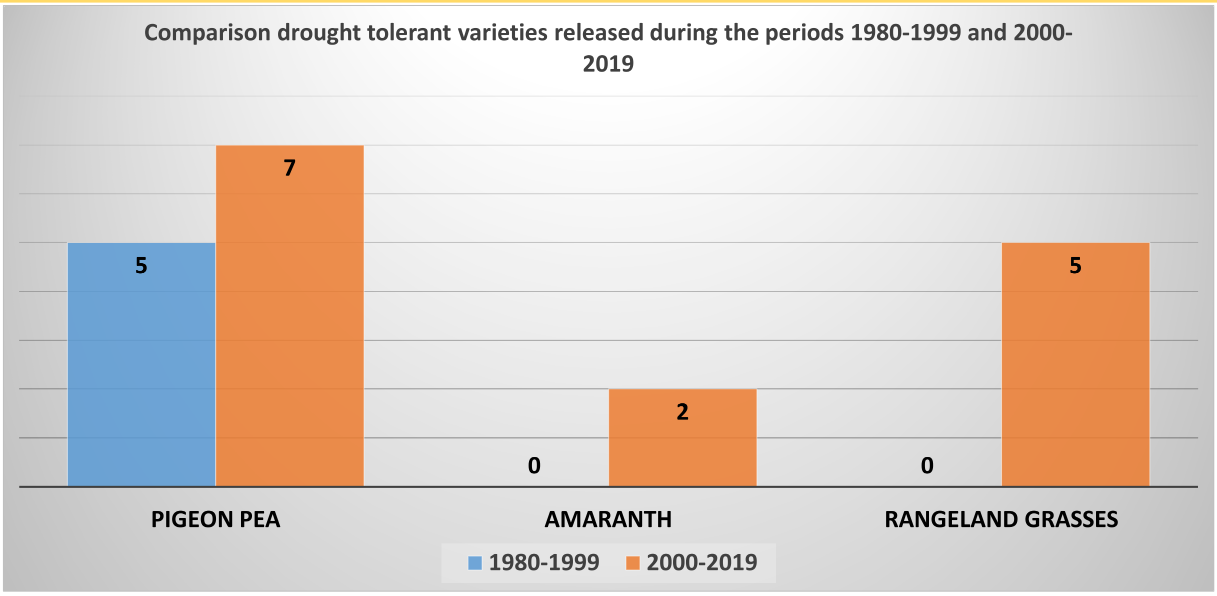
Development of Climate Smart Varieties



Development of Climate Smart Varieties

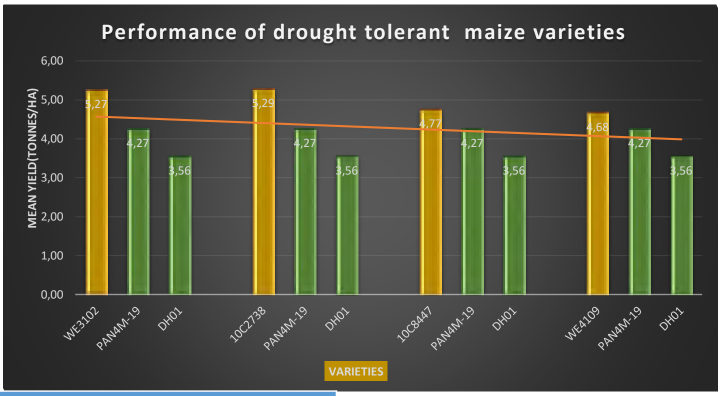


Development of Climate Smart Varieties



Development of Climate Smart Varieties

Increased production through breeding of better yielding and drought tolerant varieties



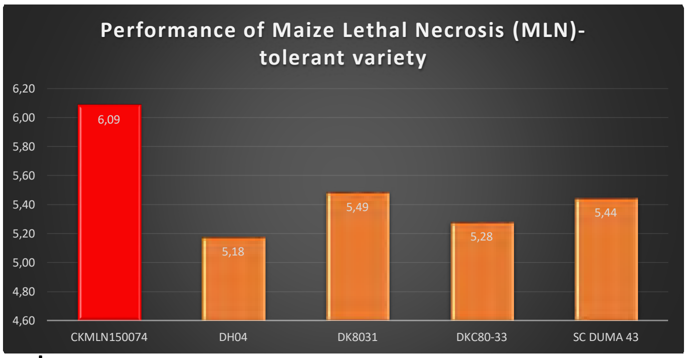
Legend

	New drought tolerant varieties
	Check Varieties

***Source*: KEPHIS VCU Data - 2017**

Development of Disease Tolerant Varieties: Food Security

- Development and release of MLN tolerant varieties thus improved yields



Legend:

***Source*: KEPHIS VCU Data;2015**

	New MLN tolerant variety
	Check (control) varieties

Conclusion

- There is considerable development of climate resilient varieties following introduction of plant variety protection in Kenya.
- This has come as a result of:
  - Breeders having assurance on return of investment following development of new varieties.
  - Enhanced capacity for testing of new varieties through cooperation with UPOV and UPOV members.
  - Collaboration and co operation between the breeders and the testing authority on variety testing.

Thank you for your kind attention!

12

IMPACT OF THE COMMUNITY PLANT VARIETY RIGHTS SYSTEM ON THE EUROPEAN UNION ECONOMY AND THE ENVIRONMENT

Mr. Francesco Mattina, President of the Community Plant Variety Office (CPVO)
Mr. Nathan Wajsman, Chief Economist of the European Observatory on Infringements of Intellectual Property Rights, European Union Intellectual Property Office (EUIPO)

INTRODUCTION

The present paper is a compilation of the main elements presented by the authors at their presentation at the UPOV Seminar on "The role of plant breeding and plant variety protection in enabling agriculture to mitigate and adapt to climate change", developed in more detail. This paper can also serve as a summary of the main findings in the study on the "Impact of the Community (EU) Plant Variety Rights' system on the EU economy and the environment" ("study"),[1] co-authored by the European Union Intellectual Property Office (EUIPO) (the project was led by the European Observatory on Infringements on Intellectual Property Rights) and the CPVO.[2]

The article begins with a few general introductory remarks about the study, followed by a presentation of the main findings included in the chapter on the impact of Community (EU) Plant Variety Rights' ("CPVR" or "EU PVR") system on EU economy and in the chapter on the impact of CPVR system on the environment, and then by some final considerations.

GENERAL REMARKS ABOUT THE STUDY ON THE IMPACT OF THE EU PVR SYSTEM ON THE EU ECONOMY AND THE ENVIRONMENT

The study is the first to assess in a holistic way the impact of the EU PVR system in the European Union. It was publicly released on April 28, 2022 in Angers (France) on the occasion of the CPVO policy conference "Plant Variety Protection: the path towards more sustainability, innovation and growth in the European Union", an event organized by the CPVO under the remit of the French Presidency of the Council of the EU.[3]

The study fulfils two main objectives: first, it quantifies the contribution of the EU PVR system to the EU's economy, by considering specific aspects of agriculture and horticulture (such as the contribution of the system to the global competitiveness of EU farmers and growers); second, the effects of the EU PVR system on the environment are analyzed. The potential of the EU PVR system to contribute to the United Nations (UN) Sustainable Development Goals (SDGs) and to the European Commission's Green Deal objectives is also scrutinized.

In terms of structure, the study is divided into the following chapters: i) introduction to the EU PVR system and to the system of marketing of seeds and plant reproductive material in the EU; ii) literature review; iii) methodology and data; and iv) quantitative results. The first chapter is of a descriptive nature, to contextualize the analysis at stake by introducing the main notions about the EU PVR system and the system of marketing of seeds and plant reproductive material in the EU. The second chapter consists of an overview of arguments in the relevant literature on the economic and environmental impact of the EU PVR system. It must be noted in this regard that, with a view to ensure an effective critical analysis, this chapter includes a presentation of both positive and negative considerations of the EU PVR system as identified in the literature.[4] The core of the analysis of the impact of the EU PVR system on the EU economy and the environment is then presented in the third and fourth chapters.

It must also be noted that the scope of the study covers over 80% of all registered varieties in the EU,[5] where the relevant period to be considered is that from 1995 until 2019.[6]

In terms of methodology, several methods are relied upon. Concerning the calculation of the economic impacts of the EU PVR system, three major standard tools of agricultural economics are applied, namely: market models, full-revenue-full-cost calculations and multiplier analyses. As to the calculation of the various environmental impacts of the EU PVR system, there are four specific methodologies that are made use of, namely: a virtual net land trade model, a global greenhouse gas (GHG) emissions model, a global biodiversity loss model and a virtual water use and trade model.[7]

Regarding the sources of quantitative data relied upon for the elaboration of the study, these include the following: CPVO and national registers of plant variety rights; national commercial registers; EU Common Catalogues; FRUMATIS database; PLUTO database (UPOV); OECD variety list query; FAOSTAT (production, value and trade in agricultural products); EUIPO registry and TMView; PATSTAT database; PINTO database; ORBIS (demographic and financial data on breeders); and EUROSTAT (structural business statistics, economic accounts for agriculture, labor force survey).

MAIN FINDINGS REGARDING THE IMPACT OF THE EU PVR SYSTEM ON THE EU ECONOMY

The departing point for measuring the general impact of a PVR system can be held to be the number of applications lodged and titles granted under the respective regime. PVR systems serve as a driving force to encourage the breeding of new varieties and, in a market economy, it can be expected that plant breeders will protect those varieties which they expect to be commercially successful. According to UPOV, it may be argued that breeders are expected to only bear the costs involved for obtaining protection if, first, they assume protection is necessary and, second, a true market value of the variety is expected.[8] Regarding farmers and growers, even though in most cases a royalty payment is expected, the uptake of new and protected varieties is in general rather strong. This stresses the high expectations of farmers and growers in terms of agronomic benefits of these new varieties.

In the study's sections devoted to the investigation on the impact of the EU PVR system on the EU economy, several quantitative conclusions are exhibited, and these are presented below.

Analysis of the impact of plant breeding on innovation-induced yield growth in farming

In the study, the conclusion is reached that plant breeding across all agricultural and horticultural crops in the EU has a vast impact on innovation-induced yield growth in farming in the past quarter of a century. To reach such a conclusion, a gradual approach is adopted to transfer statistically observable yield growth rates into plant breeding-induced yield developments. The different steps followed and the results obtained in each step are described below.

CALCULATION OF THE YIELD GROWTH OF THE FOUR MAIN CROPS

As a first step, the yield growth of arable crops, fruit, vegetables and ornamentals is examined in accordance with official statistics. When weighted by current hectare use, the average yield growth rate per year (over the past 25 years) in crops in the EU territory is the following: 1.08% for agricultural crops; 0.83% for fruits; and 1.10% for vegetables. Regarding ornamentals, the total (monetary) yield per hectare in the EU rose by 0.21% per year.

CALCULATION OF THE INNOVATION-INDUCED YIELD GROWTH

As a second step, the innovation-induced yield growth is calculated in terms of "hectare-related total factor productivity", so that the plant breeding-induced yield growth of these crops can then be determined based on the share of plant breeding in innovation-induced yield growth. In this vein, the calculated growth rates of the overall input use (excluding land)[9] are subtracted from statistically observable yield growth rates: this leads to the crop-specific annual innovation-induced yield growth rates for the EU in the past quarter of a century.

Accordingly, when weighted by current hectare use, the average innovation-induced yield growth rate per year in the EU between 1995 and 2019 was the following, depending on the crop: 1.58% for agricultural crops; 1.82% for fruits; 2.09% for vegetables; and 1.20% for ornamentals.

CALCULATION OF THE PLANT BREEDING-INDUCED YIELD GROWTH RATE

As a third step, the innovation-induced yield growth rate is multiplied by the share of plant breeding to lead to the plant breeding-induced yield growth rate in EU agricultural and horticultural farming. The outcome resulting from making this operation is the following:

- for agricultural crops, plant breeding between 1995 and 2019 accounts for an annual yield growth of 1.09%, slightly higher than the observed average yield growth for these crops (1.08%);
- for fruit crops, plant breeding annually increases the yield by 1.07%, somewhat more than what is measurable in terms of harvested yield increases (0.83%);
- for vegetable crops, it contributes to an annual yield growth of 1.31%, more than the statistically observable yield growth (1.10%);
- for ornamentals, a yearly yield growth of 0.71% is attributed to plant breeding, notably higher than the rather low total (monetary) yield growth per year (0.21%).

CALCULATION OF THE SHARE OF VARIETIES PROTECTED UNDER AN EU PVR

As a fourth step, the share of varieties with an EU-level PVR per crop is determined by calculating the ratio of the varieties included in the EU PVR register as opposed to the varieties included in national listing registers, the EU common catalogue registers and the FRUMATIS register. The result of applying this calculation is the following: 25.3% of all registered varieties of agricultural crops (the focus of this study) are varieties with an EU PVR, this number being 12.3% for registered fruit varieties with an EU PVR and 18.7% for registered varieties of vegetables with an EU PVR. As for the share for ornamentals, more than 15,500 varieties are protected with an EU PVR.

CALCULATION OF THE DECREASE IN CROP PRODUCTION IN THE EU IN 2020 IN THE ABSENCE OF THE EU PVR SYSTEM

The study also calculates the share that can be attributed to the EU protection of plant varieties in the output growth in EU agriculture since 1995 due to plant breeding. One of the approaches adopted takes as reference the impact that would have been caused had plant breeding progress not occurred (during the period ranging from 1995 to 2019). The core question is, then: what is the quantity of crops that would not have been produced, had the EU PVR system not being in place? In other words, the advantages of a PVR system are made visible by disadvantages brought along in the absence of a PVR system.

The central finding in this regard is that, in the absence of the EU PVR system, the level in the crop production in the EU in 2020 would be the following: 6.4% lower for agricultural crops, 2.6% lower for fruits, 4.7% lower for vegetables and 15.1% lower for ornamentals.

As a corollary, the additional production brought about by plant variety innovations supported by the protection granted under an EU PVR is sufficient to feed an additional 57 million people worldwide thanks to agricultural crops, 38 million in the case of fruits and 28 million for vegetables.

Analysis of the contribution of the EU PVR system to employment rates

The additional production of crops brought about by EU PVR protection also translates into higher employment in EU agriculture. Thanks to it, the agricultural crops sector employs 25,000 additional workers, the horticulture sector 19,500, and the ornamentals sector 45,000, amounting to a total direct employment gain of almost 90,000 jobs. Further, when considering the indirect effects, that is, the employment gain in upstream and downstream sectors (e.g., farm supply or food processing), the employment rate increases by 800,000 jobs.

In addition, not only does the EU PVR system contribute to employment, but the jobs created are also better remunerated than they would have been in the absence of this system. For instance, wages of workers in the agricultural crops sector are 12.6% higher than they would have been in the absence of this system, while wages in the horticulture sector are 11% higher.

Moreover, the breeders who carry out the R&D leading to plant breeding innovations also generate employment and economic activity. It is estimated that companies protecting their innovations by registering EU PVRs employ more than 70,000 workers and generate a turnover of more than €35 billion.

Analysis of the contribution of the EU PVR system to EU's GDP

The additional added value (that is, contribution to GDP) generated by EU PVR-protected crops amounts to €13 billion

(€7.1 billion for agricultural crops, €1.1 billion for fruit, €2.2 billion for vegetables and €2.5 billion for ornamentals).

From a macro-economic point of view, the conclusion is reached that without the added production attributable to EU PVR protected crops, the EU's trade position with the rest of the world would worsen, and EU consumers would face higher food prices. Without EU PVR-protected innovation, the EU would become a net importer of some crops for which it is an exporter today.

Analysis of the geographical origin of active EU PVRs

By the end of 2021, there were 28,514 active EU PVRs (with granted status). The 10 countries identified represent 91.3% of the active rights, with the Netherlands accounting for more than one third of all EU PVRs.

More precisely, the statistics gathered are the following: i) Netherlands (34.8% share, 9.919 EU PVRs); ii) France (17% share, 4.837 EU PVRs); iii) Germany (14% share, 3.985 EU PVRs); iv) United States (6.7% share, 1.911 EU PVRs); v) Switzerland (5.3% share, 1.523 EU PVRs); vi) Denmark (3.2% share, 906 EU PVRs); vii) United Kingdom (3.1% share, 872 EU PVRs); viii) Italy (2.7% share, 783 EU PVRs); ix) Spain (2.4% share, 681 EU PVRs); x) Belgium (2.2% share, 615 EU PVRs).

The EU member states account for almost 77% of EU PVRs (22,669 EU PVRs), while third countries represent around 23% of the total number (5,845 EU PVRs). The largest non-EU filing countries are thus the United States, Switzerland and the United Kingdom.

Analysis of the size of the holders of EU PVRs

By the end of 2021, 1,227 EU firms (representing around 78% of the total EU-based EU PVR holders) had registered 18,931 EU PVRs (83.4% of the total). In the study, the size of this firms is analyzed. From this sample, it is found that physical persons own the smallest number of EU PVRs on average (3.3) while, for firms, the number of EU PVRs per firm ranges from 10 for the smallest companies to 95 for large companies. It is also found that large firms own 40% of the concerned EU PRs, with the remaining 60% registered by Small and Medium Enterprises (SMEs)[10] or physical persons.[11] Moreover, SMEs represent 93.5% of all registrants of EU PVRs (in this sample).

MAIN FINDINGS REGARDING THE IMPACT OF THE EU PVR SYSTEM ON THE ENVIRONMENT

The impact of the EU PVR system on the environment is also analyzed, and account is taken of the fact that ensuring a sustainable agricultural system that functions in line with local environments is key for reaching a number of the United Nations' (UN) Sustainable Development Goals (SDGs), such as SDG 1 (no poverty), SDG 2 (zero hunger), SDG 8 (decent work and economic growth), SDG 12 (responsible consumption and production), SDG 13 (climate action) and SDG 15 (life on land). To achieve the SDGs in a European context, the EU's Green Deal and its Farm to Fork (F2F) and Biodiversity strategies are central for the agenda in EU member states. Against this backdrop, the potential of the contribution of the EU PVR system to the following elements is considered: I) climate neutral Europe; II) ecosystems and biodiversity;[12] III) F2F strategy[13]; and IV) R&D and innovation. The conclusion is reached that the EU PVR system contributes to the UN's SDGs and to the objectives of the EU Green Deal. It does so by reducing the environment impact and resource use of agriculture and horticulture, by increasing farm incomes and by keeping prices lower for consumers.

In terms of scope, it is noted that the analysis carried out for assessing the impact of the EU PVR system on the environment covers agricultural crops, fruits and vegetables. However, ornamentals are excluded due to data constraints.

The conclusions contained in the study's sections devoted to the investigation on the impact of the EU PVR system on the EU economy are presented below.

Analysis of the contribution of the EU PVR system to reductions in hectares of land needed to grow crops

Without plant breeding progress in varieties with an EU-level PVR, many millions of hectares of land would globally have been necessary, in addition to the global area already used in 2020. The figures that have been gathered in the study are the following:

- For agricultural crops, considering all factors other than land to be unchanged, this number would amount to more than 6.5 million hectares of land which would have been necessary globally, in addition to the global area already used in 2020. This would have led to an increase in necessary land almost as large as the entire (land) territory of Ireland.
- Regarding fruit crops, almost 110,000 hectares worldwide (i.e., in countries trading the listed fruit with the EU) would additionally be needed today. This is twice as large as Lake Constance at the border of Germany, Austria and Switzerland.
- Regarding vegetable crops, more than 90,000 hectares would globally be needed in addition to what is already used to cultivate vegetables.

Analysis of the contribution of the EU PVR system to reductions in annual Greenhouse Gas emissions

The EU PVR system also contributes to the fulfilment of the EU's environmental objectives. According to the findings in the study, the annual Greenhouse Gas (GHG) emissions from agriculture and horticulture are reduced by 62 million tons per year. This corresponds to the total GHG footprint of Hungary, Ireland or Portugal. Overall, the protection of plant varieties in the EU from 1995 until 2020 has resulted in the avoidance of almost 1.2 billion extra tons in GHG emissions.

Analysis of the contribution of the EU PVR system to reductions in water use in agriculture and horticulture

Thanks to EU PVR protection, water use in agriculture and horticulture is reduced by more than 14 billion m3, an amount of water equivalent to one third of the volume of Lake Constance.

FINAL CONSIDERATIONS

In the EUIPO-CPVO study on the impact of the EU PVR system on the EU economy and environment it is made clear that plant breeding innovation supports low-input agriculture and better environmental protection. Novel varieties should not only produce higher yields but also be adapted to biotic and abiotic stresses. In the context of climate change, draught resistance and less water input traits are crucial in plants.

Thanks to innovations in plant breeding, European farmers and growers have been able to increase food production in the past 25 years while at the same time reducing their use of resources and the consequent damage to the environment. Based on credible and widely accepted methods from agricultural economics, the study reports that plant breeding protected by EU PVRs has made a significant contribution to Europe's food security and to the EU's goal of making Europe climate neutral by 2050. While difficult to quantify, these innovations have also contributed to the UN's SDGs, by for example reducing water use, halting the loss of biological diversity and providing access to healthy food (not only within the EU but globally). Solving the challenges of the coming decades, namely, to feed a growing world population while moving towards climate neutrality and a cleaner environment, will require innovations in plant breeding, and those innovations will need protection under PVRs, including EU PVRs. In this context, legislation must be regarded as a key driver of innovation to accelerate transition to sustainable inclusive food systems from primary production to consumption.

Lastly, a noteworthy finding in the study is that SMEs play a crucial role in EU plant variety innovation. It has been found that SMEs constitute most EU PVR applicants and account for almost two thirds of EU PVRs in force. SMEs are key players in the plant breeding sector and as such it is necessary to adopt mechanisms that support them and incentivize them to develop and protect new EU plant varieties adapted to new environmental conditions, such as those imposed by the drastic effects of climate change on agriculture.

FOOTNOTES

[1] The full study is available in English language on both the EUIPO and the CPVO websites, and an executive summary thereof is available in all 24 official EU languages on the Observatory's webpage (EUIPO website).

[2] As this paper reproduces some of the elements in the study verbatim, the authors here refer to the original sources of the investigation as reported in the study. It is here made clear that this is only a summary of the study and not the official version.

[3] The event was web-streamed live on the website of the CPVO and followed by several hundreds of online participants from all over Europe. During the event, Mr. Francesco Mattina announced the release of the study and Mr. Wajsman presented the main findings therein. The

video recordings of the policy seminar and the study are available on a dedicated webpage in the CPVO official website at: https://cpvo.europa.eu/en/news-and-events/conferences-and-events/cpvo-policy-seminar-plant-variety-protection-path-towards-more-sustainability-innovation-and-growth-european-union.

[4] One interesting argument gathered into this chapter is that, inter alia, the expected positive effects of the EU PVR system are: i) increased breeding activities; ii) greater availability of improved varieties; iii) increased number of new varieties; iv) diversification of types of breeders; v) supporting the development of new industry sectors; vi) improved access to foreign plant varieties and enhanced domestic breeding programs; and vii) encouragement of the development of a new industry competitiveness on foreign markets.

[5] For agricultural crops, the scope includes the following: corn, wheat, oilseed rape, potato, barley, sunflower, ryegrass, and durum wheat. For fruits, the crops considered include peach, strawberry, apple, wine, apricot, blueberry, raspberry, plum, and cherry. For vegetables, the scope encompasses the following crops: lettuce, tomato, pepper, melon, bean, pea, cucumber, cabbage, onion, spinach, endive, and leek. For ornamentals, almost 100 crops would have to be integrated, and as this quantity cannot properly be handled with the standard methodologies of agricultural and environmental economics relied upon for the elaboration of the study, all ornamental crops are grouped into and considered as one single cluster.

[6] This means that the analytical approach is applied to a quarter of a century of plant breeding in general and more specifically the PVR system in the EU. The various impacts of the EU PVR system are then analysed from the perspective of the year 2020.

[7] A description of the methodological particularities of the said tools can be found in the study's sections 3.2.2. (pages 99–102) and 3.2.3 (pages 102–105), respectively.

[8] UPOV report on the impact of plant variety protection (2005), UPOV Publications, 353(E), Geneva (Switzerland).

[9] It is noted that the annual growth rates of the overall input use (excluding land) in the period ranging from 1995 to 2019 are -0.5% in arable farming and -1% in horticultural farming.

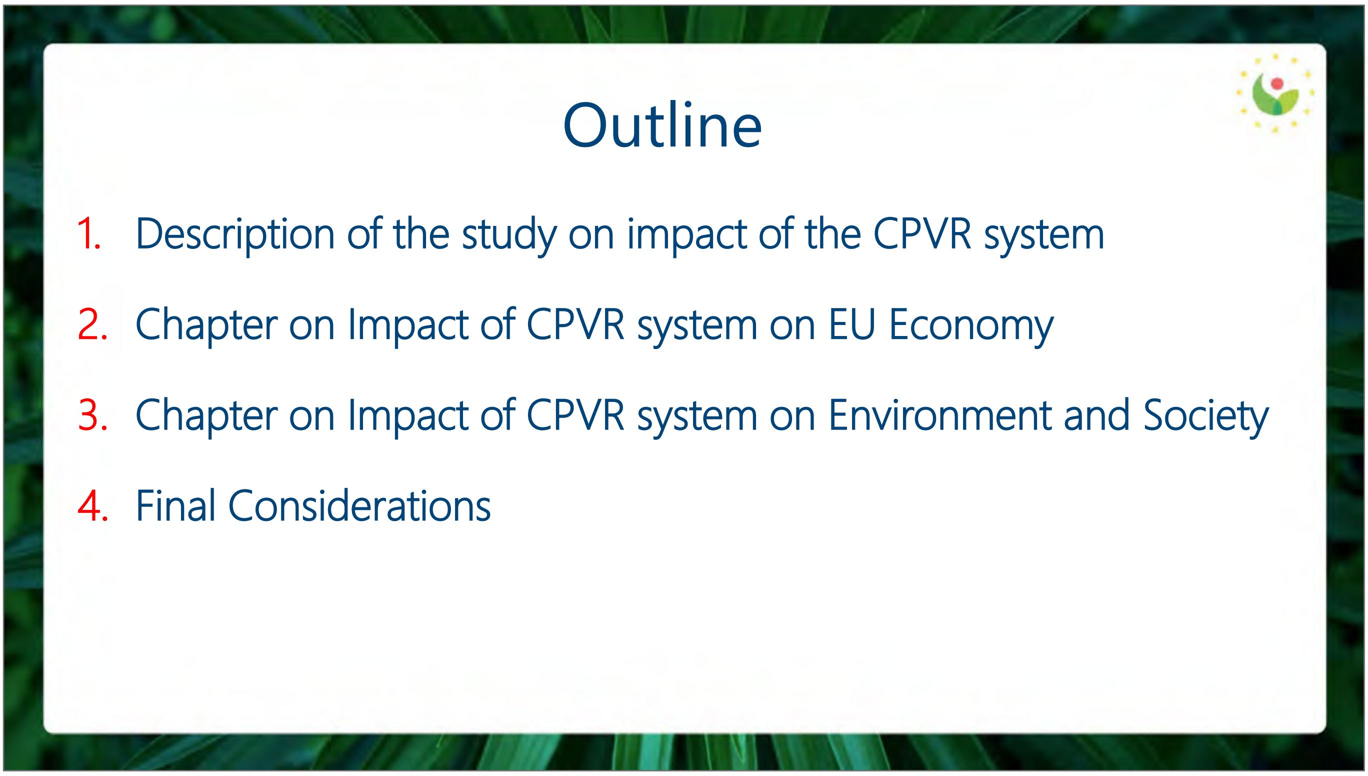
[10] SMEs are companies with fewer than 250 employees and annual turnover of less than €50 million. Within the SMEs category, "micro" companies have 10 employees or fewer; "small" companies have 10–50 employees; and "medium" companies have 50–250 employees.

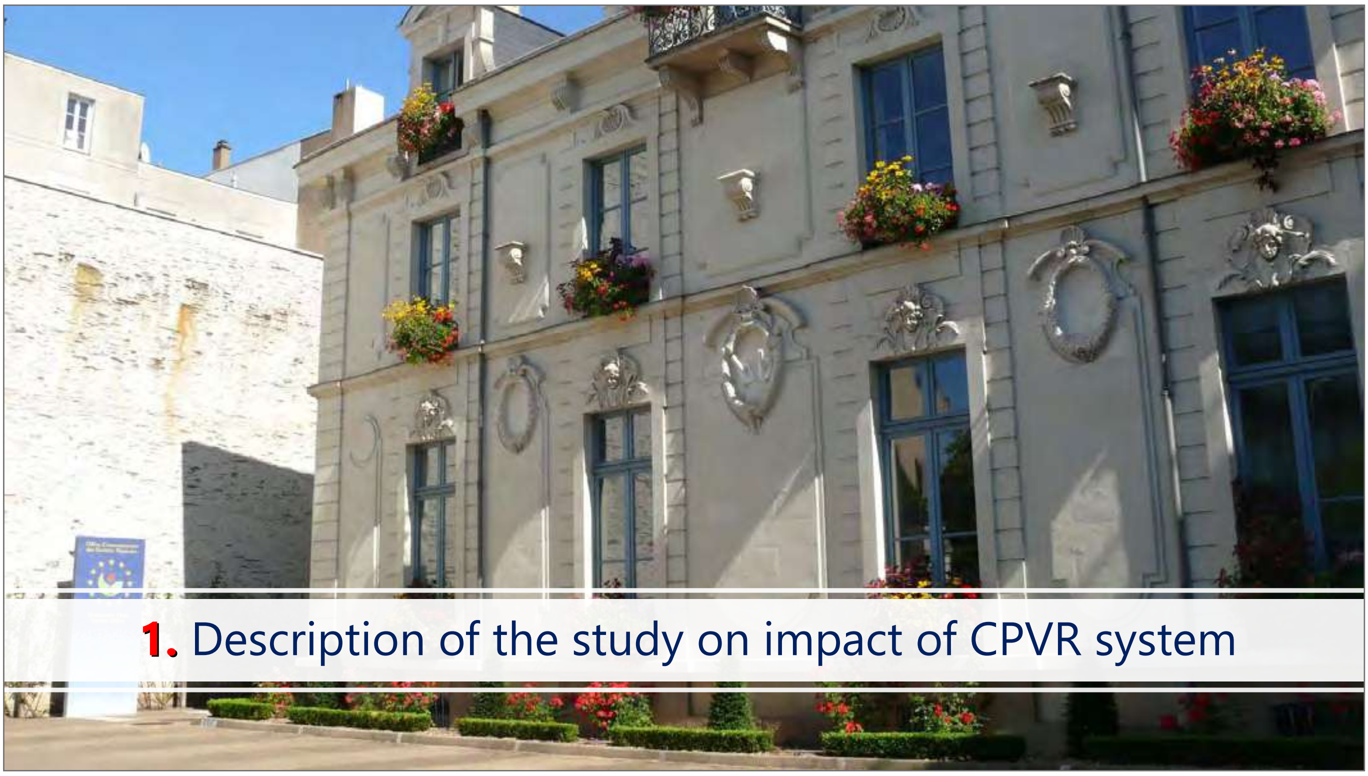
[11] This number can be somewhat higher, since the procedure used to identify firms is more successful for large firms. Since all the large firms were manually searched in ORBIS, it is likely that the true percentage of rights registered by SME is higher.

[12] More precisely, to address the protection of the environment and to contribute to the halting loss of biodiversity. Access to genetic diversity for plant breeding remains key to halting losses of agrobiodiversity.

[13] More precisely, to ensure the production of sustainable, safe, nutritious and high-quality food along the whole value chain while ensuring food security by seed security.

Presentation made at the Seminar




1. Description of the study on impact of CPVR system


General remarks on the study
Published by European Observatory on Infringements of Intellectual Property Rights in cooperation with the CPVO
Released on 28 April in CPVO Policy seminar, under the French Presidency of the Council of the European Union
The study Quantifies the economic contribution in the European Union of the CPVR system
CPVO
EUIPO
IMPACT OF THE COMMUNITY PLANT VARIETY RIGHTS SYSTEM ON THE EU ECONOMY AND THE ENVIRONMENT
April 2022

Structure of the study

1. Introductory chapter on CPVR and EU marketing
2. Literature review
3. Methodology and data
4. Quantitative results

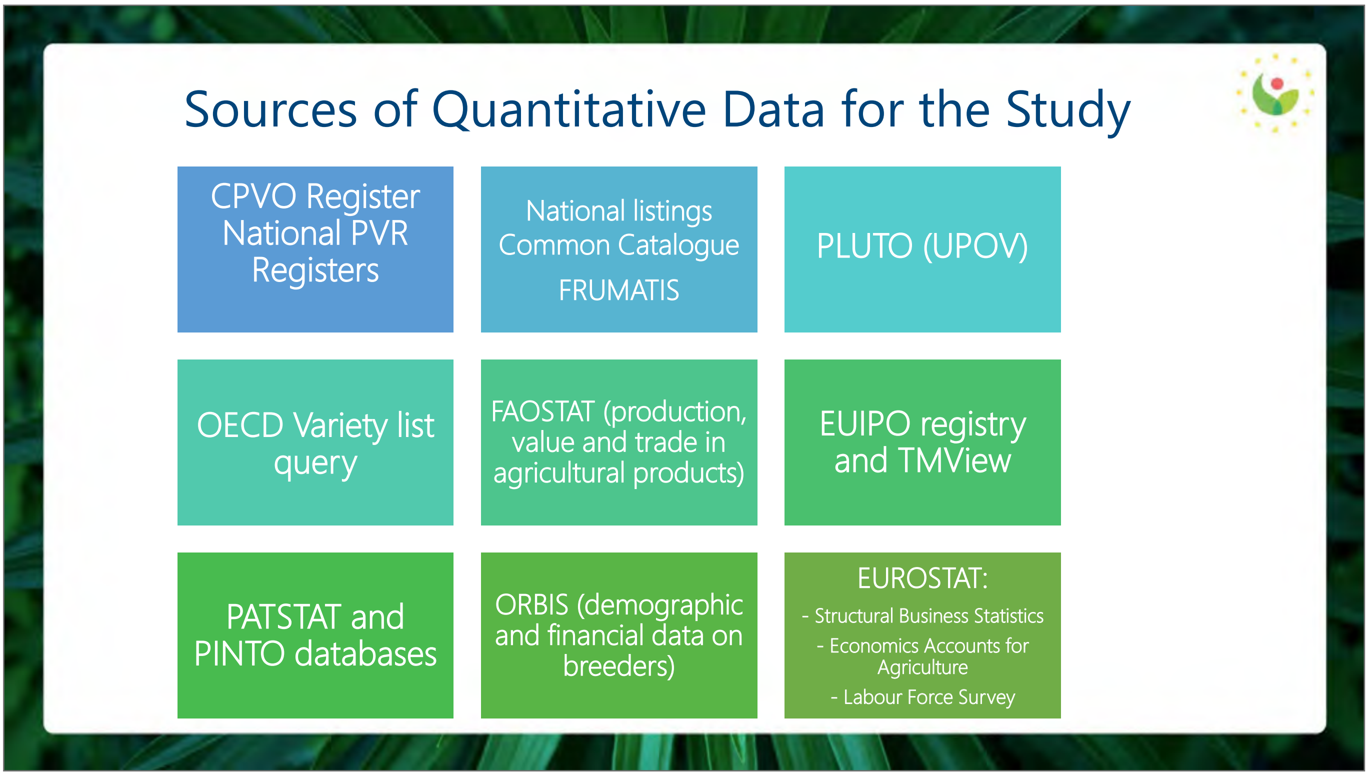
Methodology used for the study

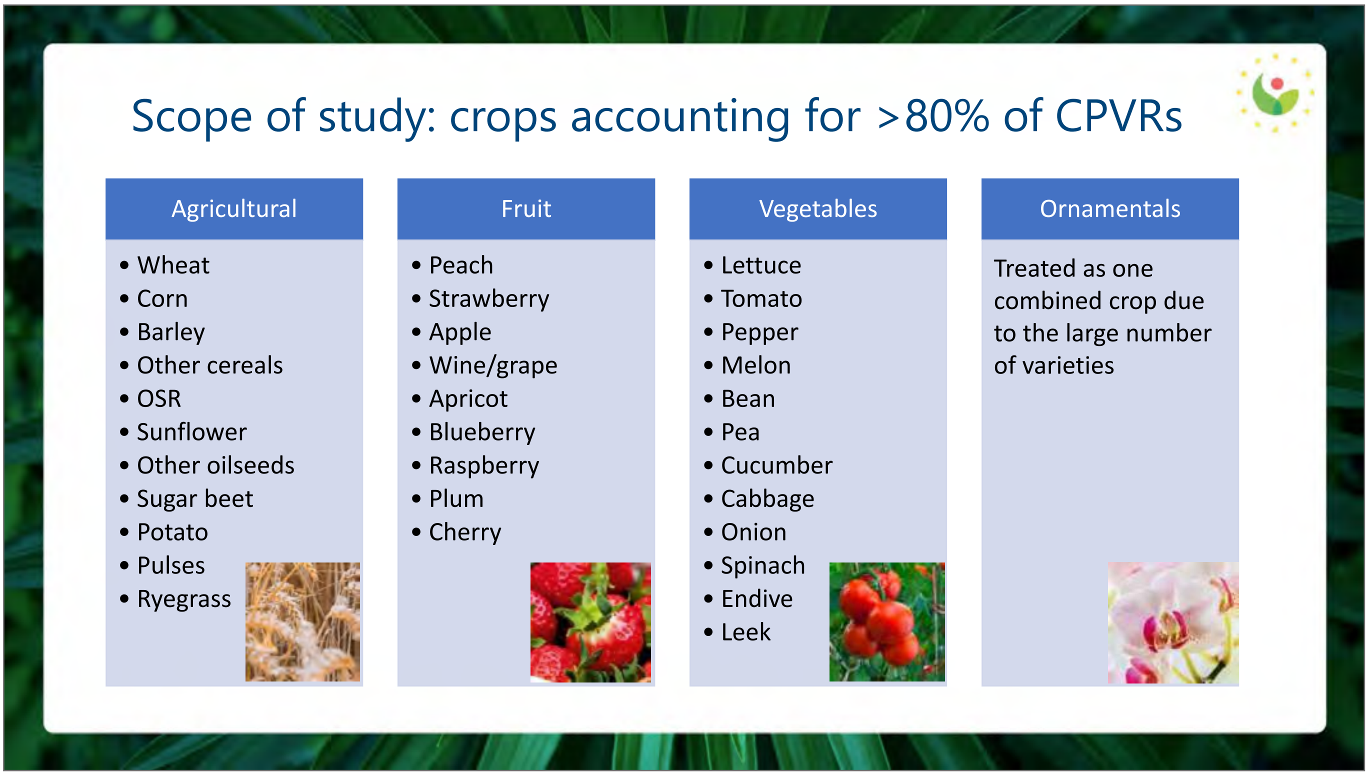
Impact on Economy

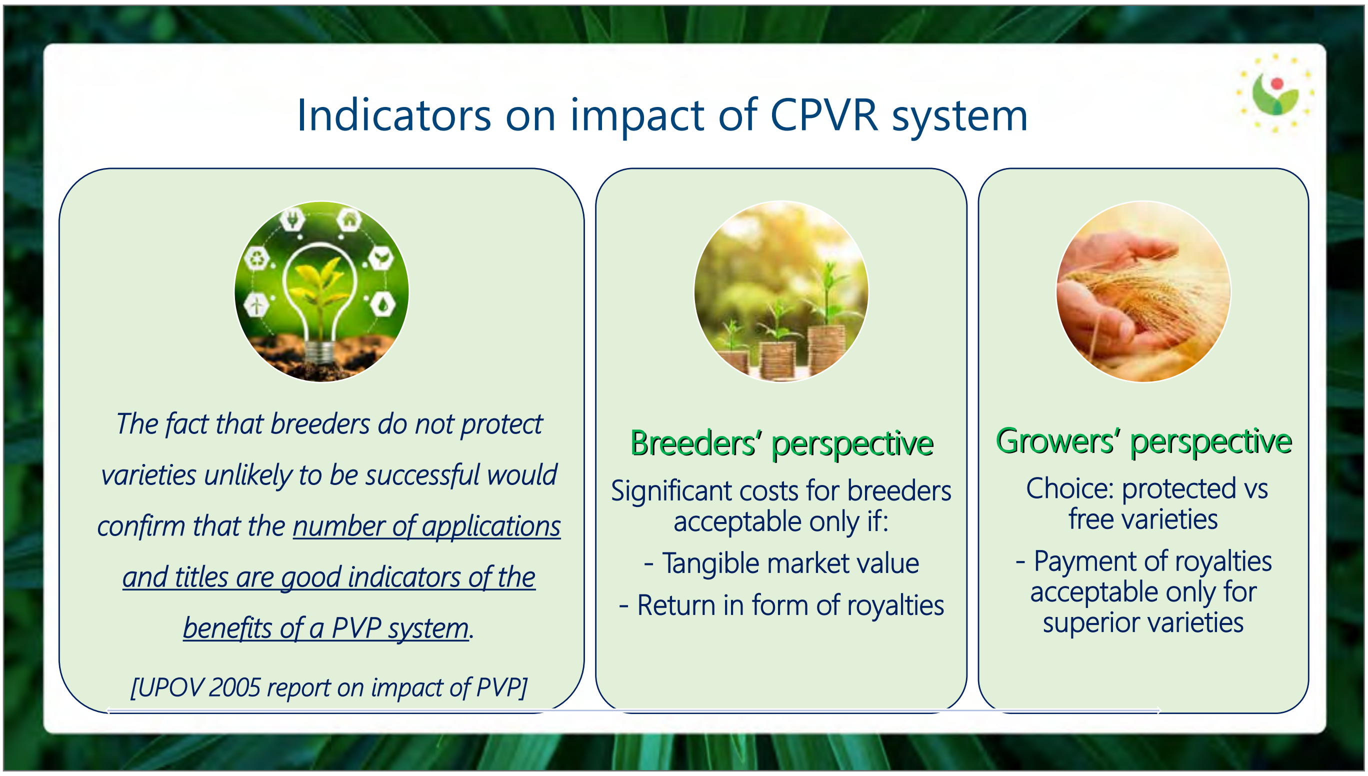
- Calculated using a computable equilibrium model
- Considers the impact of increased production on:
  - Prices
  - Farm incomes
  - Overall economic output (via multiplier effects)
  - Employment
  - Impact on EU's trade with the rest of the world

Impact on Environment

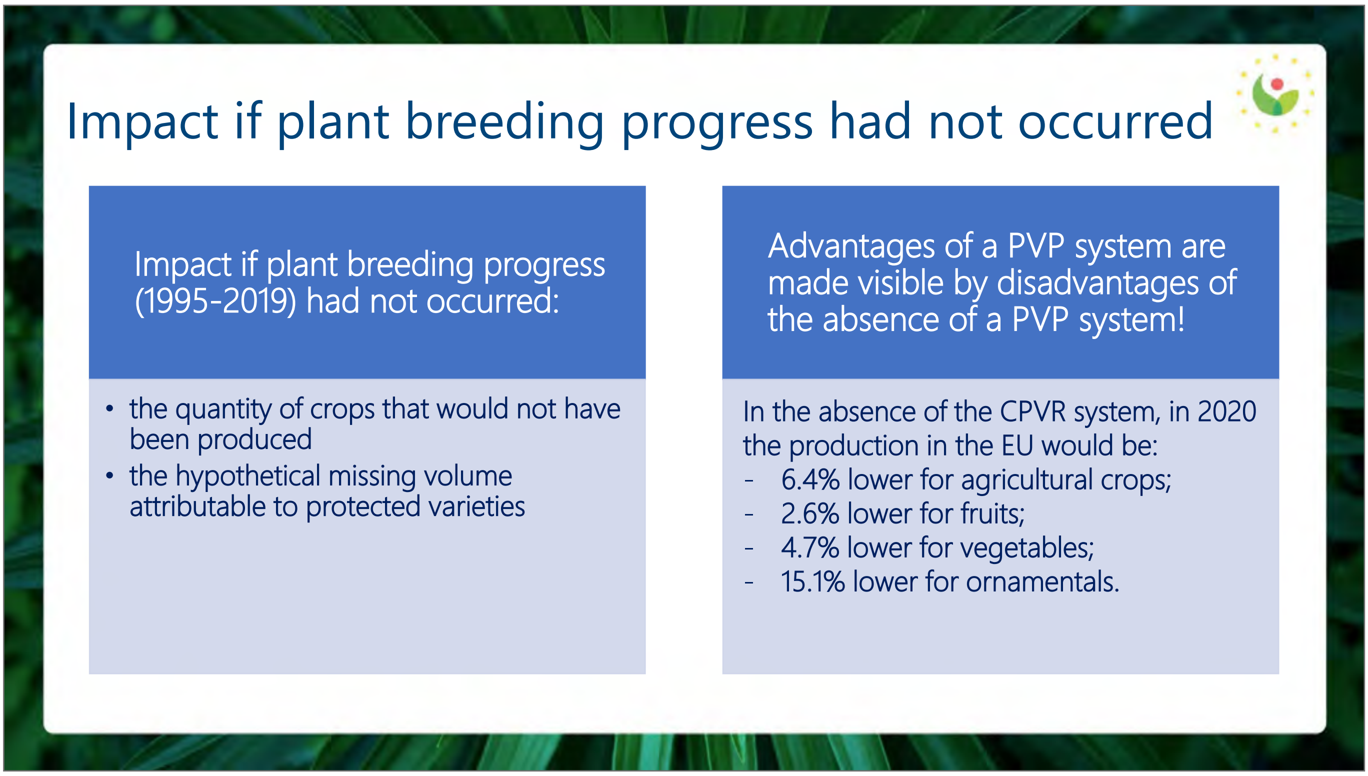
- Considers the impact of Increased productivity due to innovation
  - less imports from rest of the world
  - less land use in rest of the world
  - less water use
  - fewer greenhouse gas emissions
  - less biodiversity loss

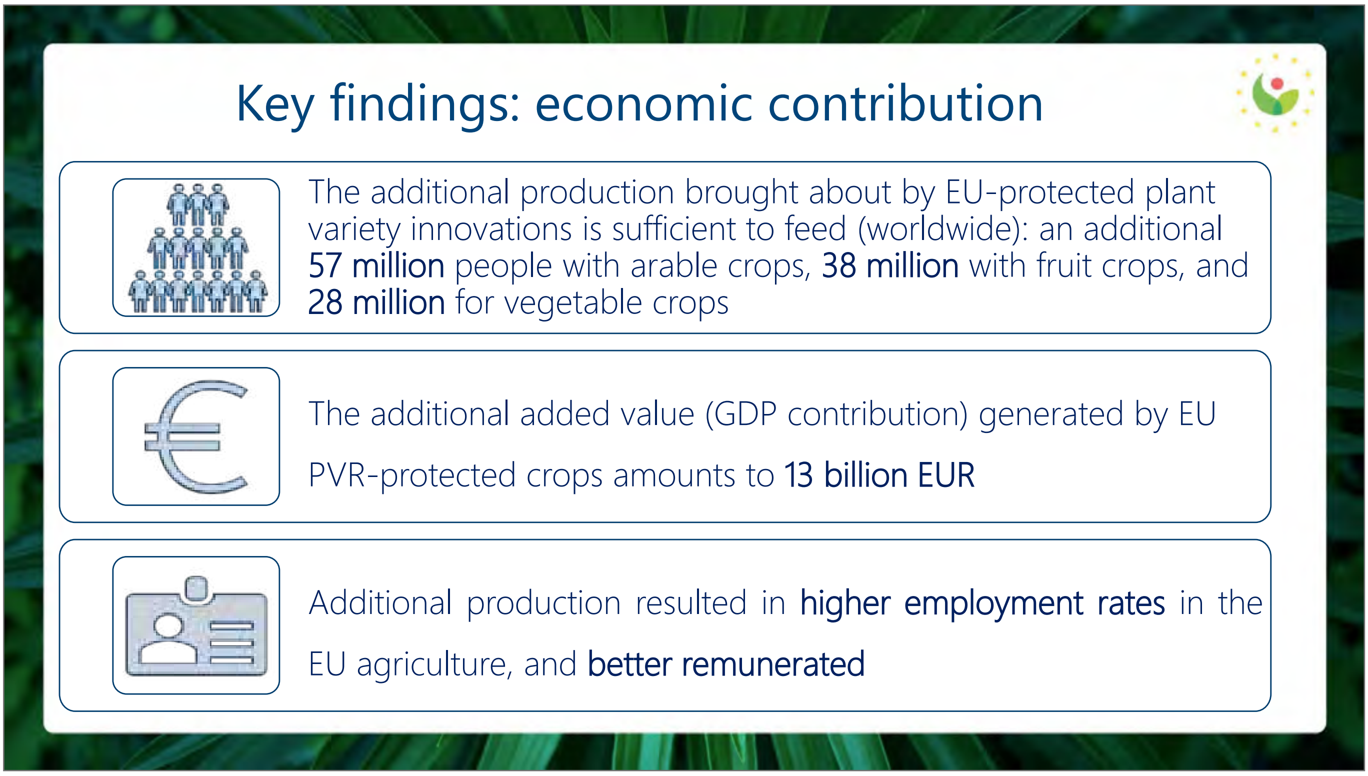

Sources of Quantitative Data for the Study
CPVO Register National PVR Registers
National listings Common Catalogue
FRUMATIS
PLUTO (UPOV)
OECD Variety list query
FAOSTAT (production, value and trade in agricultural products)
EUIPO registry and TMView
PATSTAT and PINTO databases
ORBIS (demographic and financial data on breeders)
EUROSTAT:
- Structural Business Statistics
- Economics Accounts for Agriculture
- Labour Force Survey


Scope of study: crops accounting for >80% of CPVRs
Agricultural
• Wheat
• Corn
• Barley
• Other cereals
• OSR
• Sunflower
• Other oilseeds
• Sugar beet
• Potato
• Pulses
• Ryegrass
Fruit
• Peach
• Strawberry
• Apple
• Wine/grape
• Apricot
• Blueberry
• Raspberry
• Plum
• Cherry
Vegetables
• Lettuce
• Tomato
• Pepper
• Melon
• Bean
• Pea
• Cucumber
• Cabbage
• Onion
• Spinach
• Endive
• Leek
Ornamentals
Treated as one combined crop due to the large number of varieties

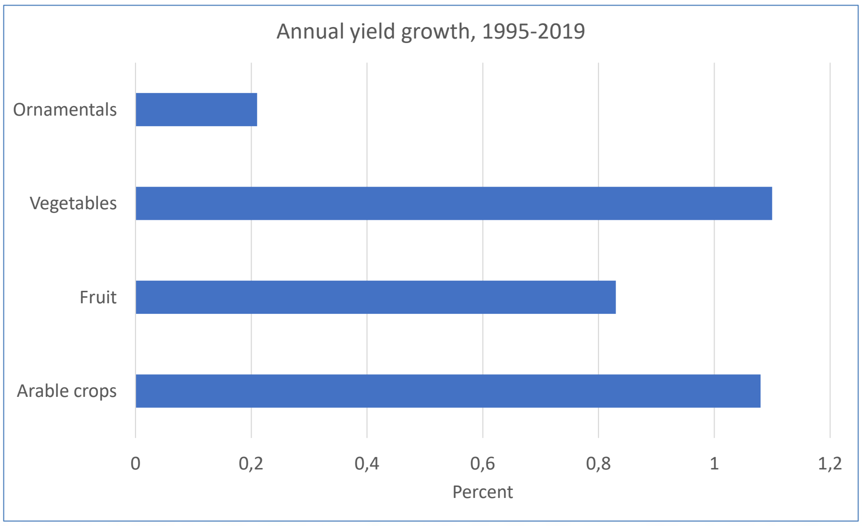

Indicators on impact of CPVR system
The fact that breeders do not protect varieties unlikely to be successful would confirm that the number of applications and titles are good indicators of the benefits of a PVP system.
[UPOV 2005 report on impact of PVP]
Breeders' perspective
Significant costs for breeders acceptable only if:
- Tangible market value
- Return in form of royalties
Growers' perspective
Choice: protected vs free varieties
- Payment of royalties acceptable only for superior varieties


2. CPVR Impact on Economy
Pic: © Wageningen


Impact if plant breeding progress had not occurred
Impact if plant breeding progress (1995-2019) had not occurred:
• the quantity of crops that would not have been produced
• the hypothetical missing volume attributable to protected varieties
Advantages of a PVP system are made visible by disadvantages of the absence of a PVP system!
In the absence of the CPVR system, in 2020 the production in the EU would be:
- 6.4% lower for agricultural crops;
- 2.6% lower for fruits;
- 4.7% lower for vegetables;
- 15.1% lower for ornamentals.


Key findings: economic contribution
The additional production brought about by EU-protected plant variety innovations is sufficient to feed (worldwide): an additional 57 million people with arable crops, 38 million with fruit crops, and 28 million for vegetable crops
The additional added value (GDP contribution) generated by EU PVR-protected crops amounts to 13 billion EUR
Additional production resulted in higher employment rates in the EU agriculture, and better remunerated

Annual yield growth for crops in the EU (1995-2019) (% per year)

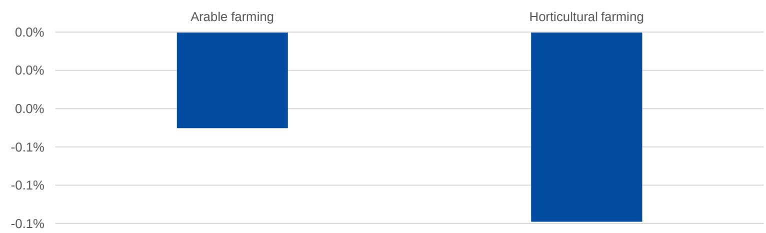


INPUT USE: DECLINING
Growth rates of input use (per hectare) for EU agricultural and horticultural farming (1995-2019) (% per year)

- "Agricultural Intensification" is factored out (= increased input, e.g.: denser planting schemes, capital, labor etc.)

FARMING	SEEDS	FERTILISERS	PPP	LABOUR	CAPITAL
Arable	-0.20	-0.07	-0.60	-0.60	-0.44
Horticultural	-0.60	-2.30	-1.40	-1.00	-0.92

Annual growth rates of the overall input use (excluding land) in agricultural and horticultural farming of the EU (1995-2019)



YIELD: INCREASING
Innovation-induced yield growth rates for crops in the EU (1995-2019) (% per year)

- Subtracting the overall input use growth rate from statistically observable yield growth leads to crop-specific annual innovation-induced growth rate

CROP	GROWTH RATE	CROP	GROWTH RATE	CROP	GROWTH RATE
Wheat	1.43	OSR	1.20	Potato	2.40
Corn	1.72	Sunflower	2.74	Pulses	0.94
Barley	1.57	Other oilseeds	0.79	Green maize	2.30
Other cereals	1.41	Sugar beet	2.63	Ryegrass	1.29
CROP	**GROWTH RATE**	**CROP**	**GROWTH RATE**	**CROP**	**GROWTH RATE**
Peach	2.20	Wine/Grape	1.59	Raspberry	1.57
Strawberry	2.22	Apricot	3.79	Plum	3.49
Apple	2.28	Blueberry	2.42	Cherry	1.48
CROP	**GROWTH RATE**	**CROP**	**GROWTH RATE**	**CROP**	**GROWTH RATE**
Lettuce	1.47	Bean	1.84	Onion	4.09
Tomato	3.16	Pea	0.91	Spinach	1.27
Pepper	3.90	Cucumber	4.71	Endive	2.31
Melon	2.14	Cabbage	1.51	Leek	1.71

Ornamental crop (as a whole): 1.20

Contribution of plant breeding to innovation-induced yield growth of EU crops (%)

CROP	SHARE	CROP	SHARE	CROP	SHARE
Wheat	67.3	OSR	73.8	Potato	62.1
Corn	69.2	Sunflower	71.5	Pulses	65.6
Barley	69.3	Other oilseeds	71.5	Green maize	65.8
Other cereals	72.3	Sugar beet	60.7	Ryegrass	53.5

Contribution by plant breeding to innovation-induced yield growth of arable crops in the EU (per cent)

GROUP OF CROPS	SHARE	GROUP OF CROPS	SHARE
Fruit	58.8	Vegetables	59.0

Contribution by plant breeding to innovation-induced yield growth of fruit and vegetables in the EU (per cent)

Ornamental crop (as a whole): Assumed to be 59 %

Plant breeding-induced yield growth rates for crops in the EU (1995-2019) (% per year)

- Merging innovation-induced yield growth rates and plant breeding's shares in innovation-induced change

CROP	GROWTH RATE	CROP	GROWTH RATE	CROP	GROWTH RATE
Wheat	0.96	OSR	0.89	Potato	1.49
Corn	1.19	Sunflower	1.96	Pulses	0.62
Barley	1.09	Other oilseeds	0.56	Green maize	1.51
Other cereals	1.02	Sugar beet	1.60	Ryegrass	0.69
CROP	**GROWTH RATE**	**CROP**	**GROWTH RATE**	**CROP**	**GROWTH RATE**
Peach	1.29	Wine/Grape	0.93	Raspberry	0.92
Strawberry	1.31	Apricot	2.23	Plum	2.05
Apple	1.34	Blueberry	1.42	Cherry	0.87
CROP	**GROWTH RATE**	**CROP**	**GROWTH RATE**	**CROP**	**GROWTH RATE**
Lettuce	0.87	Bean	1.09	Onion	2.41
Tomato	1.86	Pea	0.54	Spinach	0.75
Pepper	2.30	Cucumber	2.78	Endive	1.36
Melon	1.26	Cabbage	0.89	Leek	1.01

Ornamental crop (as a whole): 0.71

Share of protected agricultural varieties to account for the effects of the PVP system

CROP	REGISTERED VARIETIES	EU-LEVEL PVR VARIETIES	SHARE
Wheat	4 137	1 401	33.9 %
Corn/Green maize	10 942	2 537	23.2 %
Barley	2 109	650	30.8 %
Other cereals	2 502	593	23.7 %
OSR	2 431	884	36.4 %
Sunflower	3 037	686	22.6 %
Other oilseeds	1 875	370	29.7 %
Sugar beet	2 901	115	4.0 %
Potato	2 146	1 057	49.3 %
Pulses	1 075	167	15.5 %
Ryegrass	1 318	260	19.7 %

Therefore, 25.3 % of all registered varieties of the arable crops that are the focus of this study are varieties with an EU-level PVR.

Share of protected fruit varieties to account for the effects of the PVP system

CROP	REGISTERED VARIETIES	EU-LEVEL PVR VARIETIES	SHARE
Peach	3 333	640	19.2 %
Strawberry	1 868	418	22.4 %
Apple	6 748	345	5.1 %
Wine/Grape	2 444	243	9.9 %
Apricot	1 069	199	18.6 %
Blueberry	412	129	31.3 %
Raspberry	709	138	19.5 %
Plum	295	83	28.1 %
Cherry	1 731	99	5.7 %

12.3 % of all registered fruit varieties are varieties with an EU-level PVR.

Share of protected vegetable varieties to account for the effects of the PVP system

CROP	REGISTERED VARIETIES	EU-LEVEL PVR VARIETES	SHARE
Lettuce	3 314	1329	40.1 %
Tomato	5 740	922	16.1 %
Pepper	2 967	383	12.9 %
Melon	1 540	284	18.4 %
Bean	1 807	245	13.6 %
Pea	1 523	369	24.2 %
Cucumber	1 664	220	13.2 %
Cabbage	3 050	332	10.9 %
Onion	1 359	194	14.3 %
Spinach	584	105	18.0 %
Endive	461	88	19.1 %
Leek	299	84	28.1 %

18.7 % of all registered varieties of the vegetables that are the focus of this study are varieties with an EU-level PVR.

Share of protected ornamental varieties to account for the effects of the PVP system

CROP	REGISTERED VARIETIES	EU-LEVEL PVR VARIETES	SHARE
Ornamentals	15 588	15 094	96.8 %

Breeders' geographical origin in CPVRs

- 29.000+ CPVRs in force (beginning 2022)
- Largest share: EU countries (almost 77%)

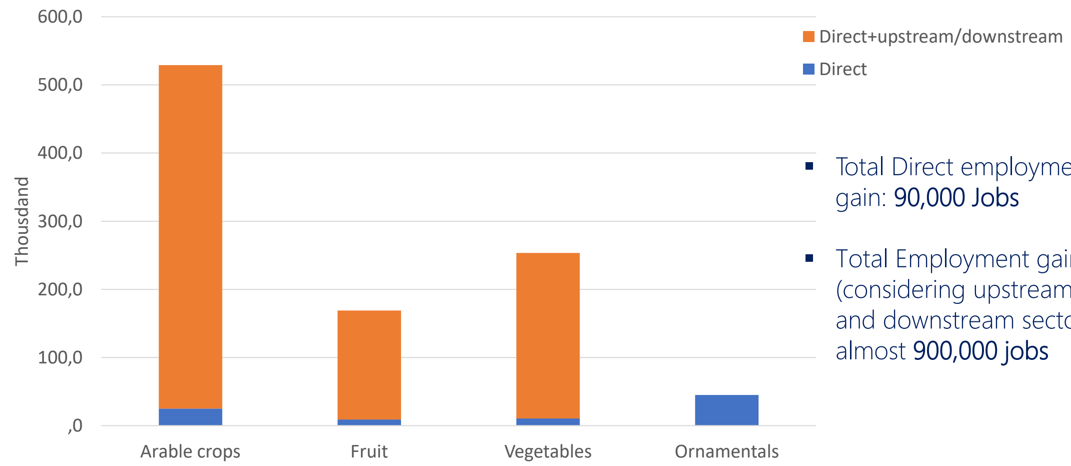
	Country	% CPVR	number CPVR
NL	Netherlands	34.8	9,919
FR	France	17.0	4,837
DE	Germany	14.0	3,985
US	United States	6.7	1,911
CH	Switzerland	5.3	1,523
DK	Denmark	3.2	906
UK	United Kingdom	3.1	872
IT	Italy	2.7	783
ES	Spain	2.4	681
BE	Belgium	2.2	615
EU27	**European Union**	**76.9**	**22,669**
	Third countries	**23.1**	5,845

Size of CPVR holders

- 93.5% of registrants of CPVRs are SMEs
- 60% of CPVRs are owned by SMEs
- SMES own each around 10 CPVRs

Size	% CPVR	% firms	Number of firms	CPVRs per firm
Physical persons	8.0	36.8	451	3.3
Micro firms	21.7	32.8	402	10.2
Small firms	11.5	15.5	190	11.4
Medium firms	18.8	8.5	104	34.2
Large firms	**40.0**	**6.5**	**80**	**94.8**
SME + Physical	**60.0**	**93.5**	**1 147**	**9.9**

Contribution to Employment of CPVR-protected varieties



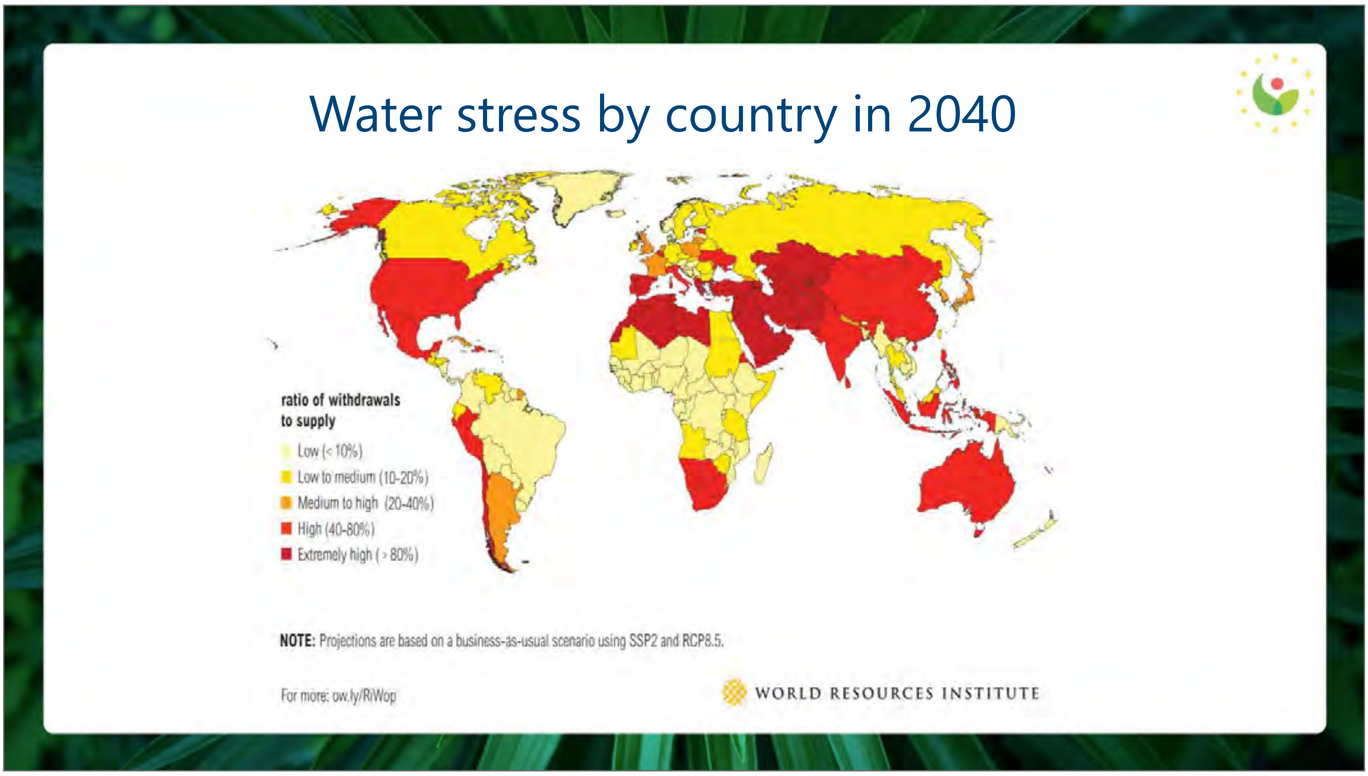
- Total Direct employment gain: 90,000 Jobs
- Total Employment gain (considering upstream and downstream sectors): almost 900,000 jobs

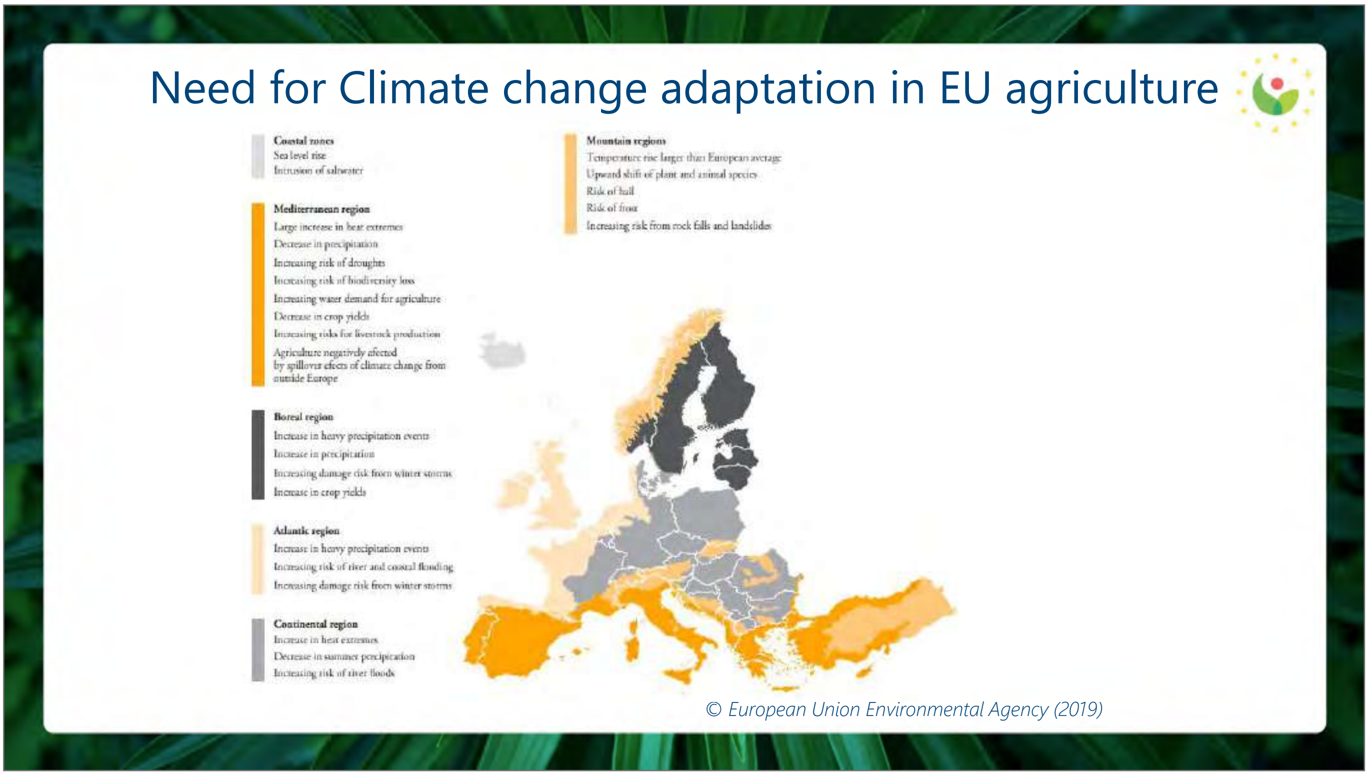
Employment and Turnover rates of CPVR holders

- 951 CPVR holders have plant breeding as primary activity
- CPVR holders employ more than 70.000 workers and have an annual turnover of EUR 35 billion

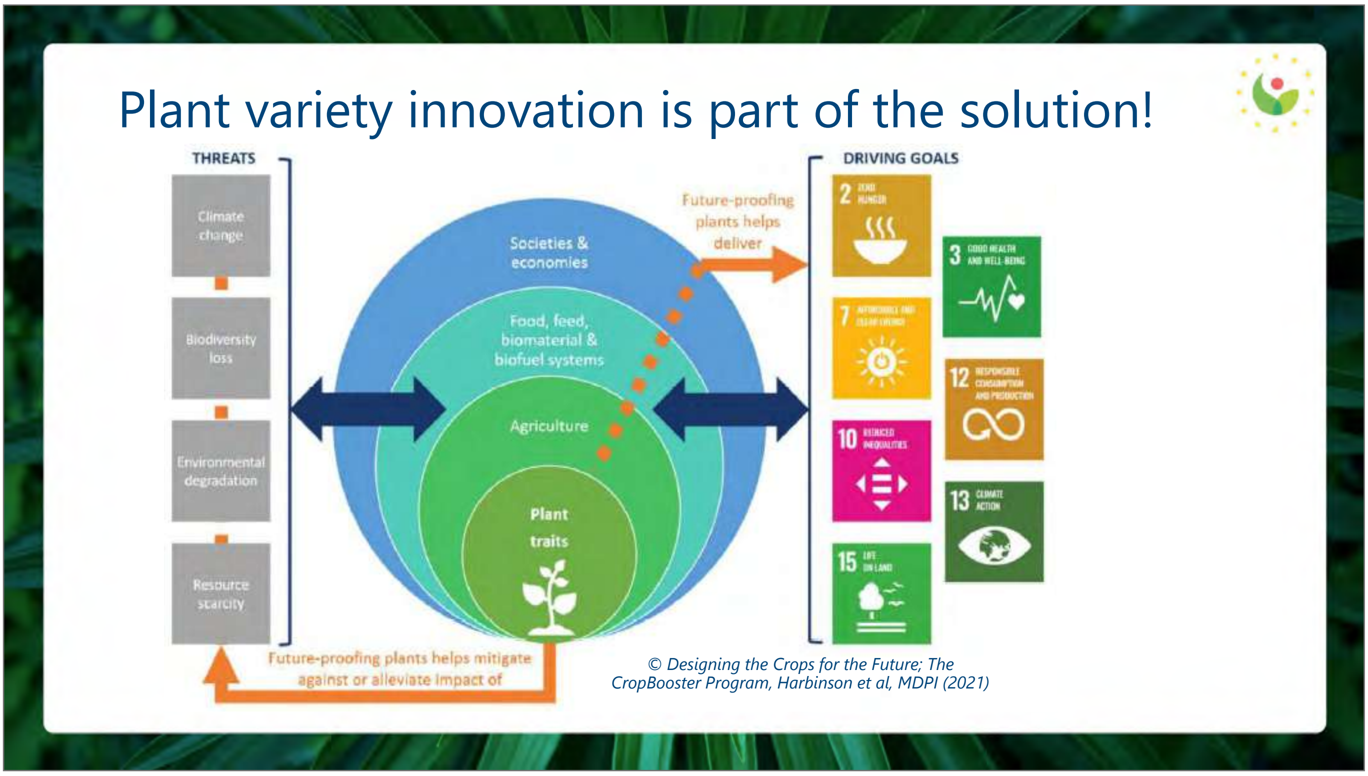
sector	firms	employees	turnover (million €)
Agriculture (seed growing)	603	35,045	17,780
R&D (agricultural & biotechnology)	128	7,970	2,364
Royalties (PVR)	47	119	722
Wholesale (seeds)	173	27,590	14,552
Total	**951**	**70,725**	**35,418**

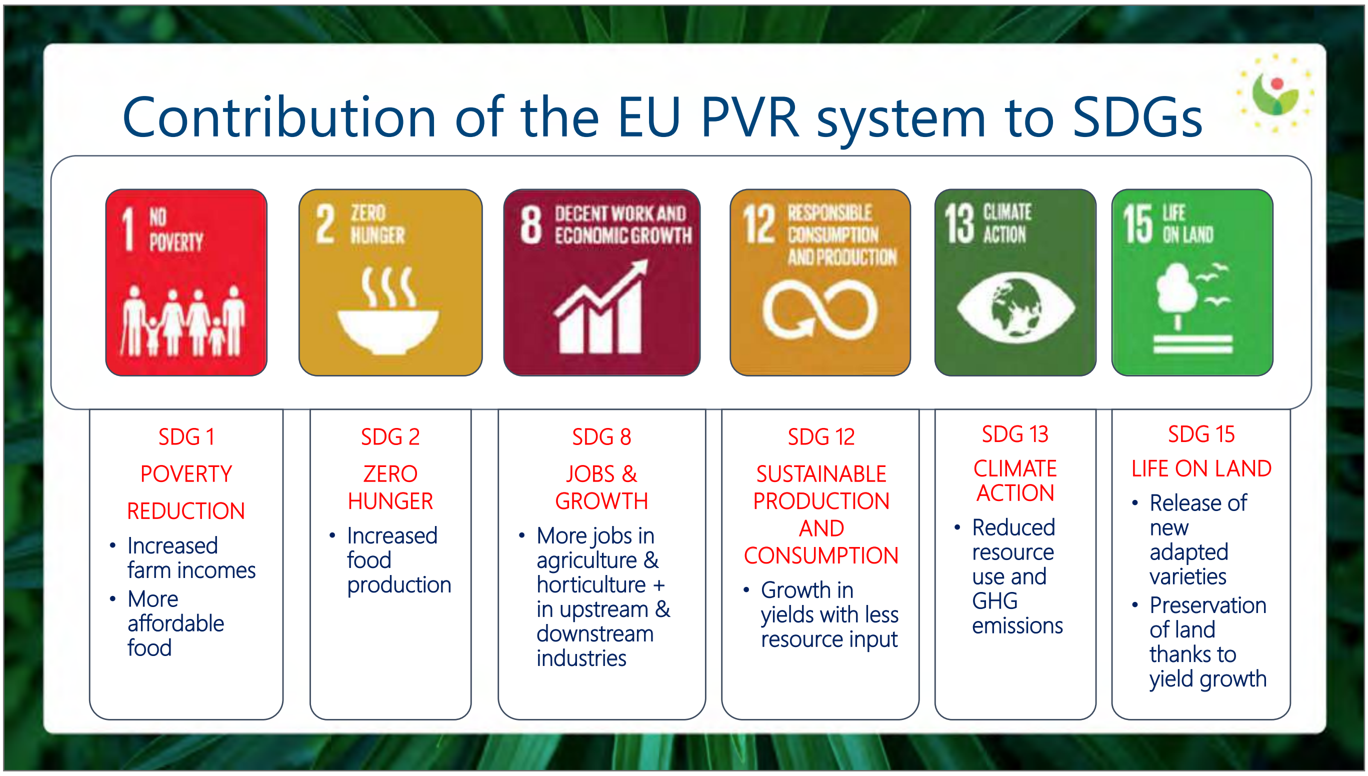
- Positive impact on wages:
  - Agricultural crop sector: +12.6%
  - Horticultural sector: +11%
- Positive impact on EU's trade balance
  - Without CPVR-protected innovation, the EU would become a net importer of some crops for which it is an exporter today

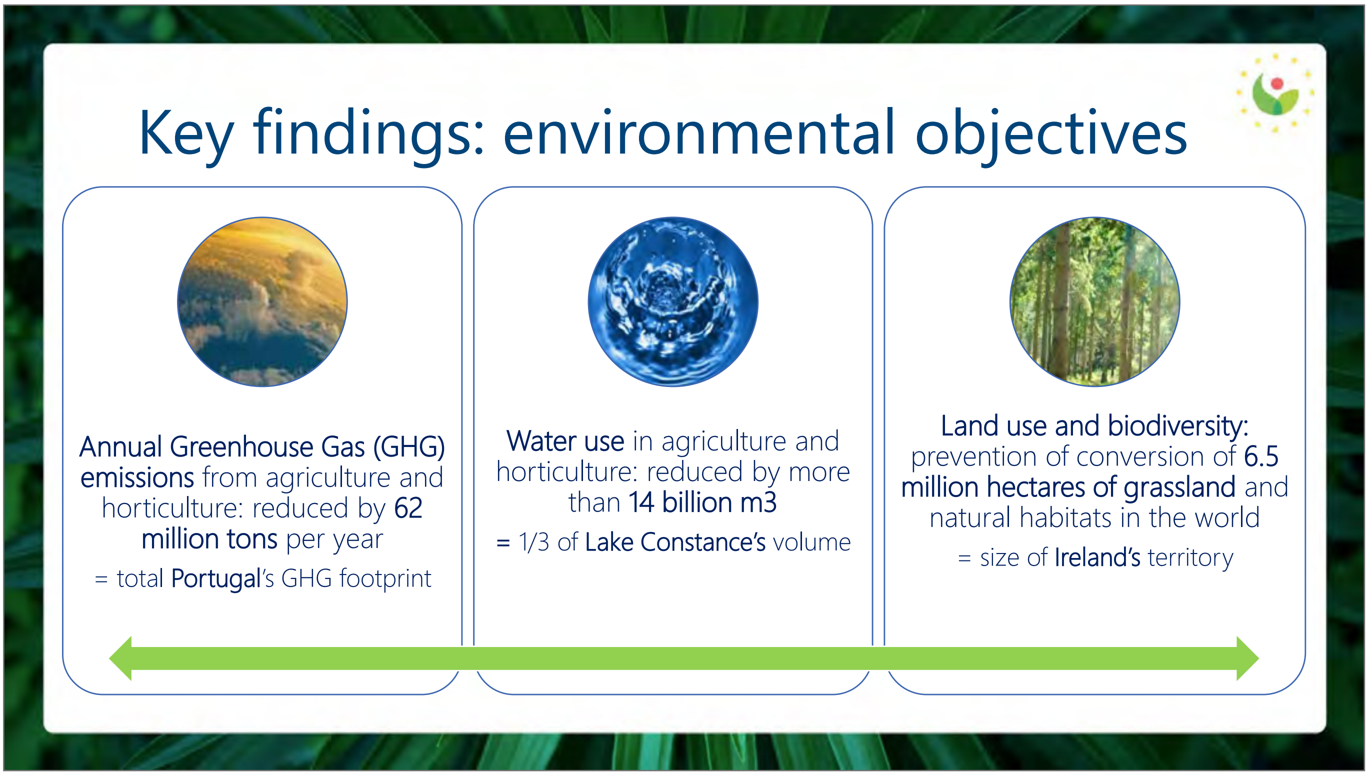

Water stress by country in 2040
ratio of withdrawals to supply
Low (< 10%)
Low to medium (10-20%)
Medium to high (20-40%)
High (40-80%)
Extremely high (> 80%)
NOTE: Projections are based on a business-as-usual scenario using SSP2 and RCP8.5.
For more: ow.ly/RiWop
WORLD RESOURCES INSTITUTE

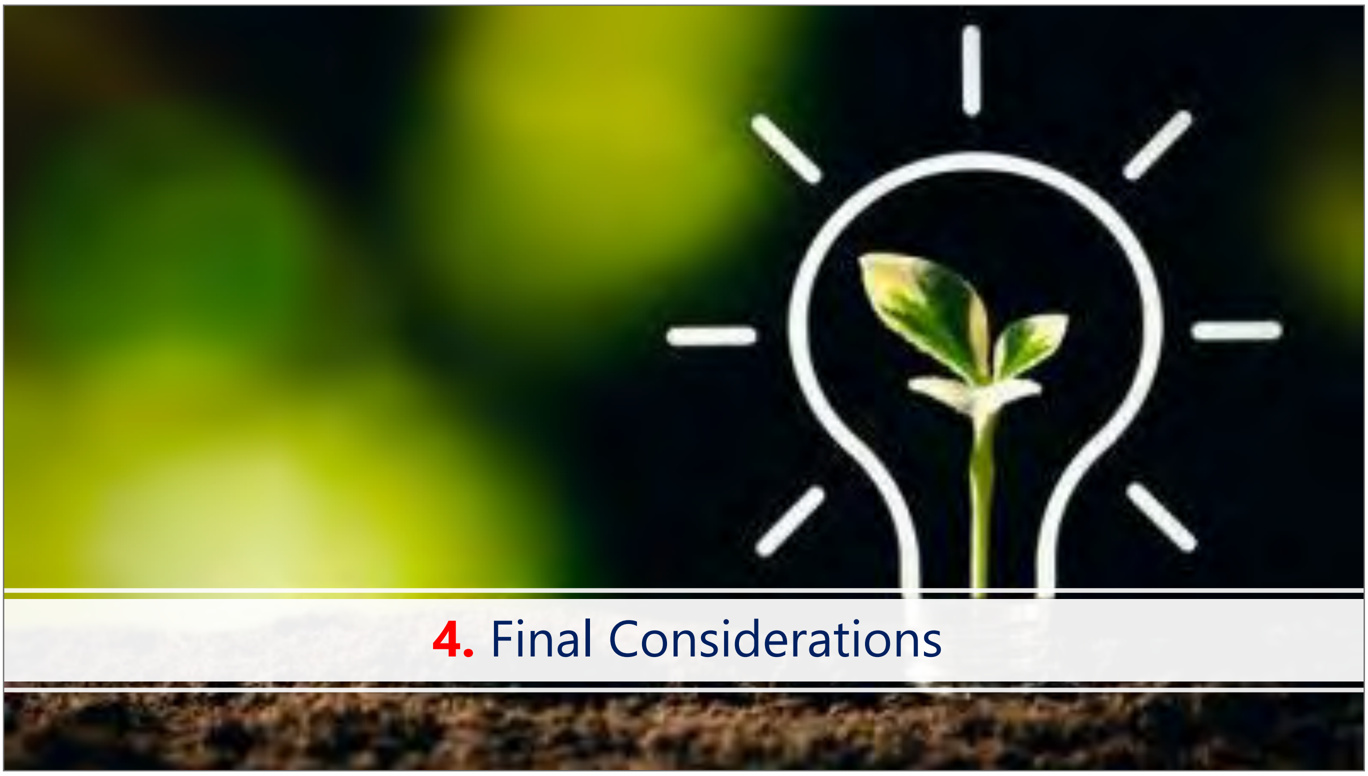

Need for Climate change adaptation in EU agriculture
Coastal zones
Sea level rise
Intrusion of saltwater
Mediterranean region
Large increase in heat extremes
Decrease in precipitation
Increasing risk of droughts
Increasing risk of biodiversity loss
Increasing water demand for agriculture
Decrease in crop yields
Increasing risks for livestock production
Agriculture negatively affected by spillover effects of climate change from outside Europe
Boreal region
Increase in heavy precipitation events
Increase in precipitation
Increasing damage risk from winter storms
Increase in crop yields
Atlantic region
Increase in heavy precipitation events
Increasing risk of river and coastal flooding
Increasing damage risk from winter storms
Continental region
Increase in heat extremes
Decrease in summer precipitation
Increasing risk of river floods
Mountain regions
Temperature rise larger than European average
Upward shift of plant and animal species
Risk of hail
Risk of frost
Increasing risk from rock falls and landslides
© European Union Environmental Agency (2019)


Commission's EU Green Deal
EU to become climate-neutral by 2050
Biodiversity Strategy &
Farm to Fork Strategy
A zero pollution Europe
Preserving Europe's natural capital
Transition to a Circular Economy
Sustainable Transport
Farm to Fork
Achieving Climate Neutrality
European Green Deal
Towards a Green CAP
Clean, Reliable and Affordable energy
Financing the transition
Take everyone along (Just Transition Mechanism)

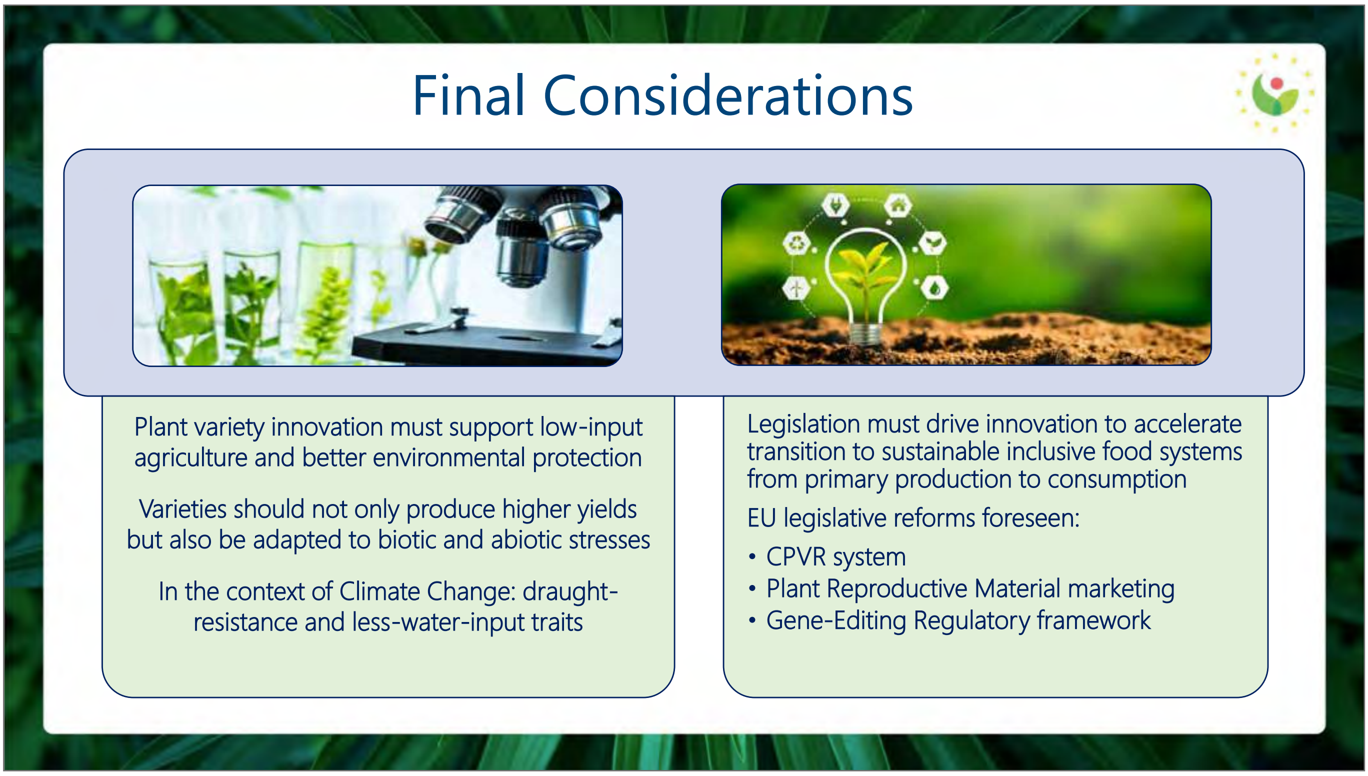

Plant variety innovation is part of the solution!
THREATS
Climate change
Biodiversity loss
Environmental degradation
Resource scarcity
Societies & economies
Food, feed, biomaterial & biofuel systems
Agriculture
Plant traits
Future-proofing plants helps deliver
DRIVING GOALS
Future-proofing plants helps mitigate against or alleviate impact of
© Designing the Crops for the Future; The CropBooster Program, Harbinson et al, MDPI (2021)


Contribution of the EU PVR system to SDGs
1 NO POVERTY
2 ZERO HUNGER
8 DECENT WORK AND ECONOMIC GROWTH
12 RESPONSIBLE CONSUMPTION AND PRODUCTION
13 CLIMATE ACTION
15 LIFE ON LAND
SDG 1
POVERTY REDUCTION
• Increased farm incomes
• More affordable food
SDG 2
ZERO HUNGER
• Increased food production
SDG 8
JOBS & GROWTH
• More jobs in agriculture & horticulture + in upstream & downstream industries
SDG 12
SUSTAINABLE PRODUCTION AND CONSUMPTION
• Growth in yields with less resource input
SDG 13
CLIMATE ACTION
• Reduced resource use and GHG emissions
SDG 15
LIFE ON LAND
• Release of new adapted varieties
• Preservation of land thanks to yield growth


Key findings: environmental objectives
Annual Greenhouse Gas (GHG) emissions from agriculture and horticulture: reduced by 62 million tons per year
= total Portugal's GHG footprint
Water use in agriculture and horticulture: reduced by more than 14 billion m3
= 1/3 of Lake Constance's volume
Land use and biodiversity: prevention of conversion of 6.5 million hectares of grassland and natural habitats in the world
= size of Ireland's territory


4. Final Considerations


Key findings: farmers, breeders, SMEs
Farmers/growers across the EU benefit from the innovations protected by the CPVR system
R&D by Breeders leads to innovations, employment and economic growth
SMEs and physical persons account hold 60% of CPVRs currently in force


Final Considerations
Plant variety innovation must support low-input agriculture and better environmental protection
Varieties should not only produce higher yields but also be adapted to biotic and abiotic stresses
In the context of Climate Change: draught-resistance and less-water-input traits
Legislation must drive innovation to accelerate transition to sustainable inclusive food systems from primary production to consumption
EU legislative reforms foreseen:
• CPVR system
• Plant Reproductive Material marketing
• Gene-Editing Regulatory framework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PANEL DISCUSSION & CONCLUDING REMARKS

Welcome and opening remarks
Mr. Marien Valstar, President of the Council, UPOV

Report of the Thematic Sessions
Moderator: Mr. Peter Button, Vice Secretary-General, UPOV

- **Report on Thematic Session 1:**
  Climate change and its impact on agricultural production
  Mr. Marien Valstar, President of the Council, UPOV
- **Report on Thematic Session 2:**
  Strategies to address climate change in agriculture
  Mr. Yehan Cui, Vice-President of the Council, UPOV
- **Report on Thematic Session 3:**
  Plant breeding for climate change adaptation and mitigation in agriculture: crop perspectives
  Mr. Patrick Ngwediagi, Chair of the Administrative and Legal Committee, UPOV
- **Report on Thematic Session 4:**
  Plant breeding for climate change adaptation and mitigation in agriculture: breeding strategies and techniques
  Mr. Manuel Toro Ugalde, Vice-Chair of the Administrative and Legal Committee, UPOV
- **Report on Thematic Session 5:**
  Role of plant variety protection in the development of new varieties to mitigate and adapt to climate change
  Ms. Kitisri Sukhapinda, Patent Attorney, Office of Policy and Affairs (OPIA), United States Patent and Trademark Office (USPTO), United States of America

Panel Discussion
Moderator: Mr. Marien Valstar, President of the Council, UPOV

- Mr. John Derera, Keynote speaker
- Ms. Arianna Giuliodori, WFO
- Mr. Michael Keller, ISF
- Mr. Edgar Krieger, CIOPORA
- Mr. Yehan Cui, Moderator Session 2
- Mr. Patrick Ngwediagi, Moderator Session 3
- Mr. Manuel Toro Ugalde, Moderator Session 4
- Ms. Kitisri Sukhapinda, Moderator Session 5

Concluding remarks
Mr. Marien Valstar, President of the Council, UPOV

WEDNESDAY, OCTOBER 26

WELCOME AND OPENING REMARKS

Mr. Marien Valstar
President of the Council, UPOV

Welcome everybody. We can start now, online is also active and welcome to the third part of our Seminar on the role of plant breeding and plant variety protection in enabling agriculture to mitigate and adapt to climate change.

It's a very good occasion to talk about these issues. Every day, at least in my newspaper or in the journals I see on the television, there are stories about impact of climate change, about strange weather patterns, about strange events and I don't want to sound panicky because I am not in panic, but there is an issue there.

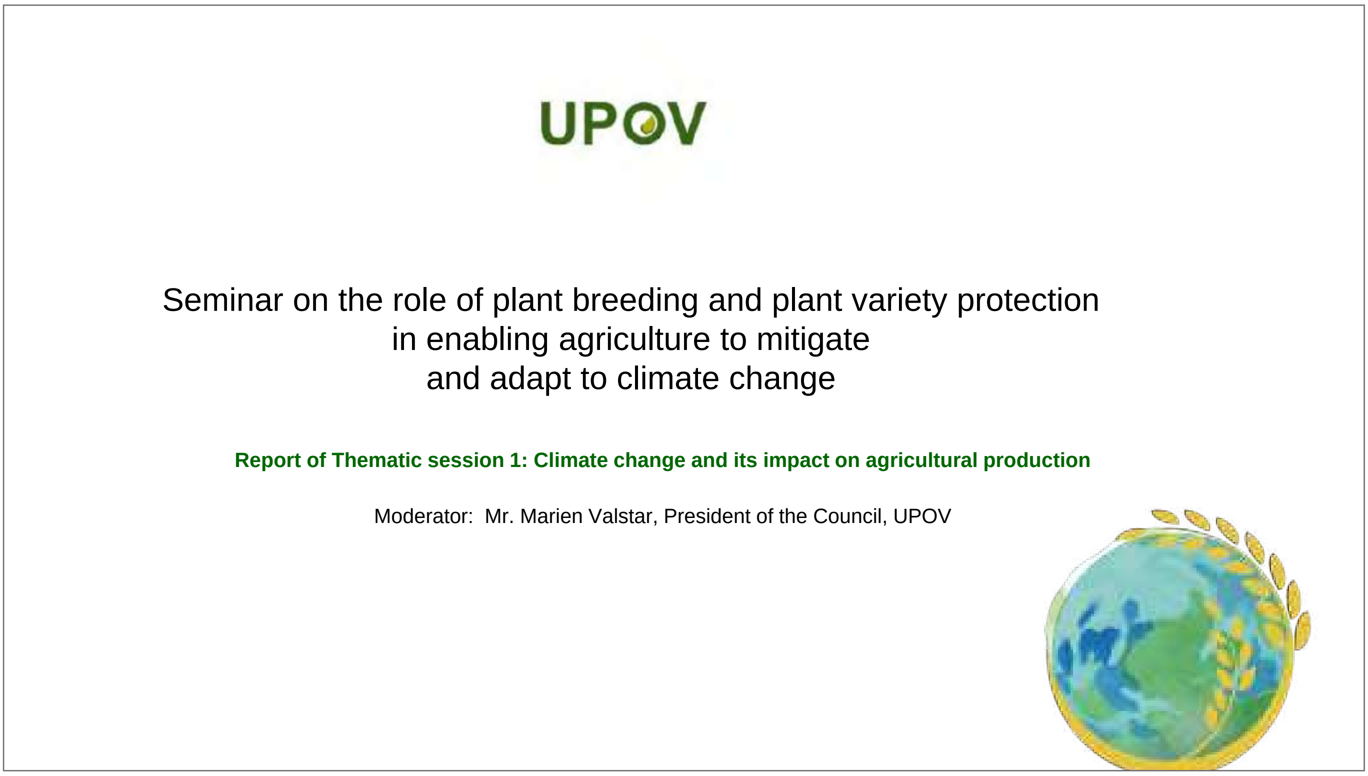
On October 11 and 12, we had our first sessions and today it is a good occasion to see what we discussed there, what we learnt there and how to move forward.

So last time, on October 11 and 12, there were over 370 participants from all over the world and now we have half a room here with in person participants and another half online. For those who are online, I would say Good morning, Good night; and for those that are here In Geneva I would say Good afternoon and welcome to the Seminar.

REPORT ON THEMATIC SESSION 1: CLIMATE CHANGE AND ITS IMPACT ON AGRICULTURAL PRODUCTION

Mr. Marien Valstar
President of the Council, UPOV

Presentation made at the Seminar



Speakers

Mr. John Derera, Senior Director, Plant Breeding and Pre-Breeding, Consultative Group on International Agricultural Research (CGIAR)

Ms. Arianna Giuliodori, Secretary-General, WFO

Mr. Michael Keller, Secretary-General, ISF

Mr. Edgar Krieger, Secretary General, *CIOPORA*

Main messages

John Derera:

Climate change impacts global agricultural productivity

Agricultural practices need to change

- Intensification
- Crop rotation,
- Cover crops,
- Irrigation

AND breeding climate resilient varieties

Main messages

Arianna Giuliodori, Secretary-General, WFO:

Farmers are impacted and are key to solutions

Support is needed (extension, knowledge exchange)

Regarding new plant varieties: > 80% of farmers said that new improved plant varieties are important to respond to climate change

Important :
- acces to seeds (affordable and available)
- enabling environment - good seed legislation
- organised agriculture
- partnerships in the value chain

Main messages

Michael Keller, Secretary-General, ISF

Seeds are a very important and powerful input

Farmers and breeders have to take many factors into account - there is not one single solution- breeders want to give farmers seed choice to address climate change at local level

Getting the best quality seeds accessible to all farmers will support sustainable agriculture and food security (SDG's)

Innovation goes hand in hand with protection of IP (UPOV preferred for plant varieties)

International regulatory environment is important (FAO, UPOV, OECD, WTO, IPPC, etc,)

Main messages

Edgar Krieger, Secretary General, CIOPORA

CIOPORA

Impact of climate change on plant breeding:
- loss of genetic diversity
- emerging diseases and pests
- water supply issues
- change in seasonality
- heat stress

Food security under pressure

Breeders need to work to create solutions

Accelerated breeding using different tools is necessary

REPORT ON THEMATIC SESSION 2: STRATEGIES TO ADDRESS CLIMATE CHANGE IN AGRICULTURE

Mr. Yehan Cui
Vice-President of the Council, UPOV

Presentation made at the Seminar

Thematic session 2: Five presantations

European Union strategy to address climate change in agriculture
Mr. Herwig Ranner, Team Leader – Climate change and agriculture, Unit for Sustainable Agriculture, Directorate General for Agriculture and Rural Development (DG AGRI), **European Commission**

Climate change: an opportunity for innovation in agriculture
Mr. Solomon Gyan Ansah, Director of Agriculture & Head of the Seed Unit, Directorate of Crop Services, Ministry of Food and Agriculture, **Ghana**

The role of plant breeding for adaptation to climate change in Mexico
Ms. Sol Ortíz García, General Director of Prospective Policies and Climate Change, Ministry of Agriculture, **Mexico**

Mitigation of climate change in agriculture
Mr. Alexandre Lima Nepomuceno, Researcher, Brazilian Agricultural Research Corporation (EMBRAPA), **Brazil**

Adaptation of agriculture/ farming systems to climate change: exploring genetic options
Mr. George Prah, Deputy Director, Directorate of Crop Services, Ministry of Food and Agriculture, **Ghana**

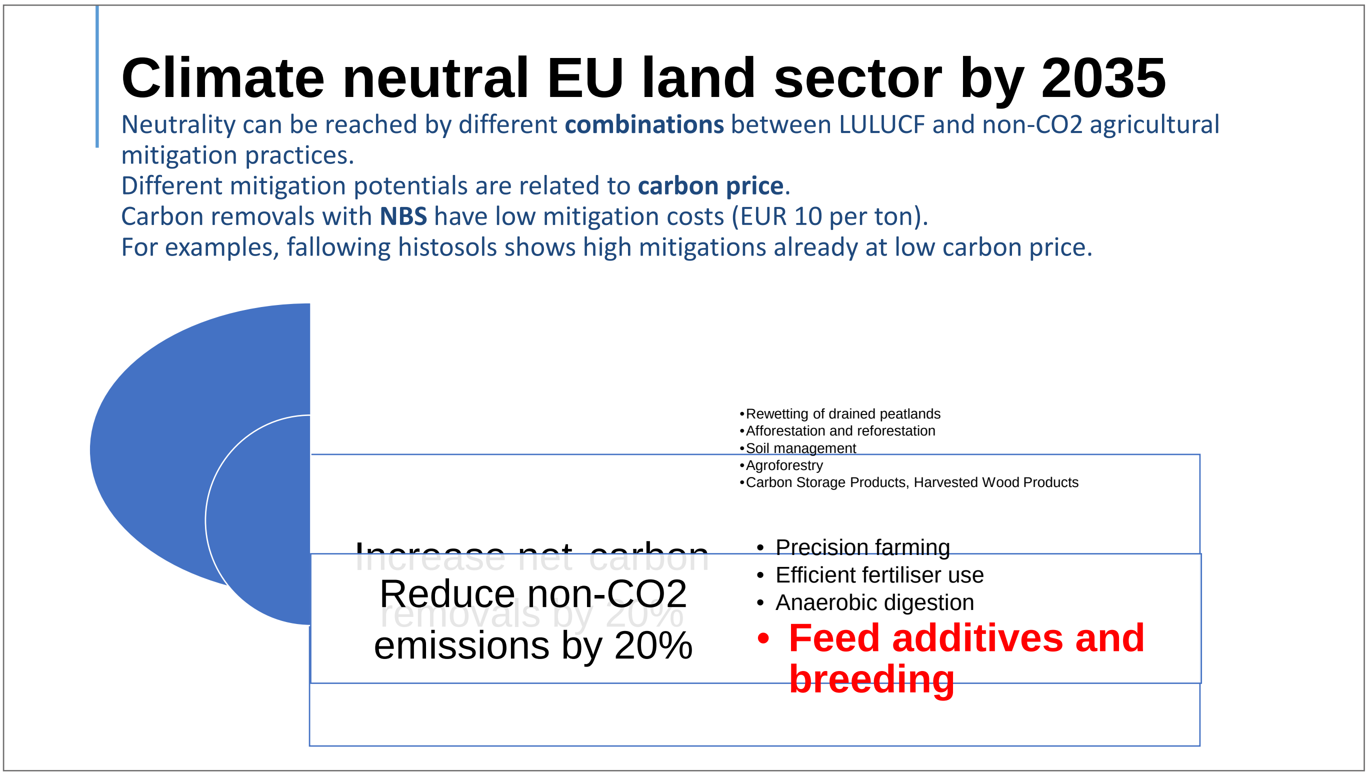
The EU Strategy to address climate change in Agriculture

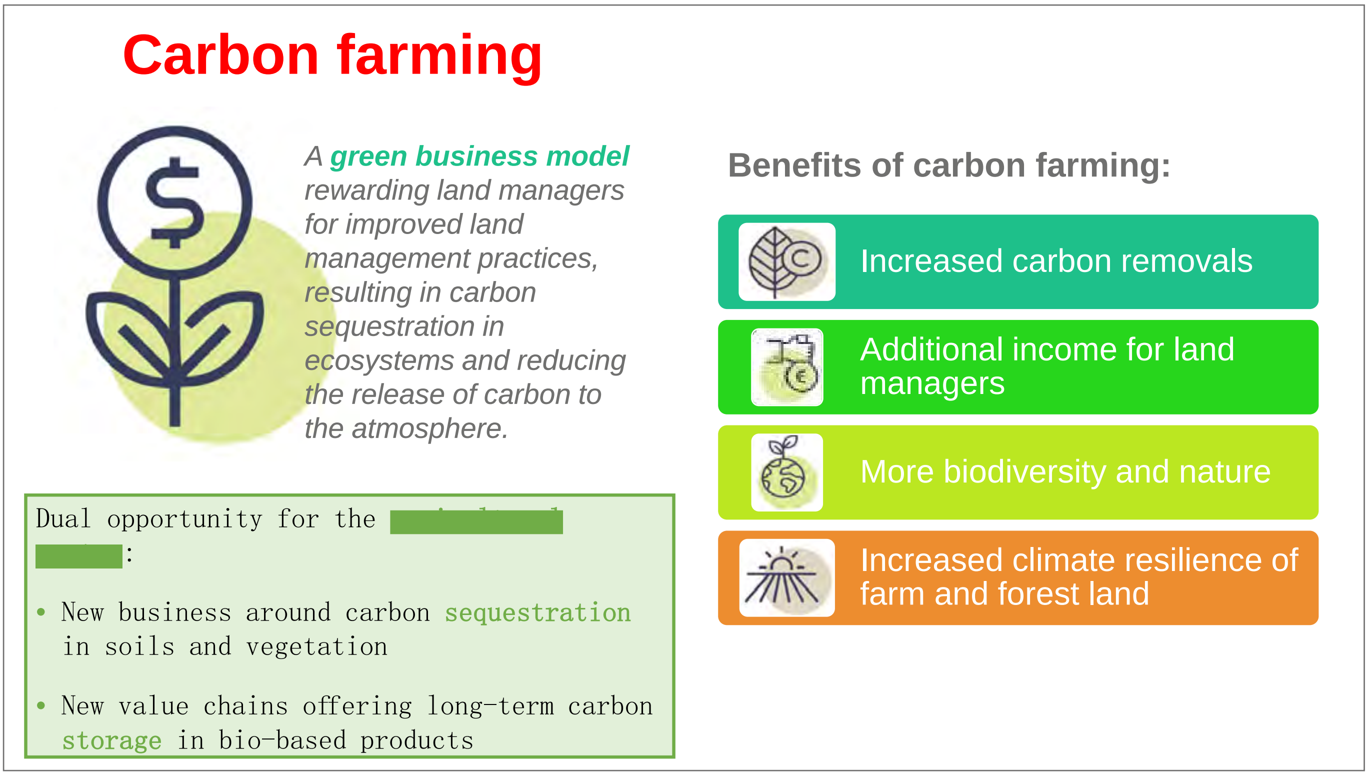
Herwig Ranner, DG Agriculture, European Commission

11.10.2022


The European Green Deal
European Commission
Increasing the EU's Climate ambition for 2030 and 2050
A zero pollution ambition for a toxic-free environment
Supplying clean, affordable and secure energy
Preserving and restoring ecosystems and biodiversity
The European Green Deal
Building and renovating in an energy and resource efficient way
From 'Farm to Fork': a fair, healthy and environmentally friendly food system
Mobilising industry for a clean and circular economy
Accelerating the shift to sustainable and smart mobility
Designing a set of deeply transformative policies
Mainstreaming sustainability in all EU policies
The EU as a global leader
Financing the transition
Leave no one behind (Just Transition)


European Commission
Deal on the Climate Law!
The European Climate Law turns our European Green Deal targets into legal obligations:
reducing net greenhouse gas emissions by at least 55% by 2030
reaching climate neutrality by 2050
Today's deal between the co-legislators also introduces:
a process for setting a 2040 climate target
a commitment to negative emissions after 2050
the establishment of European Scientific Advisory Board on Climate Change
stronger provisions on adaptation to climate change
Climate neutrality will shape the EU's green recovery and a socially just green transition.
More here → https://europa.eu/!dn66PW
#EUGreenDeal #EuropeanUnion #ClimateAction
EU CLIMATE LAW ADOPTED
'Fit for 55'
On 14 July 2021, the Commission presented proposals for revision of main pieces of legislations to deliver EU's 2030 Climate Target (-55%) on the way to climate neutrality.
2030 Target
-45 %
current policies and national measures
Reach neutrality in more gradual way


Climate neutral EU land sector by 2035
Neutrality can be reached by different combinations between LULUCF and non-CO2 agricultural mitigation practices.
Different mitigation potentials are related to carbon price.
Carbon removals with NBS have low mitigation costs (EUR 10 per ton).
For examples, fallowing histosols shows high mitigations already at low carbon price.
Increase net carbon removals by 20%
•Rewetting of drained peatlands
•Afforestation and reforestation
•Soil management
•Agroforestry
•Carbon Storage Products, Harvested Wood Products
Reduce non-CO2 emissions by 20%
• Precision farming
• Efficient fertiliser use
• Anaerobic digestion
• Feed additives and breeding


Carbon farming
A green business model rewarding land managers for improved land management practices, resulting in carbon sequestration in ecosystems and reducing the release of carbon to the atmosphere.
Dual opportunity for the :
• New business around carbon sequestration in soils and vegetation
• New value chains offering long-term carbon storage in bio-based products
Benefits of carbon farming:
Increased carbon removals
Additional income for land managers
More biodiversity and nature
Increased climate resilience of farm and forest land

From 'Farm to Fork' designing a fair, healthy and environmentally-friendly food system

Main targets in the Farm to Fork strategy

The use of pesticides in agriculture contributes to pollution of soil, water and air. The Commission will take actions to:

- ✓ **reduce by 50%** the use and risk of chemical pesticides by 2030.
- ✓ **reduce by 50%** the use of more hazardous pesticides by 2030.

The **excess of nutrients** in the environment is a major source of air, soil and water pollution, negatively impacting biodiversity and climate. The Commission will act to:

- ✓ **reduce nutrient losses by at least 50%**, while ensuring no deterioration on soil fertility.
- ✓ **reduce fertilizer use by at least 20%** by 2030.

Antimicrobial resistance linked to the use of antimicrobials in animal and human health leads to an estimated 33,000 human deaths in the EU each year. The Commission will **reduce by 50% the sales of antimicrobials for farmed animals and in aquaculture by 2030.**

Organic farming is an environmentally-friendly practice that needs to be further developed. The Commission will boost the development of EU organic farming area with the aim to achieve **25% of total farmland under organic farming by 2030.**

CLIMATE CHANGE: AN OPPORTUNITY FOR INNOVATION IN AGRICULTURE.

Solomon Gyan Ansah (PhD)
Directorate of Crop Services
Ministry of Food and Agriculture
Accra-Ghana

Seminar to explore the role of plant breeding and plant variety protection in enabling agriculture to adapt to, and mitigate, climate change, October 11 and 12 (virtual), October 26, 2022 (hybrid)

SOME FOCUS AREAS WHERE INNOVATION IS APPLIED TO CLIMATE SMART AGRICULTURE

These include:

a. Early maturity, drought tolerant, Nitrogen and water use efficient crop varieties
b. Resistance to existing and new emerging diseases and pests (eg cassava brown streak virus, maize lethal necrotic virus disease, fall army worm etc)
c. Conservation Agriculture;
e. Artificial Intelligence
f. **Meteorological** data to predict rainfall or drought, pest evasion etc
g. Investment in irrigation and water harvesting structures

Seminar on the role of plant breeding and plant variety protection in enabling agriculture to mitigate and adapt to climate change

The role of plant breeding for adaptation to climate change in Mexico

Sol Ortiz García
General Director of Policies, Prospective and Climate Change
Secretary of Agriculture and Rural Development
Mexico

AGRICULTURA
SECRETARÍA DE AGRICULTURA Y DESARROLLO RURAL

2022 Año de Ricardo Flores Magón
PRECURSOR DE LA REVOLUCIÓN MEXICANA


Public policies to achieve food security
AGRICULTURA
Mexico. Sectorial Program for Agriculture and Rural Development 2020-2024
Productivity
Food self-sufficiency
Inclusion
Sustainability
1.- Achieve food self-sufficiency by increasing production and productivity of agriculture, livestock, and aquaculture-fishing.
2.- Contribute to the well-being of the rural population through the inclusion of historically excluded farmers in rural and coastal productive activities, taking advantage of the potential of the territories and local markets.
3.- Increase sustainable production practices in the agricultural and aquaculture-fishing sector in the face of agro-climatic risks.
2022 Ricardo Flores Magón


Importance of plant breeding
AGRICULTURA
Actions to promote plant breeding and seed quality to face climate change
POLÍTICA NACIONAL DE SEMILLAS
AGRICULTURA
SNICS
1 Take advantage of existing varieties
2 Adopt and use new varieties
3 Generate varieties according to needs
2022 Ricardo Flores Magón

Genomes of Mexican crops

Crop		Genome	
Common name	**Species**	**Size**	**Status**
Agave	*Agave tequilana*	2.7 Gbp	Finished
Avocado	*Persea americana*	920 Mbp	Published
Chili*	*Capsicum annum*	3. 5 Gbp	Published
Beans	*Phaseolus vulgaris*	590 Mbp	Published
Mexican lime	*Citrus aurantifolia*	350 Mbp	Finished
Maize	*Zea maize*	2.3 Gbp	Published
Papaya	*Carica papaya*	507 Mbp	Finished
Vainilla	*Vanilla planifolia*	3.2 Gbp	Finished
Blackberry	*Rubus ulmifolius*	246 Mpb	Finished

*Not generated by Mexicans

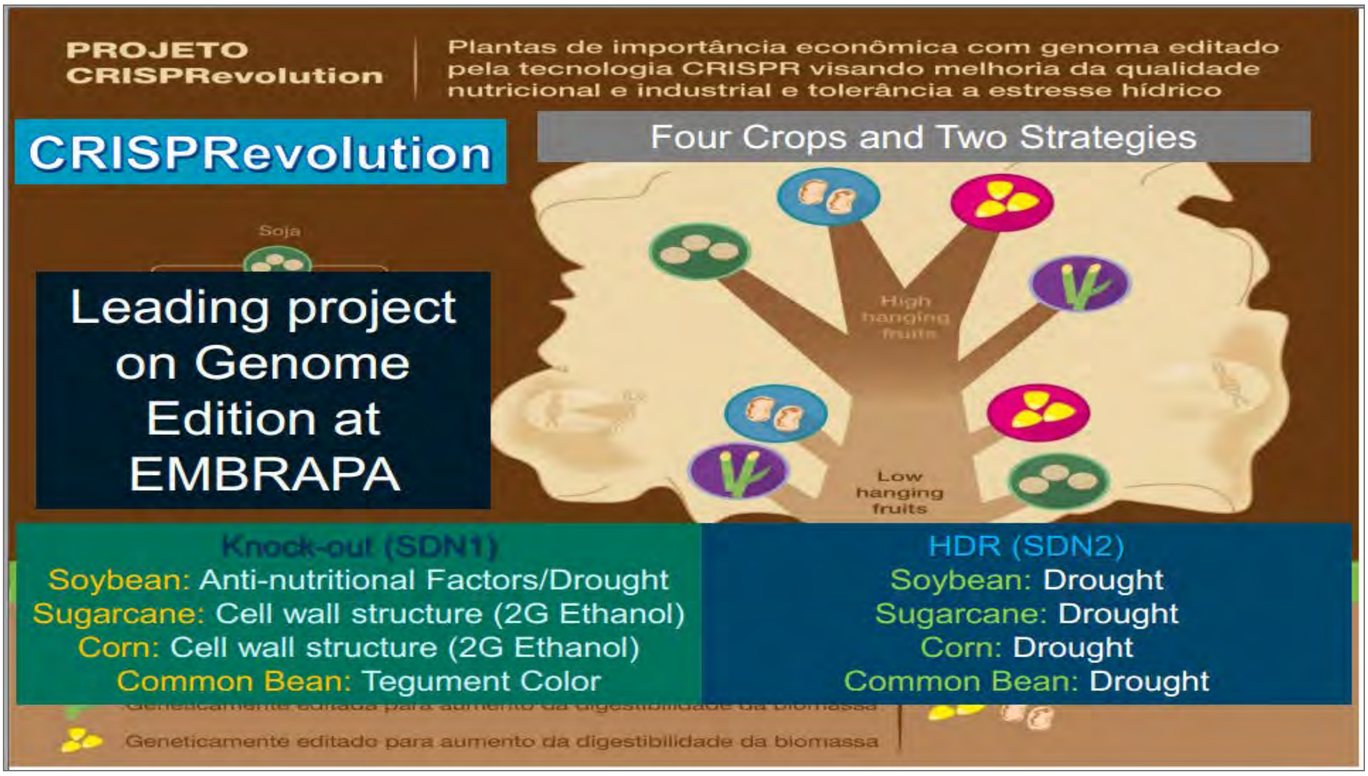
Genomics to accelerate the characterization and improvement of strategic crops in Mexico

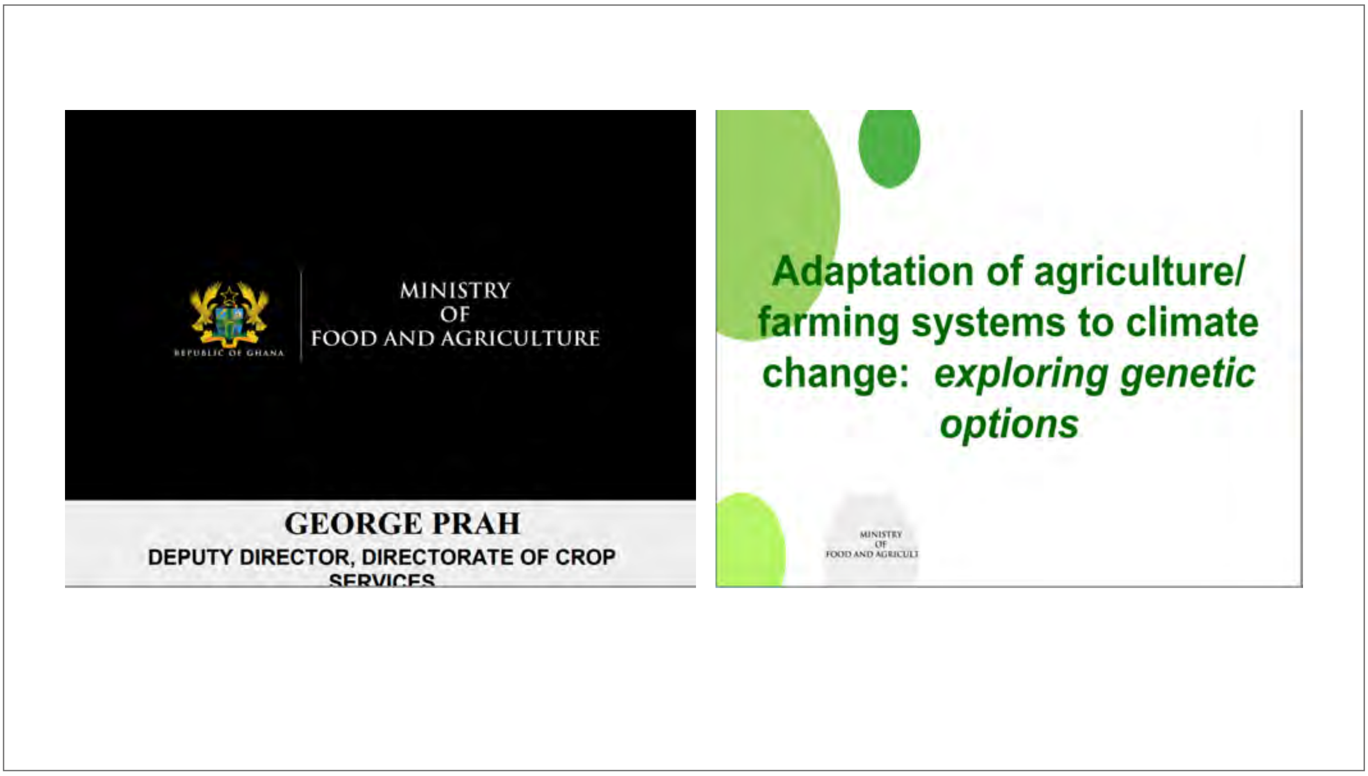
What else is needed for adaptation to climate change

- **In situ conservation** of genetically diverse populations to allow evolution to continue and the generation of adaptive traits;
- **Ex situ conservation** to ensure the maintenance of diversity of species, populations and varieties, including those from areas expected to be highly affected by climate change;
- **Diversified farming systems:** management practices that increase diversity tend to increase resilience to the various effects of climate change;
- **Sustainable soil management** practices that also contribute to mitigation;
- Knowledge, coordination, communication, collaboration, connection & commitment (6C).


"Mitigation of climate change in agriculture"
ALEXANDRE NEPOMUCENO, Ph.D.
Embrapa Soybean General Head
Brazilian Agricultural Research Corporation
Embrapa
Embrapa
MINISTÉRIO DA AGRICULTURA, PECUÁRIA E ABASTECIMENTO


How to deal with this Challenge?


PROJETO
CRISPRevolution
Plantas de importância econômica com genoma editado pela tecnologia CRISPR visando melhoria da qualidade nutricional e industrial e tolerância a estresse hídrico
CRISPRevolution
Four Crops and Two Strategies
Soja
Leading project on Genome Edition at EMBRAPA
High hanging fruits
Low hanging fruits
Knock-out (SDN1)
Soybean: Anti-nutritional Factors/Drought
Sugarcane: Cell wall structure (2G Ethanol)
Corn: Cell wall structure (2G Ethanol)
Common Bean: Tegument Color
HDR (SDN2)
Soybean: Drought
Sugarcane: Drought
Corn: Drought
Common Bean: Drought
Geneticamente editado para aumento da digestibilidade da biomassa


MINISTRY
OF
FOOD AND AGRICULTURE
REPUBLIC OF GHANA
GEORGE PRAH
DEPUTY DIRECTOR, DIRECTORATE OF CROP SERVICES
Adaptation of agriculture/ farming systems to climate change: *exploring genetic options*

Developing the appropriate strategies 1

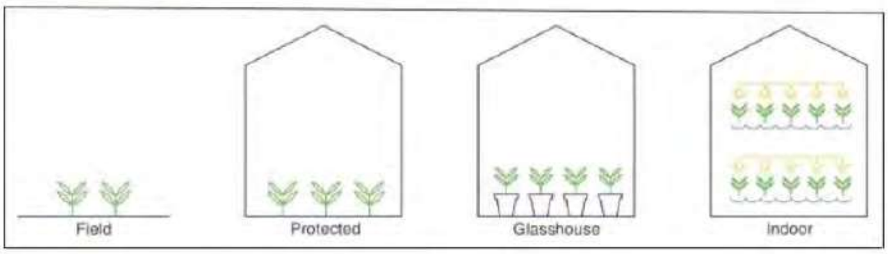
The adaptation of agriculture or making agriculture resilient to climate change requires the implementation of a myriad of complementary strategies:

- moving agriculture to new locations to follow environmental change
- adopting protected agriculture by partially or completely controlling the environment.
- Utilizing environments hitherto classified as not useful for agriculture to mitigate climate change effects
- Developing new agronomic packages for crops to mitigate climate change effects

6

Developing the appropriate strategies 2

Manipulating production/agronomic systems



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Source: Current Opinion in Plant Biology, 2020

Developing the appropriate strategies 3

- Utilization of underutilized crop species to be able to contribute to climate adaptation and mitigation
- Domestication of new species and the improvement of existing ones to adapt to climate change effects
- Extensive use of wild relatives of crops capturing much more of the available climate smart plant biodiversity into elite genotypes.
- Strengthening gene banks to preserve important genotypes for future utilization
- Accessing UPOV PLUTO database to support breeding

Genetic option

Genetic improvement technology

Traditional Crop Modification

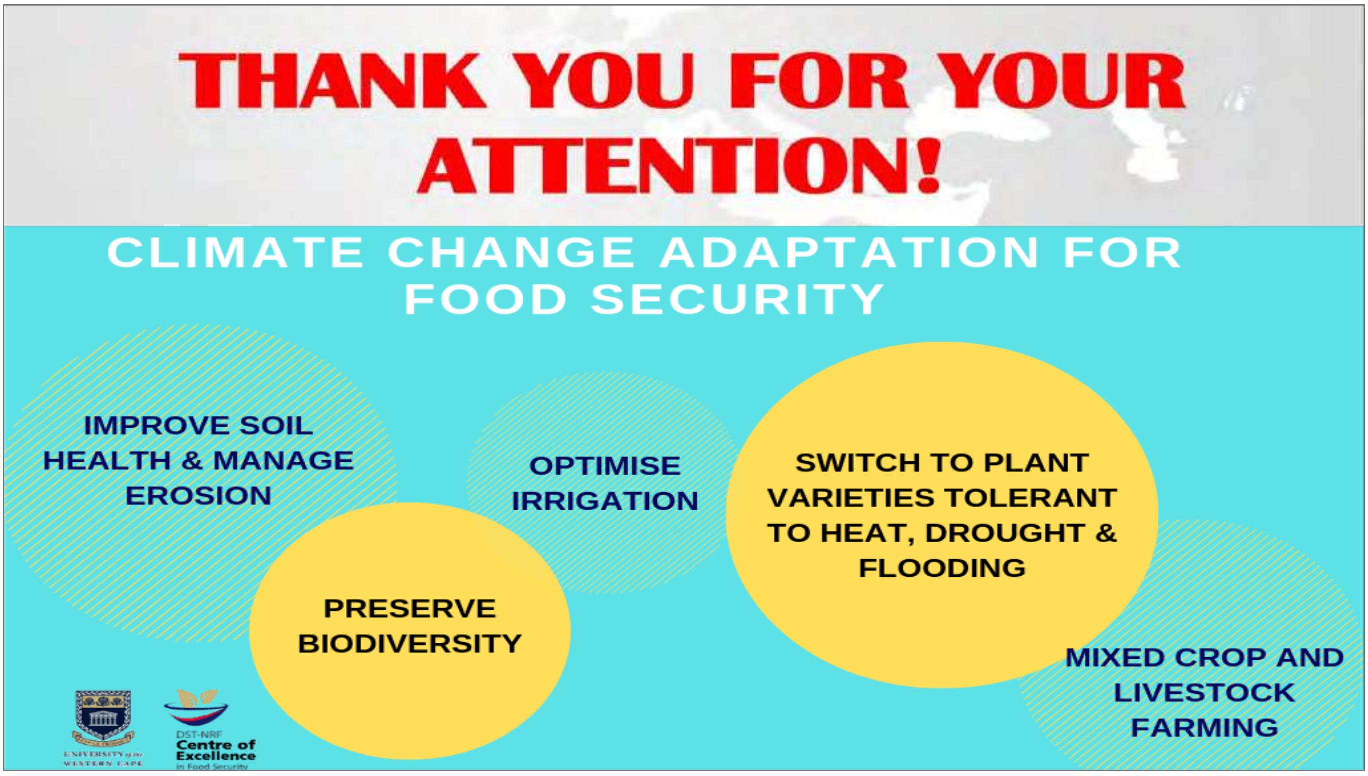
selective breeding and hybridization

Genetic Engineering

High yielding, pests and diseases control, manipulation of genome for improved varieties, including farmer preferred traits (PVS, PVB)

Genome Editing

Removal of genes responsible for deleterious traits affecting storage Nutrient uptake



Brief summary

- Strategies to mitigate the climate change in agriculture:

  -- reducing CO2 and Non-CO2 emission by enhancing climate resilience of agroecosystems towards green development, such as reduce use of pesticide, fertilizer, improve soil quality, etc.

  -- rewarding managers for improved farmland management practices, resulting in carbon sequestration in ecosystems.

- Strategies to adapt to climate change in agriculture:

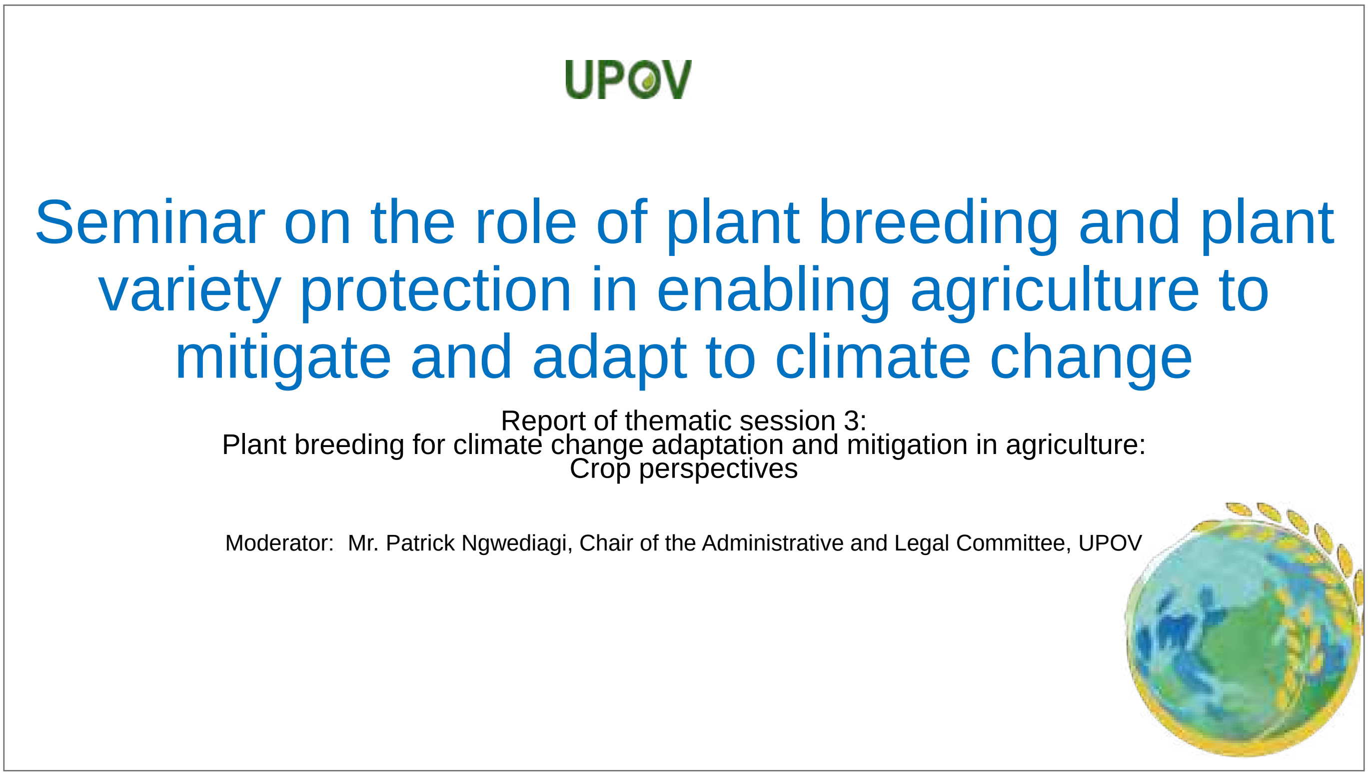
  -- improving crop variety traits adaping to climate change by conservation of plant species, by using breeding technology, such as traditional breeding and hybridization, genetic engenering and genome editing, etc.

  -- enhancing food production system adapted to climate change, such as investment in farmland construction, smart agriculture, technology innovation, etc.

REPORT ON THEMATIC SESSION 3: PLANT BREEDING FOR CLIMATE CHANGE ADAPTATION AND MITIGATION IN AGRICULTURE: CROP PERSPECTIVES

M. Patrick Ngwediagi
président du Comité administratif et juridique, UPOV

Presentation made at the Seminar

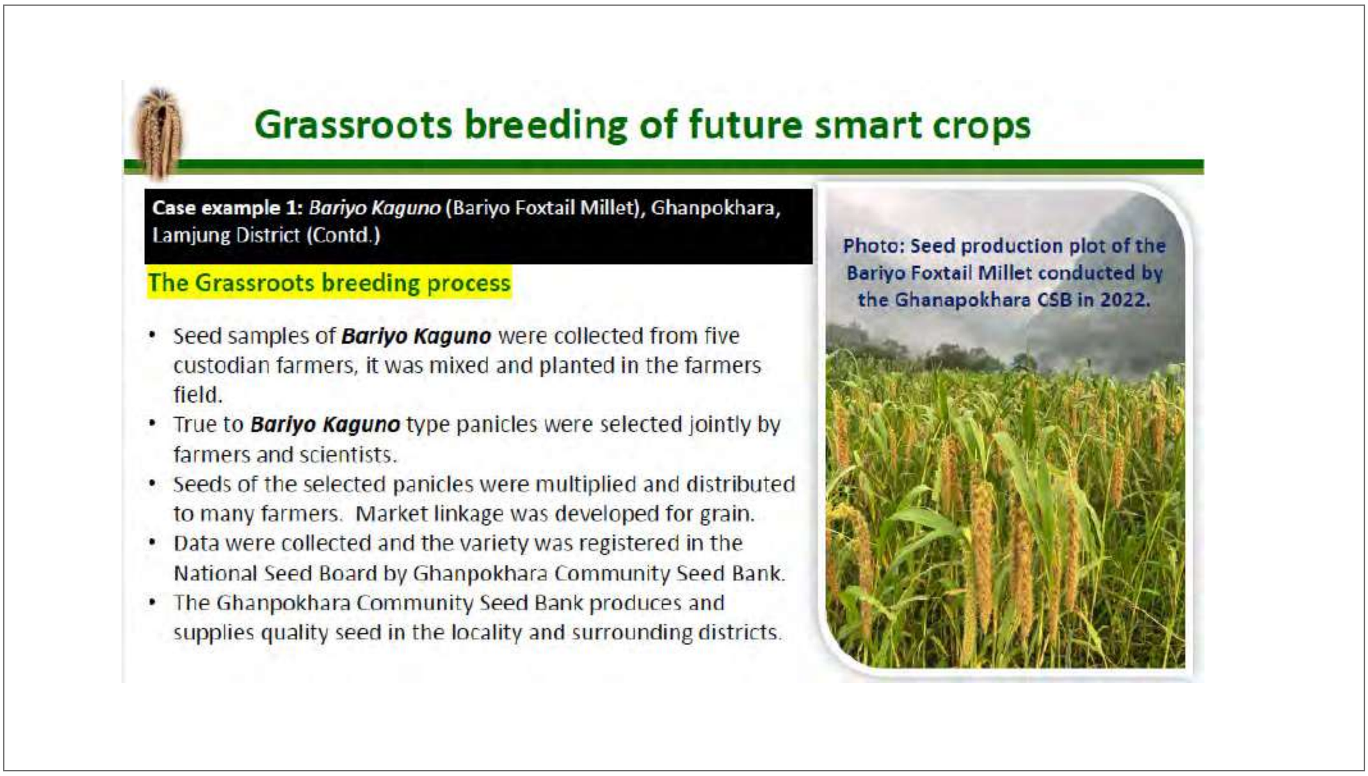


Speakers

- Mr. Greg Rebetzke, Research Genetist, Canberra, Australia
- Mr. Yu Zhang, Research Associate, Shanghai Academy of Agricultural Sciences, China
- Mr. Etienne Bucher, Research group leader “Crop Genome Dynamics”, Agroscope, Switzerland
- Mr. José Ré, Vice President, Global New Products Development – Rice Tech USA, United States of America
- Ms. Hayat Zaher, Researcher, Marrakech Regional Agricultural Research Centre (CRRA), National Institute for Agricultural Research (INRA), Morocco
- Mr. Robert Boehm, Head of Biotechnology, Selecta One, Germany
- Ms. Tina Henriksson, Group Manager Breeding, Cereals & Pulses & Senior winter wheat breeder, Swedish Company Lantmännen, Sweden
- Mr. Pitambar Shrestha, Programme Advisor, Local Initiatives for Biodiversity, Research and Development (LI-BIRD), Nepal
- Ms. Astrid Schenkeveld, Specialist Plant Breeder's Rights & Variety Registration, Rijk Zwaan, Netherlands

Plant breeding is beneficial for all crops

- Plant breeding supports the development of climate smart varieties for all crops, including those of local importance
- Plant breeding is key for adapting crops to each production area
- Crops traditionally grown in each area require adapting to new climatic conditions
- Opportunites to introduce new crops previously unsuitable for cultivation in particular areas


Grassroots breeding of future smart crops
Case example 1: Bariyo Kaguno (Bariyo Foxtail Millet), Ghanpokhara, Lamjung District (Contd.)
The Grassroots breeding process
• Seed samples of Bariyo Kaguno were collected from five custodian farmers, it was mixed and planted in the farmers field.
• True to Bariyo Kaguno type panicles were selected jointly by farmers and scientists.
• Seeds of the selected panicles were multiplied and distributed to many farmers. Market linkage was developed for grain.
• Data were collected and the variety was registered in the National Seed Board by Ghanpokhara Community Seed Bank.
• The Ghanpokhara Community Seed Bank produces and supplies quality seed in the locality and surrounding districts.
Photo: Seed production plot of the Bariyo Foxtail Millet conducted by the Ghanapokhara CSB in 2022.


In the long run
• New crops
• New characters
• New resistances
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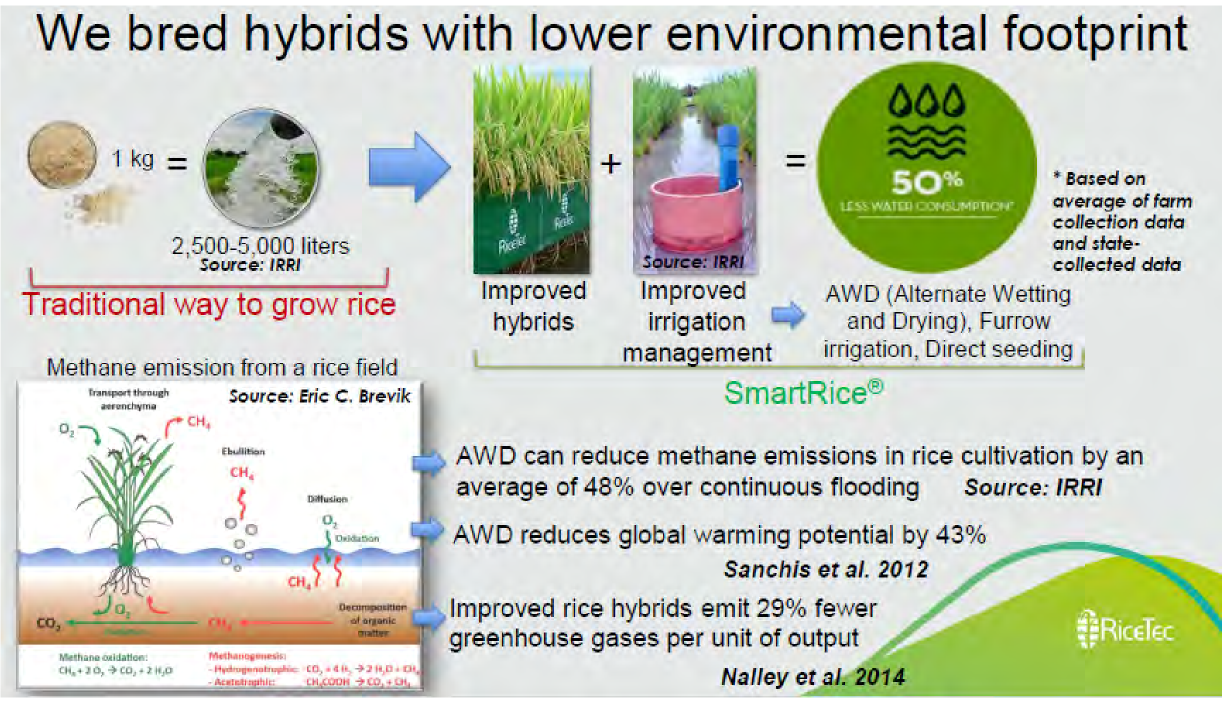
Rice: Reducing water requirement and use

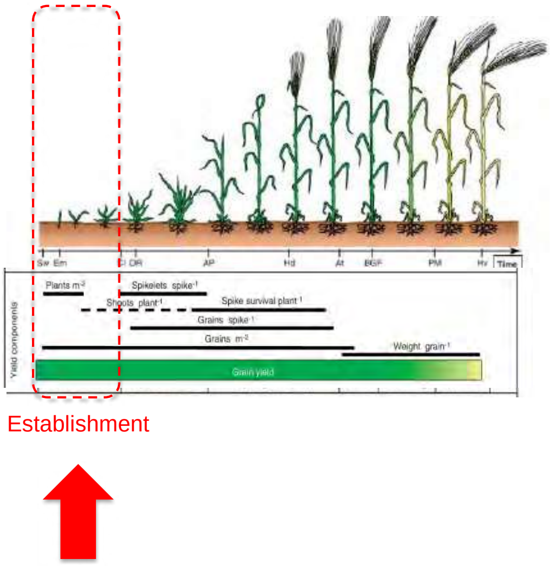
- New rice varieties incorporate upland rice characteristics (non-flooded areas).
- This is useful to reduce irrigation water
- Improves transplanting operation in paddy fields.
- Reducing water requirement reduces CO_2 emissions to the atmosphere



Wheat: Changing plant morphology to access subsoil moisture

- Plant breeding is developing new varieties with improved characteristics to access subsoil moisture during the establishment period of crops
- This improves the early establishment crops enabling young plants to support longer periods of drought.

Opportunity breeding - Optimising crop establishment



Vegetable crops: avoiding losses and waste through new characteristics

- New characteristics maximize plant production in protected environments (e.g. Hydroponics)
- New characteristics enable avoiding losses due to:
  - new disease resistances
  - longer shelf life

Examples

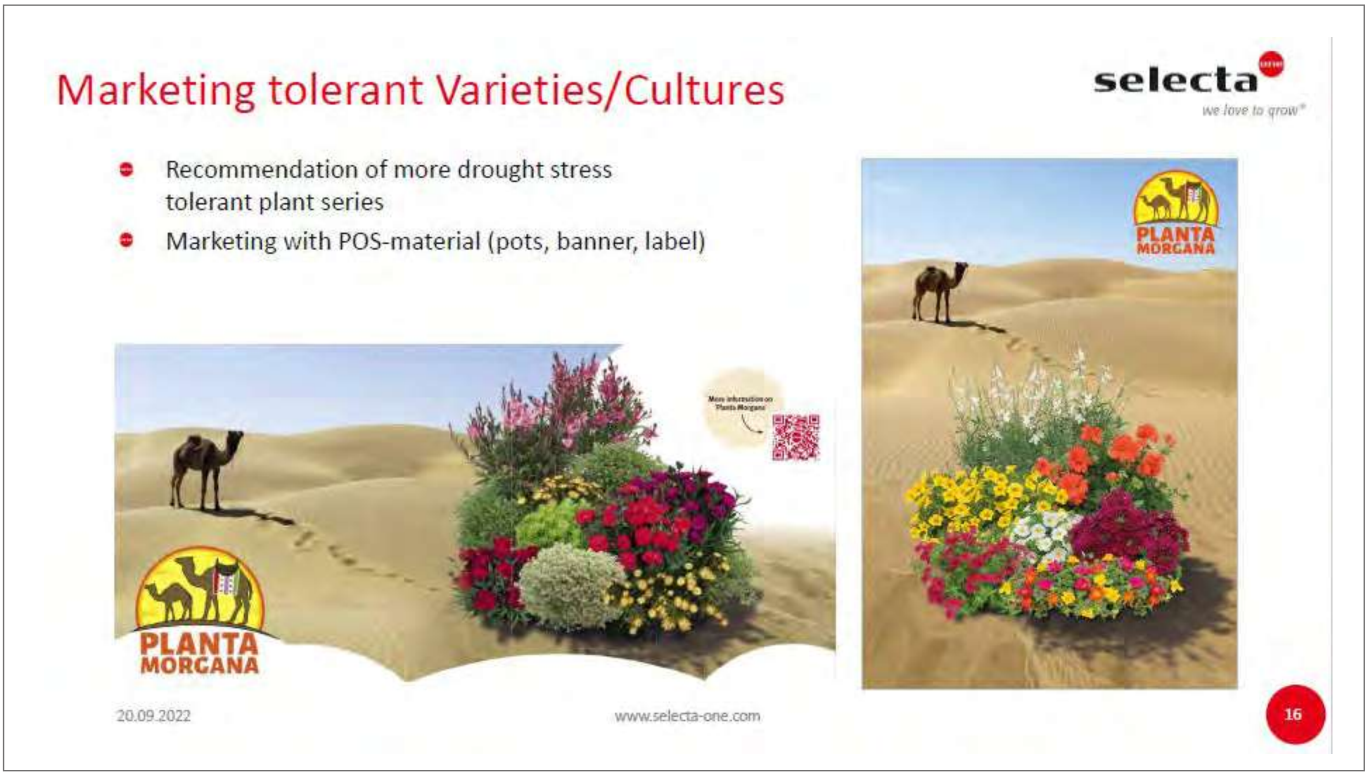
RIJK ZWAAN

Delayed pinking of fresh cut lettuce
(Leaf wound-induced discoloration)

- Extended shelf life
- Less waste
- Suitable for Food Service
- Stronger against cracking
- Less sensitive for leaking seals

Ornamental crops: breeding for drought resistance and introduction of new adapted crops

- The sector is instensively using plant breeding to develop varieties adapted to increased drought periods
- New varieties are being developed from species more adapted to extreme environments, such as succulents and others


Marketing tolerant Varieties/Cultures
selecta
we love to grow
Recommendation of more drought stress tolerant plant series
Marketing with POS-material (pots, banner, label)
PLANTA MORGANA
PLANTA MORGANA
20.09.2022
www.selecta-one.com
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Substitution by new cultures
selecta
we love to grow
Species with naturally evolved plant stress tolance mechanisms
C4/CAM-metabolism, drought-adapted morphology
Grasses
Crassulaceae (Sedum, Echeveria)
Xerophytes (Helichrysum, Calocephalus)
Others (Portulak, Brachyscome, Felicia)
20.09.2022
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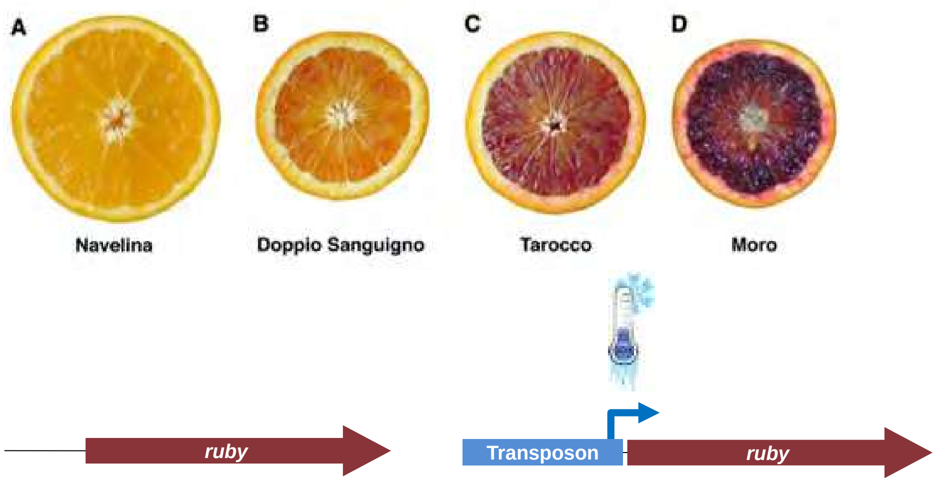
New breeding techniques: Transposable elements

- New breeding techniques are widely available with great level of precision
- Transposable elements are an example: they occur naturally and create adapted traits; e.g. response to heat stress
- Mobilizing transposable elements that respond to stress can generate useful characteristics

Crop traits influenced by transposons



Transposable elements create a link between the environment and the genome

Butelli, E. et al. Plant Cell 24
Walker, A.R. et al. Plant J 49

Agroscope

Plant variety protection is key to promote plant breeding

- PVP under the UPOV Convention is an “open innovation” system
- Breeder’s exemption is key for further research and breeding

Conclusions

- Plant breeding is fundamental for all types of crops to address the challenges posed by climate change
- Also important to support reduction of emissions of greenhouse gas emissions.
- New techniques are available (e.g. Transposable elements)
- Certain plant breeding techniques are still heavily regulated
- PVP is encouraging plant breeding by all types of breeders

REPORT ON THEMATIC SESSION 4: PLANT BREEDING FOR CLIMATE CHANGE ADAPTATION AND MITIGATION IN AGRICULTURE: BREEDING STRATEGIES AND TECHNIQUES

Mr. Manuel Toro Ugalde,
Vice-Chair of the Administrative and Legal Committee, UPOV

Presentation made at the Seminar

Thematic session 4: plant breeding for climate change adaptation and mitigation in agriculture: breeding strategies and techniques

- **"A smart green future" and "climate resilience underpinning breeding programmes".**
  Ms. Emma Brown, General Manager Plant Varieties, and Mr. Zac Hanley, General Manager Science, Plant & Food Research, New Zealand
- **Use of new technologies (molecular markers and accelerated breeding) in the development of drought-tolerant cereal varieties in Morocco**
  Mr. Moha Ferrahi, Head Genetic Resources Improvement and Conservation Department (DACRG), Scientific Division, National Institute for Agricultural Research (INRA), Morocco
- **Breeding for the future**
  Mr. Stefan van der Heijden, Associate, Innova Connect, Netherlands
- **The role of variety characteristics on climate footprint (disease resistance, nitrogen utilization and yield)**
  Mr. Morten Lillemo, Professor, Norwegian University of Life Sciences, Professorship of Biosciences, Norway
- **Research into market-driven and climate smart crop varieties: tolerance to biotic and abiotic stresses**
  Mr. Francis Kusi, Acting Director and Mr. Joseph Adjebeng-Danquah, Senior Research Scientist, Savannah Agricultural Research Institute, Scientific and Industrial Research Institute (CSIR-SARI), Principal Investigator (Host Plant Resistance) (Ghana)

Thematic session 4: plant breeding for climate change adaptation and mitigation in agriculture: breeding strategies and techniques

- **Genetic improvement by mutagenesis of oilseed crops to cope with climate change: case of rapeseed and sesame**
  Mr. Abdelghani Nabloussi, Researcher, Meknès Regional Agricultural Research Centre (CRRA), National Institute for Agricultural Research (INRA), Morocco
- **Connecting different research clusters with the aim to develop more accurate breeding**
  Mr. Muath Alsheikh, Head of Research and Development, Graminor AS (Norway)
- **Advances in the development of new varieties better adapted to climate change in crops and forages: a South American perspective**
  Mr. Fernando Ortega Klose, Forage Plant Breeder, Chilean Agricultural Research Institute (INIA), Carillanca regional center, Chile
- **Breeding program to mitigate climate change and environmental pressures on crops**
  Mr. Dave Bubeck, Research Director, Corteva, United States of America

Plant breeding for climate change adaptation and mitigation in agriculture: plant breeding strategies and techniques

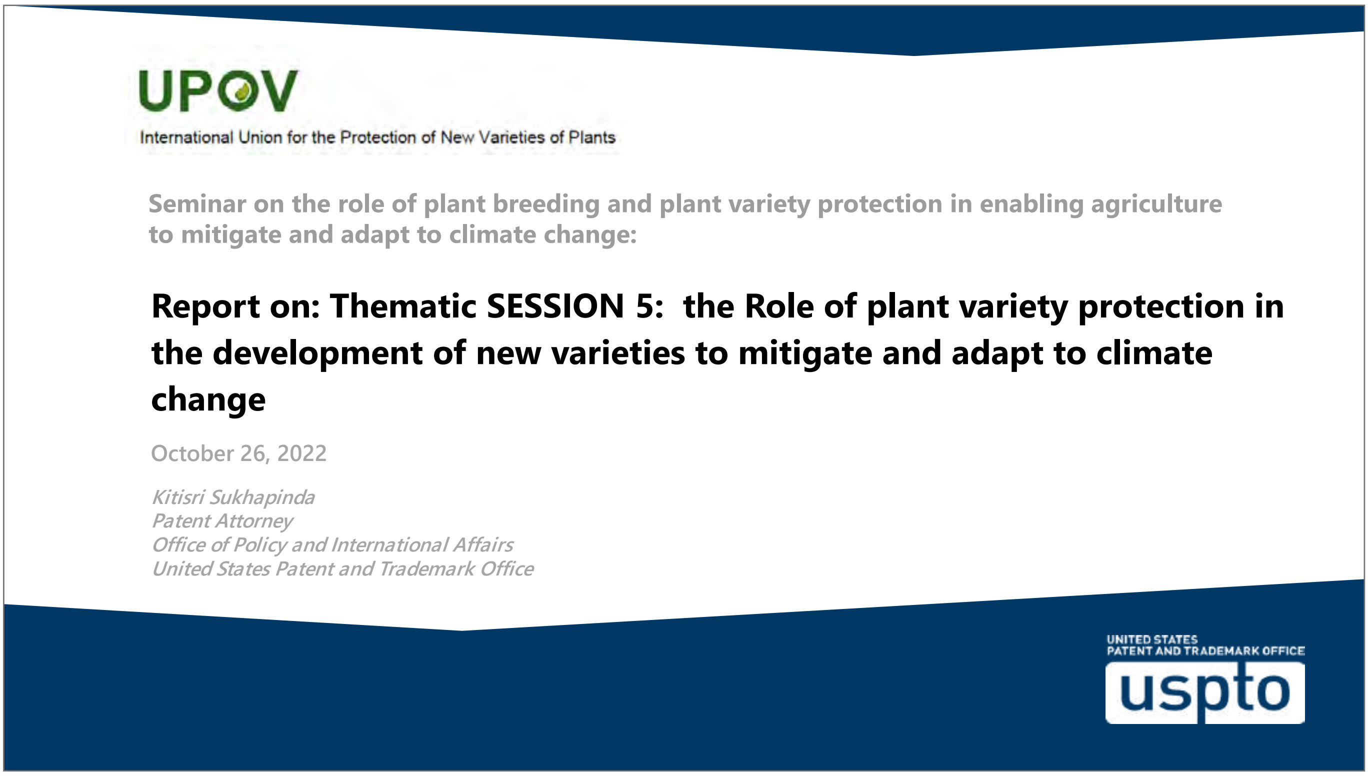
The boundaries shown on this map do not imply the expression of any opinion whatsoever on the part of UPOV concerning the legal status of any country or territory

- Climate change has impacted agriculture around the world, but there are some countries that are more affected.
- We are working on different strategies and techniques to address climate change.
- Techniques such as irradiation and gene editing in different crops
- Heat- and drought-tolerant/drought-resistant varieties
- Technology: Artificial intelligence and bioinformatics
- Public and private resources (clusters) / Investment
- Plant breeding is essential for climate change adaptation.
- Strengthening intellectual property rights and their implementation at the national level.

REPORT ON THEMATIC SESSION 5: ROLE OF PLANT VARIETY PROTECTION IN THE DEVELOPMENT OF NEW VARIETIES TO MITIGATE AND ADAPT TO CLIMATE CHANGE

Ms. Kitisri Sukhapinda
Patent Attorney, Office of Policy and Affairs (OPIA), United States Patent and Trademark Office (USPTO), United States of America

Presentation made at the Seminar



Thematic SESSION 5: Topics

- **The role of PBR in plant breeding efforts to address climate change mitigation and adaptation. Example of Canada, including public sector breeding**

  Mr. Anthony Parker, Commissioner, Plant Breeders' Rights Office, Canadian Food Inspection Agency (CFIA), Canada

- **Plant Breeding and Plant Variety Protection: a catalyst for developing climate smart crop varieties in Sub-Saharan Africa**

  Mr. Hans Adu-Dapaah, Expert, Crops Research Institute, Council for Scientific and Industrial Research Institute (CSIR), Ghana

- **Plant breeding and PVP system for adapting Japan's unique climate condition and consumers' preferences**

  Mr. Teruhisa Miyamoto, Deputy Director of Plant Variety Office, Intellectual Property Division, Export and International Affairs Bureau, Ministry of Agriculture, Forestry and Fisheries (MAFF)

- **The role of plant variety protection in promoting development of crop varieties that adapt to, and mitigate, climate change. Example of Kenya**

  Mr. Simon Mucheru Maina, Head, Seed Certification and Plant Variety Protection, Kenya Plant Health Inspectorate Service (KEPHIS)

- **Impact of the Community Plant Variety Rights system on the European Union economy and the environment**

  Mr. Francesco Mattina, President, Community Plant Variety Office (CPVO) and Mr. Nathan Wajsman, Chief Economist of the European Intellectual Property Office (EUIPO)

Thematic SESSION 5: Canada

Impact of Climate Change:

- Annual temperature increase, flooding, droughts, extreme weather events
- Northward expansion of warmer weather crops, such as corn and soybean, displacing cereals and canola
- Water/heat stress to plants and may have a negative impact on yields, new pests and diseases.

Public Research

- Example: Digital Imaging Technology and Plant Phenotyping of Wheat Varieties
- Digital imagery reveals differences in plant canopy temperatures between varieties.
- Differences identified between varieties in respiration rates and plant dehydration.
- Historic drought tolerant varieties can be used as breeding material for introgression into modern high performing varieties

UPOV/SEM/GE/22/PPT/29 Anthony Parker

Thematic SESSION 5: Canada

Linking to UPOV-based PBR

- All wheat varieties released by AAFC are PBR protected. Art 14. of UPOV secures the investments made by taxpayers and farmers. Royalties from sales and licensing are re-invested back into breeding and research, creating a self-sustaining funding environment.
- Art 15 (1) (ii) "researcher's exemption" supports ongoing research, and scientific publication, dissemination of knowledge about the qualities/attributes of specific varieties.
- Art 15 (1) (iii) "breeder's exemption" ensures that all PBR protected varieties are available for breeding purposes. Breeder's have information on varieties that are drought tolerant, and can access those varieties to introgress into their breeding program.
- Art 19, the breeder's right is finite. Unprotected varieties are "public domain", AAFC varieties deposited in ITPGRFA – MLS system.

UPOV/SEM/GE/22/PPT/29 Anthony Parker

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Thematic SESSION 5: Sub-Saharan Africa

Challenges to Agricultural Production in Africa:

- Rapid declining soil fertility (especially nitrogen)
- Increased complexity of pests and diseases
- Postharvest losses and short shelf- life of produce
- Inherent low yields of crops
- Lack of labor
- Ecological concerns
- Illegal mining activities destroying agricultural lands and water bodies and distorting ecologies,
- loss of biological diversity, land constraints

Achieving Food & Nutrition Security in 2050

- Crop production will have to double/triple by 2050, using limited resources (land, water, nitrogen etc.)
- Need to increase productivity per unit area (intensification)
- Smart breeding has a role to play to achieve food and nutrition security.
- CSIR-CRI developed high-yielding drought tolerant maize variety

UPOV/SEM/GE/22/PPT/30 Hans Adu-Dapaah

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Thematic SESSION 5: Sub-Saharan Africa

Plant Variety Protection:

- Well implemented PVP may be a catalyst for sustainable development of CSCV, since it will attract investors.
- The benefits of PVP cuts across several sectors of the economies of Sub-Saharan African countries and will promote national development.
- The PVP has an enormous potential to improve productivity, the seed system, protect genetic diversity, and empower farmers to access new markets and attract private sector investments in plant breeding.
- The formation of African Plant Breeders Association in 2019 with branches in most African countries is a positive development for PVP implementation in SSA.

UPOV/SEM/GE/22/PPT/30 Hans Adu-Dapaah

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Thematic SESSION 5: Japan

Impact of Climate Change on Agricultural Products:

- Average temperature has risen by 1.26 degrees Celsius per 100 years in Japan: agricultural production regions are expected to change with emerging high-temperature injury.
- Rice-immature starch formation in grain due to high temperatures
- Apple-poor or delayed coloring of fruit due to high temperature
- Deterioration of fruit quality reported in other fruits (grapes, peaches, etc.)

New Plant Varieties - Key to Adapt to Climate Change

- Rice-High temperature tolerant variety with few immature grains
- Grapes -New varieties with good coloration even at high temperatures
- Apple-New varieties with good coloration even at high temperatures
- Impatiens-Growing well in wide range conditions, even at high temperature

UPOV/SEM/GE/22/PPT/31 Yasunori Ebihara

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Thematic SESSION 5: Japan

- **Innovation to Facilitate Breeding of New Varieties to Adapt to Climate Change:**
  - "Smart breeding system" in combination with AI and new breeding technologies will enable more efficient and faster breeding by big data on phenotype-genotype information
- **Importance of Securing PVP Protection Aboard:**
  - Japan PVP Act Amendment to protect Japan Export Market
- **Importance of Cooperation:**
  - Efficient application
  - Enhance DUS cooperation

UPOV/SEM/GE/22/PPT/31 Yasunori Ebihara

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Thematic SESSION 5: Kenya

Climate Change Impact

- Extended dry periods and rainfall outside the normal seasons
- Emergence of new pests and diseases such as maize Lethal Necrosis (MLN), Fall Army Worm (FAW) among others
- It is very important for breeders to develop varieties that are resilient to harsh agro-ecological conditions

Development of Smart Varieties

- Development of drought tolerant varieties of maize, sweet potato, cassava, sorghum, pigeon peas, amaranth, rangeland grasses among others
- Efforts to release pest and disease tolerant varieties to counter emerging pests as a result of climate change
- Sixteen (16) varieties tolerant to Maize Lethal Necrosis Disease (MLND) released,
- Varieties of Fall Army Worm (FAW) tolerant maize are under evaluation

UPOV/SEM/GE/22/PPT/32 Simon Mucheru Maina

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Thematic SESSION 5: Kenya

Plant Variety Protection in Kenya:

- Acceded to UPOV 1978 in May 1999, UPOV 1991 in May 2016
- Kenya grants PBRs for all plant genera and species

- Breeders having assurance on return of investment following development of new varieties.
- Enhanced capacity for testing of new varieties through cooperation with UPOV and UPOV members.
- Collaboration and co operation between the breeders and the testing authority on variety testing.

UPOV/SEM/GE/22/PPT/32 Simon Mucheru Maina

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Thematic SESSION 5: EU/CPVO

The EU's impact study shows key economic contribution:

- EU-protected plant variety innovations sufficient to feed an additional **57 million** people with arable crops, **38 million** with fruit crops, and **28 million** for vegetable crops.
- EU PVR-protected crops generated additional value of 13 billion EUR to EU GDP
- Additional production resulted in higher employment rates in the EU agriculture, and better remunerated

In the absence of the CPVR system, in 2020 the production in the EU would be:

- ✓ 6.4% lower for agricultural crops;
- ✓ 2.6% lower for fruits;
- ✓ 4.7% lower for vegetables;
- ✓ 15.1% lower for ornamentals.

UPOV/SEM/GE/22/PPT/33 President Francesco Mattina – Nathan Wajsman, EUIPO, Presentation of EUIPO study

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Thematic SESSION 5: EU/CPVO

EU-Community Plant Variety Right (CPVR) system

- Not only makes an economic contribution to the EU economy, but also contributes to the fulfilment of the EU's environmental objectives by reducing annual greenhouse gas emissions and water use in agriculture and horticulture
- Contributes to the UN's Sustainable Development Goals, by reducing the environment impact and resource use in agriculture and horticulture, increasing farm incomes, and keeping prices lower for consumers

UPOV/SEM/GE/22/PPT/33 President Francesco Mattina – Nathan Wajsman, EUIPO, Presentation of EUIPO study

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Conclusions:

- **To address climate change mitigation and adaptation requires collective action, including; farmers, breeders (public and private), and policy makers.**
- **Effective PVP provides incentive for breeders to invest in innovation and development of new varieties of plants that can adapt to or mitigate the impact of climate change.**
- **UPOV-based PBR provides a framework that ensures the balance between incentives and rewards, and restrictions on the breeder's right by way of "exemptions," that ensure access to knowledge and the use of protected varieties for breeding purposes.**
- **UPOV membership provides for enhanced cooperation among members**

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Thank you!

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PANEL DISCUSSION

Moderator: Mr. Marien Valstar
President of the Council, UPOV

VALSTAR Marien (Mr.), President of the Council, UPOV (moderator)

Thank you, Peter. I would like to invite Michael Keller of ISF and Edgar Krieger of CIOPORA to join us on the podium. Now is the time for you to ask questions or make observations. And there's also another speaker Mr. John Derera. Welcome, John.

DERERA John (Mr.), Senior Director, Plant Breeding and Pre-Breeding, Consultative Group on International Agricultural Research (CGIAR) (speaker)

Thank you.

VALSTAR Marien (Mr.), President of the Council, UPOV (moderator)

So, welcome, John, and welcome, everybody on this podium.

Now, for those of you who are online, please use the interpretation system and raise your hand electronically and for those in the room, please show your country or organization name plate and then I will give you the floor.

Are there any members, any observers, any participants asking for the floor, whether online or here in the room?

As I don't see any questions yet, to get things started and I'd like to ask John Derera a question.

VALSTAR Marien (Mr.), President of the Council, UPOV (moderator)

Hello, John. You explained very nicely in the session that adaptation needs to be in many directions, like new agricultural practices, more irrigation, intensification, etcbut also including new and improved plant varieties. Do you have some sort of estimate to what extent new plant varieties wouldhelp in solving the problems? So, what is more important, practices or plant varieties? Do you have some sort of estimation on that?

DERERA John (Mr.), Senior Director, Plant Breeding and Pre-Breeding, Consultative Group on International Agricultural Research (CGIAR) (speaker)

Thanks. I am saying I will give you a very clear, precise estimation, but in general, when we look at the contribution of the improvements that come through plant variety gains all over the world, they don't come from genetics alone. But we see that complementary improvement to economic practices makes it possible to translate the improvements that have been done on the genetic side.

Various leaders in plant breeding say– fifty-fifty, whereas others would say 60% of the gains coming through are the genetic improvements and 40%, agricultural practices. I would look at it as fifty-fifty. We need to put more effort on both sides of the – of the two if we are to see significant improvements. Thank you.

VALSTAR Marien (Mr.), President of the Council, UPOV (moderator)

Okay. Thank you, John. So, more or less, rule of thumb, fifty-fifty genetic improvement and improved practices. So, that means indeed, we need – these things need to go hand in hand and be complementary to each other. A big challenge for breeders.

And maybe if there are still no questions in the room or in – online, that would be a good moment to ask the breeders, indeed, how they cope with these challenges. And maybe it's good to start first with Edgar, Edgar Krieger from CIOPORA. So, can you give some light on how you deal with these challenges?

KRIEGER Edgar (Mr.), Secretary General, International Community of Breeders of Asexually Reproduced Horticultural Plants, CIOPORA (speaker)

Yes, climate change is reality. I presented this already in a presentation online a couple of weeks ago. And we see the global warming, we see droughts, we see floods, we see increased humidity that results in more pests and diseases. And breeders find solutions for this. They develop varieties which are more resilient to these stress situations. And we heard several times this afternoon that plant breeding is essential to cope with the climate change, but in order to continue this, breeders need protection and they need effective protection.

And when we speak about breeders and the breeding techniques, at the moment, it's mainly conventional breeders who innovate. Of course, biotech companies play their role too, but they base their improvements on existing genetics and on existing varieties.

Last week, I was visiting a rose breeder in the south of France, very traditional company, everybody knows this name, and they improve varieties and make them tolerant against the diseases and pests, more tolerant by traditional breeding. They know the parents which are tolerant against the pests and diseases and cross and select the best genetics for this. So, and this is the basis of the improvement which takes place at the moment.

So, these conventional breeders need protection. And when I hear the discussions this week and in the last months in UPOV, I never heard this kind of tension in between the UPOV members about what is the right level of protection. And we need to – and UPOV is the institution in the world who has to protect plant breeders and plant breeding. And so, when I hear discussions about broadening the exemptions in the plant breeders' rights system, like the extension on private and non-commercial use, when I hear the discussions on Essentially derived varieties (EDV), when I hear the discussions on protection of harvest material, propagating material, provisional protection, there needs movement. We need to move in the scope of protection.

I am doing this since eighteen years and I have lobbied worldwide for the improvement of protection. And what we see, very few countries really improve their laws. We really have to work that they do not decrease the protection instead of improving it.

There are many countries who still their laws are based on the 1978 Act which is substandard. And when we speak here in this building about plant breeding and the importance of plant breeding, I really ask you to think about your role and to provide effective protection. This is an initial statement which could fuel some discussion. Thank you.

VALSTAR Marien (Mr.), President of the Council, UPOV (moderator)

Thank you, Edgar, and yes, it is good that you highlighted challenges we are facing. I would be happy if we could stick to climate change now as the biggest challenge we are facing and not get into a discussion on EDVs or harvested material.

Michael, I also challenged you to say – have a few words how breeders face the challenge of climate change and what the International Seed Federation, what your breeders do or don't do or need to do.

KELLER Michael (Mr.), Secretary-General, International Seed Federation (ISF) (speaker)

First of all, thanks to UPOV to take this initiative to speak about climate change. But let me turn it another way. We speak too much about challenges. We should speak also about opportunities. How we move forward.

Last week, perhaps you have seen at the Food and Agriculture Organization of the United Nations (FAO) meetings on science and innovation, everybody is speaking about agricultural production, about seeds and wants to transform food systems. UN's Food System Summit, let's transform. Yes, we have challenges but we should also think about what has to be done yet.

Also, we have done good things and breeders have done good things and public breeding have done good things, but we need to do more. And therefore, I am not somehow going in the direction to say we need to transform. But I liked Edgar's word about moving. We need to move things. And what moves things – and what means moving things? That's what UPOV is also about. Because seed is the starting point of agricultural production. I think we all agree. We all agree also, if the starting point of agricultural production is not right, then what you get is not right.

Even the best fertilizer or crop protection will not help.

At the same time, we know there is no one size fits all solutions. That is also what the breeders are doing. All what we are doing is to bring to the farmer varieties they can use wherever they are. It's not a commodity.

And by saying this, we need to be very careful when we speak about this, transform. We will not transform the world within two months or ten months. When we speak about changing things, we have to move things and we have to change things. We have to accept first of all, that no one size fits all solutions. But a lot of solutions are coming through science and innovation. Science and innovation, is for me, the critical one.

And more importantly, and I think we forget this, because even with the best UPOV protection, even with the best seeds, if we don't get the seed to the farmer, it makes no sense. And when you look, the count is still – let's take the count of Haiti. 90% of all seeds supplied to Haiti is local – is – can be indigenous, can be landraces. How can it be that we are still until today unable to build also seed supply chains?

In many countries, and Haiti is the example, I take it because just today I got information, 90,000 persons have hunger more this week than last week in Haiti. That means if we don't think about also how we impact, how we make accessible, and that's for all of us, countries and private sector, how we make accessible solutions, seed and others to all of the farmers, I think it makes no sense. We need to take this part into account.

Let me finish on perhaps one thing. We know we need more solutions. We know it. We know also we need more investment. So, question mark. We know Consultative Group on International Agricultural Research (CGIAR), public research, extremely important. We know we need all of this. Civil society. Indigenous people. We need all of this.

But we need at the same time, more investments, because again, we have more challenges.

So, last week I heard the figure. Public research in agriculture is flat or decreasing. That means how we address this, that means private sector, could do more, should do more. But to do more, here we are coming back. We need also the incentives. Because you know there is no other private sector industry out there who is investing more percentage of its turnover into research than the breeders. Twenty-five – up to 25%. Even in the medical industry, you don't find this. And if we want to find solutions and if we have also somehow to fill a gap, we need attraction, we need incentives to invest. We need incentives also to start to invest perhaps also in underutilized crops. That means that is also the discussion when we speak about climate change.

Impactful, making accessible, but at the same time, yes, taking perhaps also into account the specificity and the way of functioning of the private sector. And again, I am always saying this. In any case, yes, we are business people. Yes, we are here also to make money. But we cannot make money if the farmers are not making money. In any case, it needs to be a win-win situation for both.

Thank you so much, Chair.

VALSTAR Marien (Mr.), President of the Council, UPOV (moderator)

Thank you, Michael. Many messages at once but I pick out of that, whatever good varieties we can create as private companies, if they don't get to the farmers, we only have half of the solution. That's like, in a way, John Derera also said. 50% is genetics but there is also another 50% that we need to work on.

And I hear you very well that we need to invest in public research and in the whole institution everywhere.

Again, a possibility to ask questions and I see Japan. The floor is yours.

HAGIWARA Minori (Ms.), Director, Intellectual Property Division, Export and International Affairs Bureau, Ministry of Agriculture, Forestry and Fisheries (MAFF), Tokyo, Japan

Thank you, Chair. Thank you, Marien. Just wanted to make a quick comment. I think it's very important that we do provide more access to, you know, our varieties to the farmers. In order to increase that access, to have an effective PVP system is the core to it, to attract investment and to provide access. Yes, it is important to have PVP.

EDV or harvested material are very important in terms of effective PVP. And by having this good PVP, we will be able to face the issues a lot better and create varieties that will deal with climate change. And Japan is definitely interested in making good varieties. So, thank you.

VALSTAR Marien (Mr.), President of the Council, UPOV (moderator)

Are there others in the room or online that would like to pick the brain of a panelist? I see Canada. The floor is yours.

PARKER Anthony (Mr.), Commissioner, Plant Breeders' Rights Office, Canadian Food Inspection Agency (CFIA), Ottawa, Canada (speaker)

Thanks very much, Mr. Chair. Thanks so much, UPOV, for organizing this very important event the panelists for being here to share their thoughts with us.

I don't want to re-till ground that we've already been over, but you know, it would be useful to have an assessment from the breeding community. Is the current UPOV framework, is it going to be sufficient? Does it provide the proper incentives for you to tackle this enormous challenge of increasing breeding efforts?

And the part that I fear is if it isn't, will this drive you to seek more restrictive forms of IP protection that perhaps are not as balanced in the public interest at this sui generis that really has on the one hand, incentive and rewards, but on the other hand, these restrictions or limitations on the breeders' rights to serve public interest, like the researchers exemption, like the breeders exemption that may essentially make everything available as if it were public domain for the purposes of breeding. So, could you give me your honest assessment? Is it working? Will it be sufficient for the future? And please don't make my fear come true that if it's not, will you be pursuing more restrictive forms of IP? Thank you.

VALSTAR Marien (Mr.), President of the Council, UPOV (moderator)

Thank you for that question, Anthony. And before giving the floor to both breeders' associations, I do recall that in this last session, there was this presentation about the European Plant Variety System which clearly indicated there is money to be made and sustainability to be made at the same time and lots of innovation there as well.

So, at least at the moment, it seems to be working. But I get the gist of your question. Is it working good enough, also looking at the future? So, I would like first to ask Michael to give an answer to that question. Michael?

KELLER Michael (Mr.), Secretary-General, International Seed Federation (ISF) (speaker)

I think that the important one, Anthony, is the system is really – it's a good system. Sui generis is a good system because again, you know, ISF, we are representing nearly eight thousand companies. The diverse range of companies are in there, from the one person companies to mid-size to corporates to multinationals.

I think we all agree that for us, the philosophy is the sui generis protection is important, because also, somewhere, it is showing this long-term perception we have.

Now, we know exactly when we start to invest, it takes us five, ten, fifteen letters variety, twenty-five years to bring a new variety on the market.

I would take it like this. Yes, ninety-one is good, but we have discussions which like Edgar mentioned, we know are not going the right direction. Perhaps that is the point I would like to make. Perhaps at the national level, when it comes to implementation, but also when it comes to the recognition of what the private sector is doing and can do, perhaps we should do more. And that's for me, where I have trouble sometimes.

I met last week – I will not name any country – countries in FAO where I still have this feeling. You know? You come, you bring in your varieties, and then it's over. One time, you make money, and then it's over, you know? That is where also I think the countries have really a responsibility today with regard to all the challenges we are facing, to have a really clear debating and showing the private sector, it's complimentary to what we are doing perhaps in public research or not. But we need to collaborate. We need to – we need you on the ground also. And I think that's where sometimes I'm thinking, my goodness, yes, it's good to have UPOV. It's good perhaps it's even in place. But when you look on the implementation or on the discussions on the ground, it's not going the right direction.

I think that's for the first. Is UPOV the right tool? In some years, we will reflect on this one. Perhaps one day we will come with a paper saying we have to review. Yes, it is thirty years old, things are changing. That is the reality also.

It’s a reality.

When you look where we are today from where we are coming also in terms of all we mentioned a lot, genome editing, all the things, continued new processes of breeding, but also continued need of investment and even more investment perhaps we should think about, but we are not there. For me, it’s rather today, let’s really work together. Let’s recognize the complementarity and let’s really perhaps together also, engage with some countries where you don’t have protection system yet.

And just let me finish with this. We know exactly that agricultural investment in Sub-Saharan countries, for instance, private sector is investing there perhaps 10% of the overall investment. There is a gap why we are not investing there. Those are exactly the countries where we should invest, I think in this perspective, that means rather in thinking on implementation and collaborations.

VALSTAR Marien (Mr.), President of the Council, UPOV (moderator)

Okay. Thank you, Michael. I hear you very well. You started by saying UPOV is the preferred system, but we need to keep UPOV an effective system and there are many players in that, both we as members, but also countries that haven’t joined UPOV yet I would say that many responsibilities are there.

Edgar, also, your view on that – is UPOV the preferred system now and forever?

KRIEGER Edgar (Mr.), Secretary General, International Community of Breeders of Asexually Reproduced Horticultural Plants, CIOPORA (speaker)

Thank you for the question Mr. Chair. Yes, it is. Yes, it is. UPOV is the preferred system for breeders. And CIOPORA, although we sometimes are critical on the system, are strong supporters of the UPOV system. But we are not shy to point the fingers where the weaknesses are.

And Michael already gave a very diplomatic answer on this question. I can be a little bit more direct as we usually are, because we have different crops. In our crops, we have vegetatively propagated ornamentals and fruits and no seeds. And our impression is that from the beginning, the system is a little bit based and focused on seeds. This leaves alone, a little bit, the harvested material. In our crops, the harvested material is the most essential part.

So, and we need protection of harvested material. It’s not very strong. And if you have the decision in the European Union that is clearly a signal that there is a need for some change.

UPOV 1991 is thirty years old. UPOV ’78 is forty-five years old. Thirty years ago, we didn’t have a lot of climate change. The global trade was not that as it is now. We had no new breeding techniques, no green techniques. So, the world is changing a lot. Maybe we should think about this and start a discussion about it.

One thing which concerns me is, and I have a lot of discussions with breeders on enforcement. When I ask them, did you enforce recently something? Have you been successful? They said, yes, we have been successful. We had a case. We have been successful. I said, oh, on breeder’s rights? No, on trademarks. No on breeder’s rights.

Almost nobody is successful in enforcing breeder’s rights because it is so complex, it takes a lot of time. It is very expensive. And at the end, it is not predictable. And we see several court cases which go in the wrong direction. Trademarks are easier.

The innovation capacity in other industries are not less than in agriculture and in horticulture, and they have patents. And when – I predict if the patent system is open for plant varieties, the breeders will go for patents for their best genetics. And this happens in the United States at the moment, utility patents. If you have a really top variety, you don’t go for variety rights. You don’t go for PVR. You go for utility patents. And you have a broad claim and these claims don’t kill the industry. They protect the innovation and they get the breeder a return on investment.

So, for us, the UPOV system is the right one, but we need to improve it.

VALSTAR Marien (Mr.), President of the Council, UPOV (moderator)

Thank you, Edgar. And it's good to be critical. We need to be critical together to make sure that the system is foolproof now and in the future. So, please, stay critical. Of course, with the right words and the right attitude. But please, now we need to really see where we can – how we can improve our system.

I saw the European Union asking for the floor. EU, please.

MANNERKORPI Päivi (Ms.), Team Leader - Plant Reproductive Material, Unit G1 Plant Health, Directorate General for Health and Food Safety (DG SANTE), European Commission, Brussels, Belgium

Thank you very much. And so, in the European Union, we really like to refer to plant breeding as a solution for the problems and for the transformation to the sustainable food system, but can plant breeding deliver? I mean, the challenges are immense and is the breeding progress indefinite? Is plant breeding really able to deliver and answer all these challenges?

Then my second question is, it's more about horizon scanning. Actually, the seminar was a bit of a horizon scanning seminar. My question would be how do you see the UPOV system in 2030, in a longer time period, in the horizon? Is it still there? Should we, meanwhile, have a diplomatic conference and improve it? How do you see it? Thank you.

VALSTAR Marien (Mr.), President of the Council, UPOV (moderator)

Thank you for your two questions. Again, directed to breeders. And I just got a message that John Derera asked for the floor and I was already about to ask him because maybe he also has views on the first question that European Commission asked. Is plant breeding able to deliver? John, the floor is yours.

DERERA John (Mr.), Senior Director, Plant Breeding and Pre-Breeding, Consultative Group on International Agricultural Research (CGIAR) (speaker)

Thank you so much. Yes, I also wanted to comment on the first question in terms of effectiveness of UPOV and breeders' rights. I think it is effective when you look at it from a public plant breeding view of things and we look at climate change, we are looking for diversity. And we are also looking at deriving traits from certain materials to improve for adaptation. Through that provision for public breeders to be able to breed from the materials that are protected under this system I think is a big plus.

Then coming on the point if breeding can deliver, I will say yes. My answer is yes. Plant breeding definitely can deliver and there is abundant evidence of new varieties coming. For example, even in this seminar, it has been shown of those varieties that are resistant to drought in rice, maize, and even within the agronomy crops, we have seen an increased area of production of maize in the Sahara, one which is quite dry, when drought and heat resistant varieties were introduced.

We also are seeing in Sub-Saharan Africa wherefore AGRA is quite new. Devastating, three or five years ago from Kenya going down South Africa. But the materials that are coming through the CIMMYT program that are resistant were tested in many countries are showing that we can have a solution even using the natural traits.

So, I would say plant breeding can deliver and it requires investment to drive it. The UPOV protection is one the elements that will provide both. Thank you.

VALSTAR Marien (Mr.), President of the Council, UPOV (moderator)

Okay. Thank you, John. Indeed, of course if we look back in time, then we see that plant breeding is delivering and I think the important thing is that we must keep the system that it keeps delivering. We need this innovation not only now but also in the future.

Now, I could ask breeders whether they think plant breeding can deliver but I think they would both say yes. So, I would rather go to the second question that the European Union asked. How do you see the system in 2030? Well, that's very soon, you would say. But anyway, would there be a need of a real revision of the Convention? Edgar? Maybe you will first, being so critical?

KRIEGER Edgar (Mr.), Secretary General, International Community of Breeders of Asexually Reproduced Horticultural Plants, CIOPORA (speaker)

Thank you very much, Mr. Chair. We have developed the position papers and the last one from 2014 and it started 2010. And I hope that all of you read them. And if you have read them, you know that we see a need for a revision, not a drastic one. Maybe some people find it drastic. I think we should – we should step away from the thinking that weak protection is good for farmers and growers. This is not the case.

Good protection is good for honest people, for the breeders and for the licensees who are honest, because they pay their share and they contribute to the system anyway. A weak system is only good for infringers because you cannot enforce against them. This is what we face day to day.

And so, against this background, I would say, yes, a revision would be nice. 2030 is already very close. Five years to go, I said let's start with 2030, thinking about 2030. Maybe we should now think about 2040. And if I see the discussions in some Member States of UPOV, I am a little bit skeptical if that would happen because countries could do more on their own national legislation but they don't do it. So, this is a little bit what makes me a little bit concerned. But I think a revision should take place. Thank you.

MANNERKORPI Päivi (Ms.), Team Leader - Plant Reproductive Material, Unit G1 Plant Health, Directorate General for Health and Food Safety (DG SANTE), European Commission, Brussels, Belgium

Sorry. Mr. Chairperson, I was referring to 2030 years' time in a longer, longer horizon. Thank you.

VALSTAR Marien (Mr.), President of the Council, UPOV (moderator)

Does that change your answer, Edgar?

KRIEGER Edgar (Mr.), Secretary General, International Community of Breeders of Asexually Reproduced Horticultural Plants, CIOPORA (speaker)

Sorry, I did not get that right.

VALSTAR Marien (Mr.), President of the Council, UPOV (moderator)

But yes, I heard you, Edgar, and thanks for that answer. And okay, 2040, we come to a reasonable estimate. But of course, always, and I think it's important that you also highlight, with the current Convention we have, there is still so much to do in so many countries, with implementation, with improvement, et cetera, et cetera. And that's of course the balance we're also looking for. If we start revising the Convention, then probably implementation of improvement in many countries will not speed up at that time. So, there's balance to be found.

I think Michael, it would also be nice to get your views on the next 2030 years.

KELLER Michael (Mr.), Secretary-General, International Seed Federation (ISF) (speaker)

I would like to start again because one point we didn't mention enough also is this – today we have – and since ever somehow, we have an interdependency on seed. No country is independent when it comes up to seeds. Seed is moving around the world. We like it or not but we saw it also during COVID. That's a reality. And I think this is a reality and I have a really interesting status out perhaps for you also from OECD on the Asian Pacific market, on this interrelation, because it's good. In times of climate change, we should never forget, if you are only relying on one production site and you have a flooding, it's dead. That means we have to think also – we need to find ways to somehow guarantee ourselves that we have enough seed and diversity of seed.

The second point also is yes, we need protection and yes, we need also some consistency because we are working with farmers. And the reality of the farmer today, sometimes the farmer is deciding a week before he's planting what he wants or she wants to plant, a week before. A week before. Okay. And then you have nothing there in this country, and you need to move varieties.

That means, you know, that we need to have in mind also the whole thing is changing but it's changing in a good way because also farmers are switching because of the situation they are facing on the ground.

So, opening – now, having, how you call it, a diplomatic conference could be an interesting approach and perhaps farmers could be interested. I am looking carefully at Edgar. He is watching me.

But the point is we have what we have. If we have, in this multilateral world we know, a diplomatic conference, would we get something which is perhaps supporting private sector or breeding as a whole? In a way, we need – it would even decrease.

I ask you. You are the decision makers. We are – we would watch you and would we go in a direction, perhaps, even in ten or fifteen years, in a changing world where yes, we need protection, perhaps we need even stronger protection? Perhaps we need stronger protection but shorter because also farmers are switching quicker.

But if we go there, wow, are countries, all of you, agreeing? Because I think it is unanimity. That is the question mark. Therefore, should we try to work with what we have but to really implement it, enforce it in the right way instead of perhaps dreaming and then ending up with something or with nothing?

VALSTAR Marien (Mr.), President of the Council, UPOV (moderator)

Okay. Thanks for this word of warning, Michael. On the line that we need to do a lot with the current Convention and we still can do a lot. I think – I hope, European Commission, that answers your question on where are we going.

Is there anyone in the room that wants to react to the question that Michael posed to you as countries? Are you looking for a new Convention? But if there is not, I see that Kenya is asking for the floor, probably on a different question. Kenya, the floor is yours.

MAINA Simon Mucheru (Mr.), Head, Seed Certification and Plant Variety Protection, Kenya Plant Health Inspectorate Service (KEPHIS), Nairobi, Kenya

Thank you very much, President. I have two related issues going to, maybe Michael, today is your day, or someone else from the private sector.

We have seen good, very positive involvement with the private sector in breeding in our country and also other neighboring countries in Africa, which is a very positive move. But traditionally, we have had a lot of varieties, especially what we are calling the climate varieties developed by the public sector. And it happens that these varieties, sometimes they don't find their way to the farmers because of the limited capacity of the private sector – I mean, with the public sector to do that.

So, as much as the private sector is breeding, and I know breeding takes time, we always ask ourselves maybe why the private sector would not take the public varieties in the meantime as they work on their own. I don't know what is your experience in other parts of the world because that has a way of limiting the access of farmers to some of those good materials.

The other aspect that is related is where you find in the private sector, they will come up with one good variety, very popular with farmers. We are aware that we have already tested, they have better varieties, but they will stick to that one so that the farmers are limited in what they are accessing. There are better varieties that are shelved because there is a variety that is doing very well necessarily. So, I don't know what you would comment about that because we feel that is a limitation. The farmers are missing out on some good materials. Thank you.

VALSTAR Marien (Mr.), President of the Council, UPOV (moderator)

Okay. Thank you, Kenya. Very interesting and challenging questions because indeed, we talk all the time about creating better varieties and making sure they get to the farmers, and apparently there is a need in Kenya or at least a question, a demand. Like, how can – or maybe, how can the private sector help us getting these publicly bred varieties to the farmers? Very interesting question. And I think Michael, you were addressed, so I will address that question indeed to you.

KELLER Michael (Mr.), Secretary-General, International Seed Federation (ISF) (speaker)

I think that's a point, and it's a serious point we have in many countries, and it's the same. We have a colleague from CGIAR here. We have CGIAR, sometimes good things at CGIAR, but it's not up taken. How to bridge it?

And I think this is exactly when we speak about how we need to have also the dialogue in the countries and the recognition, what can the private sector do and perhaps what is not the role of the public research, because public research, I think, are they ready to go to market? No. That's the role of the private sector. And when I speak we are representing eight thousand companies, many of them are not at all breeding companies. Many of them are companies specialized in production or in trading.

That means this is exactly the question mark we have in several countries, in Africa, for instance, but also in Asia, how we can also structure the private sector in these countries that they are not starting from one moment to another breeding program, but they are collaborating with the public authorities. We have and had this discussion but I think that's exactly the dialogue we should have in many countries and I think that's also a discussion we have sometimes with CGIAR to how we can also use best what is there to bring it and to breed it to commercial variety and to bring it to the market.

But this is not something we can, from scratch. That means there is also a whole knowledge and value chain to be structured. But I think this is – I fully agree with you, it's a major domain. And I mentioned at the beginning, it's not only private breeding. Public breeding is extremely important everywhere but how we can bridge this gap here is essential.

How many varieties are on the market? What we are looking for is to provide choice, at least that the farmers can choose. And in the end, we're always saying it's up to the farmer to choose a landrace indigenous variety or public bred variety or others. How many varieties are on the market from the private sector depends perhaps also on the competition which is existing in the country.

VALSTAR Marien (Mr.), President of the Council, UPOV (moderator)

Okay. Thank you, Michael. Food for thought but especially food for collaboration. And I know it's very difficult to find the right level, the right platform to collaborate, because in a meeting room, it's very easy to say yes, let's work together but to really do it in the field or at least where it needs to be done, that takes another effort.

I hope and I see that also, that the private sector is reaching out. Please, which hand can we take and shake and see how we can improve on that. So, I hope also that from the public side, this hand is recognized and accepted and collaboration can start in this regard, how difficult it may be.

John Derera from CGIAR. You were mentioned also in Michael's answer. Do you observe the same with varieties or materials developed in your system? Do you experience the same, that it's hard to get these better varieties in the end to the farmers?

Can I give you the floor, John? Yes, the floor is yours.

DERERA John (Mr.), Senior Director, Plant Breeding and Pre-Breeding, Consultative Group on International Agricultural Research (CGIAR) (speaker)

Thank you. Yes. It's actually a challenge as explained here, that the varieties have been bred in the public system sitting within CGIAR and also sitting with our national program partners. But it's one of the areas that we are working on, that challenge, trying to provide solutions. When we come up with the market intelligence initiatives within the CGIAR, the new initiatives that started this year in 2022, which is there to try and narrow that gap. Perhaps one of the elements could be that when public breeders develop these varieties, they lack sufficient information in terms of which varieties can sell when we give them to the private sector.

So, we are trying to work more on focusing now on what the target product profile is. That's what the industry does if there is a new thing that we're introducing in the public system breeding, both in the CG system and in the national programs. While also at the same time, we expect our market intelligence initiative to be much closer to the farmers and also closer to the private sector in providing the information about the demand, what do farmers want in our varieties, that we will be able to provide the varieties to the farmers.

So, it's a challenge and the solution is the market intelligence initiative that we have. Thank you so much.

VALSTAR Marien (Mr.), President of the Council, UPOV (moderator)

Okay. Thank you, John. So, room for collaboration, I would say. And thank you, Kenya, for the really important question that you asked because we can spend lots of time discussing, oh, how good we are as a UPOV system and how wonderful plant breeding is. In the end, it's about the effects that we have in the field when we talk about food security, when we talk about climate change

So, we need action not only in this room but elsewhere.

So, it's almost getting to the end of the meeting but I see the final question being asked by Argentina.

VILLAMAYOR María Laura (Sra.), Coordinadora de Relaciones Institucionales e Interjurisdiccionales, Instituto Nacional de Semillas (INASE), Secretaría de Agricultura, Ganadería, Pesca y Alimentación, Buenos Aires, Argentina

Thank you, Chairman. To be honest, I didn't really have a question. I wanted to contribute to something on the interaction between the public and private sectors.

We still don't have the 1991 Act of UPOV in some Latin American countries, even as we head towards having a new one. So, we do have to manage with what we have. But we recognize that public-private cooperation is very important. In Argentina, we have worked as mediators between the public sector and others to develop molecular markers and to identify varieties on the market. This gives us an idea of the varieties which producers in agriculture and the fishing sector actually use. We provide this information to breeders so that they can exercise their breeder's rights. That is an example of cooperation between the public and private sector, which has been functioning pretty well really.

We have in some cases detected inconsistencies in the information that the producers are providing to us and we sometimes have seeds that breeders have provided to us which you can then do molecular market testing on.

Sometimes we have to think about changing our legislation in countries. Sometimes we have to be a bit more creative than that, and as I said, use what we have in order to ensure that breeder's rights can be properly exercised and enforced.

We shouldn't go straight for changing legislation because sometimes that's difficult. It's not only a technical matter, it's a political matter of course, which makes it difficult by definition.

Encouraging private-public sector cooperation as we're doing in Argentina does usually lead in a positive direction. It helps us to change things for the better and it avoids the very unwieldy, lengthy, and sensitive issue of having to change legislation. Thank you.

VALSTAR Marien (Mr.), President of the Council, UPOV (moderator)

Thank you, Argentina, for providing this example of how public-private collaboration can work and is fruitful. And there are many of these examples but also many that have started but are struggling. It really takes an effort to get there. So, I commend you for that.

Since it was not a question, I still have time for one question from the room if there is any. And if not, I will start by going to conclude this meeting.

CONCLUDING REMARKS

Seminar on the role of plant breeding and plant variety protection in enabling agriculture to mitigate and adapt to climate change

Mr. Marien Valstar
President of the Council, UPOV

- Climate change is increasingly affecting everyone around the world: farmers, breeders and consumers. Effects are biotic (new pests and diseases) and abiotic (heat, drought, rain, seasonal changes).

- A range of strategies is needed to respond to the challenges. Plant breeding has a vital role to play in these strategies; farmers need new plant varieties to adapt to climate change but also to sustainably increase productivity in order to minimize climate change.

- Plant breeding is a long-term process that requires long-term investment from public institutions and from private companies. Plant breeders need a regulatory environment that promotes innovation and supports the conservation and utilization of genetic resources.

- The UPOV system enables plant breeders to provide farmers with the varieties they will need to feed the world in the face of climate change.

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