GRAIN SA

CLIMATE RESILIENCE CONSORTIUM

Progress Report to the Maize Trust

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Department: Science and Innovation
REPUBLIC OF SOUTH AFRICA

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CLIMATE RESILIENCE CONSORTIUM

BACKGROUND AND INTRODUCTION

Climate change has the potential to devastate food and nutrition security in southern Africa. Grain serves as the dominant staple food in sub-Saharan Africa with South Africa exporting large amounts of grains within southern Africa. South Africa therefore plays a major role in stabilising food security in southern Africa. Since this region is highly dependent on climate sensitive economic activity, sub-Saharan Africa is said to be one of the region's most severely affected by climate change[1]. Climate change places an immense burden on food security in southern Africa and most urgently calls for mitigation and adaptation strategies to be put in place.

The 2015/16 El Niño-induced drought devastated grain production in South Africa and was noted as one of the strongest El Niño events on record. Extreme drought conditions reduced maize plantings and production significantly and therefore had an impact on food security. This is a concern shared by government and industry. Understanding this, industry has made significant efforts to co-fund with government to understand this threat and conduct research to build resilience. Following engagements with government, industry and the research community, the Climate Resilience Consortium was established to investigate the effects of climate change on maize production. The consortium started with 2 projects, one assessing future climatic conditions on maize production and the second to expand local maize genetic variability and develop release superior hybrids and OPV's (open pollinated varieties) adapted to high temperature and low rainfall conditions for the smallholder producers in South Africa. The consortium has grown significantly to include specific climate change and variability challenges faced by producers. This consortium has therefore been an important step for industry to start comprehensively addressing the challenges of climate change and variability for the local grain industry.

The devastating effects of climate change on food security in South Africa means that tackling climate change in agriculture is a high priority shared by government and industry. Through engagements with industry and government, key objectives were identified to address challenges posed by climate change (Table 1). The first is focussed on building a knowledge base of the effect of climate change in agriculture. It is well known that climate change will greatly disrupt national food security, but how this will affect production is largely unknown. Through

[1] Zewdie, A., 2014. Impacts of climate change on food security: a literature review in Sub Saharan Africa. Journal of Earth Science & Climatic Change, 5(8).

this objective, a greater knowledge base will be developed by investigating the specific effects of climate change and variability in a local context and how producers engage with this challenge.

The second key objective is to develop climate change response plans (Table 1). In response to climate change and building resilience in South Africa, the approach will be to tackle challenges and explore solutions from various angles. Here the focus will be to look at expanding maize genetic variability for more heat and drought tolerant crops suitable to our local conditions as well as production practices that could be used to help build resilient production systems.

Table 1. Overview of consortium

Strategic priority	Objective	Sub-objective	Project number	Current partners	Expected outputs
Climate Change in Agriculture	1. Build a knowledge-base of the effect of climate change on agriculture	Generate knowledge on the impact of future climates on the production of economically important crops such as wheat and maize	1	UCT	Knowledge on the impact of climate change and variability on grain production.
		Investigate the effect of intra-seasonal climate variability	2	UFS, UP, ARC	
		Important agricultural pests and diseases under a changing climate	3	UP, DALRRD	
	2. Develop climate change response plans	Expand maize genetic variability to promote availability of affordable, quality seed to smallholder producers (Maize breeding)	4 and 5	Syngenta, SU	Maize hybrids developed with increased resilience to drought and heat stress
		Establish long-term trials to build resilient production systems	6 and 7	UFS, PSA	Long-term agronomic trials

UCT: University of Cape Town; UP: University of Pretoria; UFS: University of the Free State; ARC: Agricultural Research Council; SU: Stellenbosch University; PSA: Potato South Africa; DALRRD: Department of Agriculture, Land Reform and Rural Development.

CONSORTIUM PROGRESS

The overall aim of the consortium is to investigate the impact of climate change and variability on agricultural production and develop sustainable response plans to ensure food and nutrition security for the future, while developing capacity to respond to the climate change challenges. Progress will be provided based on projects that contribute to the objectives.

1. Build a knowledge-base of the effect of climate change on agriculture

Within this objective, progress will be provided on four projects:

- Project 1: Building resilience to climate risks
- Project 2: The effects of a changing environment and late-planting dates on maize plant development and yield in South Africa
- Project 3: Important agricultural pests and diseases under a changing climate

Project 1: Building Resilience to Climate Risks

Research conducted by University of Cape Town

Project leader: Dr Peter Johnston

The final report of the project is attached as **Appendix 1**.

Introduction

South Africa's agricultural sector experiences multiple stressors, including (but not limited to) variable rainfall, widespread poverty, environmental degradation, uncertainties surrounding land transfer and transformation, limited access to capital and markets, inadequate infrastructure and technology, and HIV/AIDS. Climate variability and change—superimposed on all these other stressors—already exacerbates these issues and is anticipated to aggravate them in the future. With low adaptive capacity throughout the value chain the South African agricultural sector is highly vulnerable to the effects of climate and the anticipated increase in climate variability.

Farmers, both subsistence and commercial, have developed some strategies to cope with the current climate variability in South Africa. When planning for resilience to climate variability, it is important to understand and consider the longer-term climatic change possibilities, so that adaptations and infrastructural investments are in line with longer term future conditions. The current strategies, however, may not be sufficient to cope with climatic changes of the future.

It also appears likely that there will be yield reductions for wheat in the Western Cape due to increased temperatures and lower levels of rainfall. Some studies have shown that there are areas in the western and eastern maize growing region that will experience losses due to increased temperature and rainfall changes. It is recognised however that there are many factors that affect crop production and profitability.

However, in the short to medium-term, it is the variability of conditions that are most concerning to farmers. The frequency and intensity of droughts, extreme temperature, and episodes of dry spells, shifting rainfall onsets and cessation are all threats to the farmer on an annual basis. The uncertain impacts of El Nino Southern Oscillation (ENSO) create unreliable projections of future seasons and farmers need to negotiate more than just seasonal weather. Input costs, currency exchange rates and world market conditions all provide variable risks that affect the profitability of agriculture.

It is imperative to recognise vulnerability to these factors; critically, climate risk vulnerability assessment offers the opportunity for effective and meaningful responses to alleviate the risks.

Existing response strategies should be evaluated and where, appropriate, more effective, and sustainable solutions applied.

Project aim

Assist grain producers to manage imminent climate risks (such as anticipated droughts) by identifying risks and proposing ways in which management practices can be adapted to minimise the expected impacts.

Project objectives

Stage 1

1. To determine the impact of climate variability on the yields of these crops over the last +/- 20 years
2. To determine the main climate risks that impact on crop yield
3. To determine the relationship between climate risk and the profitability of the crops
4. To scope climate risk mitigation in the different agricultural systems and their cost effectiveness and success
5. To analyse downscaled projections of climate change in terms of changes of rainfall and extreme events to align responses to future impacts on crop production
6. To develop guidelines on how producers can respond to decrease the impact of climate risks

Stage 2

7. To scope climate risk mitigation in the different agricultural systems and their cost effectiveness and success especially noting the differences between formal commercial and developing commercial farmers
8. To codesign and develop guidelines on how producers (both developing and established commercial) can respond to decrease the impact of climate risks including the possibility of sharing resources, information, skills and technologies at national and local levels

Approach

The project followed a consultation, scoping and analysis pattern. Consultations were held with smallholder, emerging commercial and commercial producers from the North West (Lichtenburg), Free State (Welkom) and Eastern Cape (Mthatha and Ugie) provinces. Two meetings were held with producers during 2019, with follow up meetings during 2020 and 2021 as per COVID-19 regulations. The number of attendees at each meeting ranged from 15-30 (which included Grain SA and non-Grain SA members). The purpose of the consultation phase was twofold; i) to gain an understanding of the climatic challenges producers face (as it relates to climate change) and ii) to increase producers' awareness of climate change and associated impacts.

During the scoping and analysis phases, analysis of producers' responses (during the first meeting) and the appropriate scientific data determined the content and focus of the follow up meetings, which were held to share progress and to co-develop a strategy for guidelines toward increasing resilience to climate risks. It was not the intention of this project to prescribe any specific course of action, but rather to work with the farmers to develop a possible course of action to face current and future climate risks within the context of their specific situations and other non-climatic risks.

Progress

This 3-year project was concluded during March 2021 (see attached final report, Appendix 1). In order to share the information from this study as widely as possible, a process was started with the researcher to develop information packages which can easily be shared. This process is envisioned to be concluded by March 2022 and does not require funds for the 2021/22 season.

Objective 1: To determine the impact of climate variability on the yields of these crops over the last +/- 20 years

While climate variability certainly has an impact on yield, it was evident that there was no direct correlation between seasonal rainfall and yield. Having said that, it was evident that during a drought year (i.e., the seasonal rainfall was consistently less than 60% of normal rainfall) there are significant decreases in yield. The converse is true as regards to price. When climate variability is high with some lower overall yields, the price increases.

The information obtained from farmers shows a remarkable difference among the study areas (ranging from 2-4 t/ha in Kokstad and Welkom and up to 4-6t/ha in Mthatha and Lichtenburg) mainly due to soil and climate differences, but perhaps also due to the scales at which the crop is grown. The variability of yield is not, according to the farmers, significantly linked to the variation of amount of seasonal rainfall, but more due to the timing of that rainfall.

A correlation analysis was performed on maize yield data from 6 districts in the maize belt of South Africa and the corresponding precipitation for those districts. The goal of the analysis was to find microtrends between small time windows of precipitation and overall yields. In other words, what 5-day time spans are most important throughout the growing cycle of maize for the overall success of the yield? Data from 1980-2017 in the districts of Bethlehem, Carolina, Kroonstad, Lichtenberg, Vrede, and Welkom was used in the project. Pearson Correlation Coefficients were used for each 5-day span in the year for each district. Ultimately, it was found that the most valuable times for rain to fall was in late January to mid-February, a time that marks the end of the dry season meaning that the most harm for yields comes if there is an extended dry season. However, this conclusion comes with the caution that there are many other practical, economic, and social factors that contribute to yield and much more study is required to determine best practices for maize growth. The implication is that any delay of the onset in these regions after January will result in the greatest impact on yields.

Objective 2: To determine the main climatic risks that impact on crop yield

The main risks facing the farmers are mainly:

- Timing of onset of rainfall, which seems to be later
- Extreme events such as heavy rain and high winds.
- Heat waves during January and February (mid-season droughts affect both crops and livestock).
- Increases in veld fires.

If the onset of rainfall (normally September to early November) is normal or early, planting can take place well before December and the crop is ready before the first frost (though late season rain can cause fungus problems). However, if the rain onset is late (from December to January) then the planted maize can be subjected to very high temperatures during the early growth stage and cool temperatures during ripening, as well as early frost in April/May when the drying is incomplete. This correlates with the results and conclusion of the study mentioned above.

Objective 3: To determine the relationship between climate risk and the profitability of the crops

A high temperature range is detrimental to crop growth and subsequently yield. High temperature ranges have been experienced more often (a Tx/Tn range of more than 10 degrees). If temperatures are very high (especially over 40 degrees) the resultant impact on soil temperatures (which also increases) have detrimental effects on crops and can lead to crops dying. Although crops can recover with rain and lower temperatures, yields are then lower.

While there is no direct correlation between the amount of rainfall and yield, patterns are emerging on the importance of timing of rainfall. Delayed plantings due to late onset of rain can lead to reduced sunshine day length effects as well as cloudy and cool conditions during pollination (which can lead to disease onset). Late plantings also increase the risk for damage due to frost. Excessive rainfall (especially in short bursts) lead to flooded fields which hampers activities such as planting, spraying and weeding. High winds can cause erosion of soils and may lead to lodging when seedlings are small.

Extreme rainfall amounts, whether low or high, have consequences for yield, although it seemed the worst impacts are from extended dry periods (of 2-3 weeks) and heavy rainfall, which causes flooding that damages shoots and roots. It was also mentioned that hail was occurring more frequently. While farmers were hesitant to say that the climate was changing, it was a common thread that the rainy season seems to be later more often and hail more frequent than in the past.

The exact financial impact of a shifting seasonal onset and extreme events would require some financial modelling, which is beyond the scope of this project. However, considering that profitability was a function of two main factors (input costs and market prices), the impact of climate variability are being noticed by farmers. Input costs are increased when:

- Planting is delayed and multiple plantings are incurred.
- Input prices increase due to increased demand and world price (of oil).
- Storage costs are incurred due to market conditions.
- Increases in theft.
- Outbreaks of pests and diseases, often due to a shifting season.
- Labour costs increase.

Market prices vary according to:

- International trends
- Local production levels
- Crop quality
- Transport costs/subsidies

Objective 4: To scope climate risk mitigation in the different agricultural systems and their cost effectiveness and success

Reducing risk was a very contentious issue among the farmers. Some were in favour of the conservation agriculture (CA) principles approach, while others believed that better seed and other input availability would better prepare them to adapt to climate risk. Farmers believed that CA would require considerable losses in the conversion and were not sure of the long-term financial benefits.

It was also reported that the lack of finance and access to loans placed farmers at risk to climate variability as planting could not take place at the optimal timing, due to the unavailability of inputs.

When the rainfall onset was delayed beyond December, the common reaction was to plant an alternative, less sensitive crop such as sunflowers, soybean, dry beans or oats. These were almost guaranteed to provide some income if a dry season persisted. However, it was reported that if the rainy season (from January onwards) was normal or wetter than normal, these crops may not produce the profits that a late planted maize crop would have (assuming there was no frost before mid/end May).

The round of fieldwork completed after the 2019/20 harvest revealed that the later seasonal rainfall was in many respects, anticipated by the farmers and adaptations were made, such as quicker seed varieties, some switching to sunflower and others trusting in their experience of previous years. Frost was not a problem but there were some problems with grain quality. Fortunately, the price has remained high (relatively), and most farmers were able to make a profit and service their debt.

Conservation agriculture, while often touted by practitioners in Western Cape, KwaZulu Natal and Limpopo, is not regarded as a viable option by most farmers interviewed in the Free State and North West provinces. It is recognised that retaining soil moisture is important, few farmers acknowledged that reducing their chemical dependence would benefit soil and yields in the long run. Farmers were encouraged to consider and educate themselves about the latest technological and experimental research.

Objective 5: To analyse downscaled projections of climate change in terms of changes of rainfall and extreme events to align responses to future impacts on crop production

Downscaled projections for the regions are available and can be summarised as follows:

- Average temperatures are set to increase by between 1.8 – 4°C, according to the RCP8.5 scenario, by 2055.
- The number of hot days with Tmax over 32°C is set to increase by 3-13 more days each month between October and March.
- The number of hot days with Tmax over 36°C is set to increase by 0.5-7 more days each month between October and March.
- In many cases, rainfall is projected to decrease in September and November, but increase in January, with uncertainty in other months.
- Days with frost are set to decrease by between 0.5 days per month in April and up to 3 days fewer per month in May-August.

Objective 6: To develop guidelines on how producers can respond to decrease the impact of climate risks

Farmers were consulted in November 2019 to discuss their strategy at a stage when there had been little to no rainfall in their regions. Based on their previous experience with climate risks the following strategies were discussed:

- Alternative planting dates – planting could shift according to the rains, but if the rain came early and was not followed by more rain (false onset) then a crop could be lost completely. Planting could be shifted later, but after January the risk of damage from an early frost increased.
- Seed selection - If the rain came late, it was possible to obtain a different seed variety (shorter season), but this may be more expensive and require different inputs.
- Alternative crops – if the rainfall came as late as January, farmers were inclined to plant sunflowers and/or soybeans/dry beans/teff.
- Fallow (oorlê) field options – certain fields could be left for recovery with a stubble overlay. This reduced the expense of inputs if a return was risky.
- Growing pasture for cattle grazing – this was risky if the season remain dry, as it required some inputs.
- Implement CA techniques – some farmers expressed the desire to move towards no-till planting but had fears about weed control and disrespecting local traditions.

Problems encountered were:

- An early frost would devastate maize – for late plantings frost before late May was a huge problem.
- Late plantings were also subject to a lack of heat units which retarded ripening.
- Sunflowers often produced a disappointing yield (good rain does not necessarily produce a better yield).
- Crop rotation options are reduced due to theft.
- With good rains, maize was still a good option, so farmers sometimes waited until it was too late or planted maize regardless and lost a good proportion of their crop through low heat units or frost.
- Sorghum planting needs a contract to be assured of profitability.
- Mid-season heatwaves still remained a problem, especially as weeds thrived.
- Crop insurance was only available for maize.

A seasonal overview was presented with all forecasts issued in October showing a dry rainfall season for DJF and JFM. As it happened, the season was above normal with some flooding in Lichtenburg. It was thus of some concern from the farmers that the available climate forecasts were not always accurate.

Objective 7: To scope climate risk mitigation in the different agricultural systems and their cost effectiveness and success especially noting the differences between formal commercial and developing commercial farmers

A new set of meetings with experienced commercial and developing commercial was scheduled for the second half of March 2020, but only one was held due to COVID-19 concerns. In September 2020, follow up meetings were held in Kokstad, Welkom and Lichtenburg. The strategy was to open a conversation with the farmers to share their experiences and practices so that learning and cooperation could be facilitated among the different groups. The envisaged combined meetings did not eventuate due to a number of reasons, so discussion about possible liaison between groups ensued.

At the subsequent meetings, their response and progress during the season was discussed. As discussed above, farmers were responding to climatic shifts. A few key observations:

- Maize was still a preferred crop in most regions with white maize, as a food crop, which is in constant demand (imports are not a possibility). Yellow maize could be imported so being able to compete with imports was always a challenge.
- Depending on soil and rainfall conditions it was still possible to attain yields in a range of 4.5-7.5 tons per hectare (FS), 7-10 tons/ha (KZN) and 3-4 tons/ha (NW). Breakeven yields varied depending on area.
- Sunflowers as an alternative had problems when exposed to Sclerotinia and worked best as an alternative during drier years.
- Shorter planting windows meant that there was an urgency to plant entire farms in the time available.
- Appropriate maize seed availability remained a problem for developing farmers.
- Development farmers still struggled with loans, and this was likely to be exacerbated in 2020/2021 as ABInbev was not renewing loans. (In 2021 it was announced that the loans would be reinstated)
- Development farmers all made some profit in the 2019/20 year and were encouraged to keep sufficient amounts aside for input costs for 2020/21.
- There was some resistance to the conventional pesticides and pests remained a serious threat.
- Many farmers were enthusiastic about using seasonal forecast services offered by academic institutions and this will be facilitated.

A climate or weather diary was designed and disseminated to farmers to encourage record keeping. This would assist them in post season analysis and also contribute to the overall records used by scientists to develop forecasting tools.

Objective 8: To codesign and develop guidelines on how producers (both developing and established commercial) can respond to decrease the impact of climate risks including the possibility of sharing resources, information, skills and technologies at national and local levels

Final stakeholder meetings were designed to elicit from the farmers specific needs for the future, how these may be met and what resources would best assist them to build resilience to climate risk. While information and advice were the most common requests, it was important to interrogate the nature and availability of current climate information and to assess how useful this was.

The development of guidelines is a complex task as each region under investigation experiences a different climate regime of both temperature and rainfall patterns. Each region also has different soils, and may experience different pests and diseases, too.

The most desired aspects of climate information that could increase resilience to climate risk were the need for early warnings of conditions for the upcoming growing season. Early warnings of any non-normal conditions are required for planning inputs, planting and harvesting times, marketing strategies and topdressing timetables. While climate change is a longer-term concern in terms of the ongoing sustainability, and farmers are aware that adaptations are required, the nature of grain farmers is that the loan/plant/harvest/repayment cycle is an annual one, and thus farmers are always focused on the upcoming season.

Building resilience involves a) the identification of climate risks and vulnerability, b) the sharing of knowledge regarding the climate information that is up to date, relevant, and useful, c) the tailoring or modifying that information to suit a particular crop and or agricultural region, and d) the uptake or application of that information to improve preparedness and resources to face the climate risks, reducing vulnerability and adapting to variation and change.

To achieve these aspects and develop resilience the following actions are recommended.

1. The continued and expanded dissemination of climate forecast products, ranging from shorter term forecasting through seasonal scales and then to longer term climate change scenarios. To facilitate this an output of this project will be a resource containing:
    a. Links to climate information products with diagrams and explanatory text. The latest climate science will be presented, and the information will be selected and adapted to meet the needs of the maize sector. This may include links to short- and medium-term forecast resources.
    b. A selection of historical seasonality plots showing the long-term monthly climatology of rainfall totals and monthly averaged minimum and maximum temperatures for specific locations within the study area. This would provide a useful overview of the annual variation during the year. Different climate regimes will have very different seasonality. These monthly climatology (long term average) values are calculated from the historical records.

   c. An indication of changing suitability for maize in South Africa. This would show where climate risk is increasing to reduce the suitability in existing maize regions and easing in others where climatic conditions would be more suitable.
2. The creation of a discussion forum where any maize farmer could contribute, locate, use, and disseminate resources about maize farming. This could have separate channels for different regions and topics such as seed, pest management, fertiliser, management techniques, marketing and conservation and regenerative agriculture. 3
3. The development of an agriculture and climate research needs analysis.

The remainder of this project's lifespan will be devoted to implement much, if not all, of these 3 points.

Highlights

A highlight of the project so far has been the reported usefulness of meeting the farmer groups. Feedback has shown that the farmers value an independent but knowledgeable reflection of their situation with the added benefit of climate information.

A paper presenting the aims and progress of this project was presented at the South African Association for Atmospheric Sciences (SASAS) conference in Vanderbijlpark on 8/9 October 2019. It was well received and stimulated discussion about the provision of climate services to all farmers.

Hearing about the climate risks facing the farmers helps to frame the adaptation responses. Much of the reported and observed climate changes may actually be climate variability, and that needs to be recognised. All in all, farmers are becoming more aware of how climate risk can be reduced by alternative approaches.

A new experiment is being introduced, where farmers liaise with academics and supply their rainfall data to produce a tailored seasonal forecast. This exciting development will hopefully lead to an increased uptake and understanding of climate information.

There was lively discussion at all meetings about the skill and uptake of seasonal forecasts. At each meeting a summary of future seasonal forecasts was presented, and farmers expressed their reservations and cynicism about forecast probabilities. Overall, however, they all expressed interests in finding out more about available forecasts.

While seasonal climate forecasts are not only NOT freely available to them, and their skill is not very high, there are other data, such as rainfall and temperature records that are helpful in their decision making. Agricultural apps such as Agricloud (ARC) were promoted, and farmers were encouraged to keep rainfall records for their own reference. A weather diary was demonstrated, and 60 copies distributed to those interviewed and for coordinators to distribute to any farmers who showed interest.

The experience of co-designing a guide for farmers has been enlightening and invigorating. There is a strong sense of positivity within the agricultural sector despite the many challenges, both climatic and non-climatic. The focus on support through existing and possible new partners in agriculture can only facilitate the continued success of the transitional process of appropriate smaller scale farmers into sustainably commercial operations.

Conclusion

While the project aims to be as applicable as possible to all the stakeholders in the region, it must be recognised and acknowledged that with the relatively small number of participants in each region (15-30) the results and outputs may be not be fully representative of all development and commercial farmers in all regions. Efforts will thus be made to share the information from this study with as many producers as possible. Therefore, a process was started to develop information packages to be shared with producers. This will be reported in the next progress report.

The analysis of climate data and yield shows that there is no direct correlation between seasonal rainfall and yield, but as pointed out by all involved, it was the distribution of the rainfall that was most significant. Further analysis on the identification of critical rainfall periods (in the historical data) that have significantly impacted on the yields was undertaken and reported on in the attached appendix 1.

The combined threats of climate variability and change have been experienced throughout the study region and elsewhere and adaptations are part of farmers' everyday operations. However, the threats of increased temperatures and shifting rainfall patterns demanded new responses and the general lesson learnt was that the experiences and practices employed during extreme years (including seed selection, alternative crops, shifting planting dates etc.) were key in guiding responses for future conditions where these extremes would be more frequently experienced.

Finally, it is encouraging to notice two specific trends. Firstly, there is some enthusiasm towards investigating the benefits and advantages of Conservation Agriculture, where the focus is on soil health and moisture preservation. The many field trials and research projects around this are filtering down to the development farmers and this bodes well for their sustainability in the future. Secondly, there is a positive sense of cooperation among many of the commercial farmers that have been interviewed both within this project and elsewhere, and this shows a huge opportunity for information and skill sharing between and among the groups.

Project 2: The effects of a changing environment and late-planting dates on maize plant development and yield in South Africa

Research conducted by University of Pretoria, University of the Free State and the Agricultural Research Council – Grain Crops

Project leaders: Dr Nicky Creux (UP), Dr Gert Ceronio (UFS) and Mr Deon du Toit (ARC GC)

Detailed results are provided in **Appendix 2**.

Introduction

Region specific planting dates are one of the major determinants of maize yields, and require regular updates to keep track with new cultivars and a climate that is subject to change on a range of time scales (and is already showing signs of significant change) (Baum 2019). In South Africa, a key issue is onset of frost, which can come as early as April in parts of the Free State, the major production region. An early frost event may lead to significant losses due to frost exposure occurring before the crop reaches maturity (Moeletsi et al 2016). Several planting-date trials across continents have shown that late planting dates decrease grain yield significantly and this has led to the production of short life cycle hybrids to counteract such phenomena. While they may flower early, the plants are smaller and thinner resulting in lower yields and increased potential for lodging, which contributes significantly to yield loss (Baum 2019, Maresena et al 2019).

In recent years, producers in South Africa experienced challenges relating to late plantings. While delayed plantings were quite frequently due to late onset of rain, excessive rainfall in parts of the Eastern Cape delayed planting. While it is essential to investigate the effect of planting dates on yield, it is also important to determine the effects on plant development and quality in different growing regions.

Project aim

This study aims to investigate late maize plantings in South Africa and their association with late rain and other extreme weather events. The impact of late maize planting dates on the crop's growth, development, health and grain yield will be assessed using both tested and new technologies. We hope to contribute to current predictive models based on planting date and aim to highlight risk factors though this study.

Approach

This project is a collaborative effort between the University of the Free State, the Agricultural Research Council (Grain Crops) and the University of Pretoria. It therefore draws on various areas of expertise including agronomy, plant physiology and climate sciences.

Four field sites have been identified for this project (Potchefstroom, Bethlehem, Bloemfontein and Coligny), which will provide us with two sites representing the eastern and western regions of key maize producing provinces. At the experimental farm sites, Potchefstroom, Bethlehem and Bloemfontein, a detailed randomized planting scheme will be employed to cover six cultivars (3x yellow medium/medium-short growing cultivars and 3x white medium growing cultivars). At the three experimental farm sites, four planting reps will be performed based on date in the season (rep 1: 15-20 November, rep 2: 15-20 December, rep 3: 13-18 January and rep 4 :1-5 February). The Ottosdal site is located on a working farm and the planting scheme will be altered to conform to the farmers requirements with no supplemental irrigation. Planting dates are constrained to the timing of the rains at this site and will likely only constitute 2-3 planting rep. The planting dates at this site that match planting dates in the other three sites can be used for comparisons across sites for planting date effects on yield and quality. This site is a test site and if successful comparisons can be made with this site, other farm locations could be added in subsequent years to obtain a finer scale mapping of planting date, region, yield and seed quality.

The following measurements and observations will be monitored at all three experimental farm sites: Weekly leaf number counts and time to physiological maturity, weekly measurements for leaf area and leaf area index calculations, days to germination, days to silking, grain filling, grain moisture content, grain protein content, grain yield, grain grading and milling quality. From the site at Ottosdal only grain measurements, including grain filling, grain moisture content, grain protein content, grain filling, grain yield, grain grading and milling quality will be measured. Weather stations measuring temperature, rainfall, wind, humidity and evapotranspiration (ETo) will be present at every site.

Historical weather data over the last 30 years for the four major maize producing provinces (North West, Free State, Mpumalanga and Gauteng) will be assessed. The focus will be on data for daily rainfall, daily maximum and daily minimum temperatures. This data will enable us to identify trends and weather shifts in the maize producing provinces over the last 30 years. Once the climate trends and shifts and their effect has been assessed for each province, we will use these trends and yields to predict the impact of climate change on maize yields in the major production regions of South Africa, give current climate models and predictions (looking at a plausible range). This will enable us to simulate changes in maize yield over the next 50 years in these regions taking into account different climate change scenarios. Later, this work could be extended to other provinces with a view to find environmental niches in the future that maybe more stable maize production niches for potential maize crop migration.

Objectives

University of the Free State

1. To evaluate the phenological development of different genotypes in the warmer western Free State (Bloemfontein) region.
2. To compare the difference in the water productivity of the selected maize genotypes over different planting dates.
3. To compare and evaluate the grain yield and quality of maize at varying planting dates in different agro-ecological regions.
4. To model water usage, soil moisture and planting date to project the effect on final yield.

Agricultural Research Council - Grain Crops and Biotechnology Platform

1. To compare growth and yield traits between cultivars at different planting dates at different locations.
2. To compare time to physiological maturity and days to 12.5% moisture of different cultivars at different planting dates and to assess if these cultivars change their time to physiological maturity at different planting dates.
3. To identify the risk factors associated with different planting dates and use these to update current crop models.

University of Pretoria and Agricultural Research Council - Biotechnology Platform

1. To test the hypothesis that the rains in maize growing regions are in fact trending later, and that this trend is correlated with later planting dates, using historical weather and planting data.
2. To catalogue the extreme weather events documented in historical weather data to observe any trends or patterns in extreme weather events and how this is changing over time in maize growing regions and its effect on maize yield.
3. Using first effective rain in a season as a proxy for planting date, estimation of heat units and comparison to yearly yield data and current field trial data.
4. To measure fine-scale physiological changes at different growth stages under different planting dates and correlate these with temperature, soil moisture, photoperiod and genetic changes under both controlled and field conditions.

Progress

Results from the current season (2020/21) will be presented in this report and will include yield and yield component data, certain phenological development parameters as well as an update on the climate modelling work. Grain quality analyses of the first season (2019/20) will be provided in this report as the quality analyses is still ongoing for the current season (2020/21). Further analyses for the current season are still ongoing. Once the final data for the 2020/21 season has been collected, the data across the two seasons will be compared and described in the full-length for an overview of the planting dates effects.

Planting date trials were completed at all sites proposed for the second successive season of the project. Four planting dates were established at the three major experimental farm sites (Potchefstroom, Bloemfontein and Bethlehem) in the 2019/20 and 2020/21 season. In addition to the three experimental farm sites, the trial is also being executed on an operational farm (Ottosdal/Coligny) but is altered to align to the farmer's requirements with no supplemental irrigation. In the 2020/21 season the Ottosdal site was exchanged for the Coligny site and an additional site was included at NAMPO as a demonstration site for the Grain SA NAMPO Harvest Day. Table 1 provides a comparison of the dates selected and actual planting dates for replicates 1-4. While the actual dates were slightly altered to accommodate weather conditions these plantings still represent plantings in November, December, January and February as initially proposed (Table 2). These sites were under initial irrigation to facilitate specific planting dates. An additional expanded trial was planted at Bloemfontein. This trial was included to accommodate detailed and destructive measurements in large enough plots. Plants are sampled on a weekly basis to follow the growth and development of the different cultivars planted on the selected planting dates. Additionally, the soil water content of each plot is measured to determine the water use efficiency of the different cultivars planted on different planting dates.

Table 2. The anticipated planting dates reflected in the initial proposal and the actual planting dates which were influenced by weather factors for field seasons 2019/2020 and 2020/2021.

Site location	Rep number	Planned Planting Date	Actual Planting date	
Season			**2019/2020**	**2020/2021**
Potchefstroom	Rep 1	15th – 20th Nov 2019	11th Nov 2019	20th Nov 2020
	Rep 2	15th – 20th Dec 2019	20th Dec 2019	18th Dec 2020
	Rep 3	13th – 18th Jan 2020	20th Jan 2020	20th Jan 2021
	Rep 4	1st – 5th Feb 2020	13th Feb 2020	5th Feb 2021
Bethlehem	Rep 1	15th – 20th Nov 2019	13th Nov 2019	17th Nov 2020
	Rep 2	15th – 20th Dec 2019	18th Dec 2019	15th Dec 2020
	Rep 3	13th – 18th Jan 2020	16th Jan 2020	19th Jan 2021
	Rep 4	1st – 5th Feb 2020	6th Feb 2020	2nd Feb 2021
Bloemfontein	Rep 1	15th – 20th Nov 2019	19th Nov 2019	16th Nov 2020
	Rep 2	15th – 20th Dec 2019	17th Dec 2019	14th Dec 2020
	Rep 3	13th – 18th Jan 2020	15th Jan 2020	11th Jan 2021
	Rep 4	1st – 5th Feb 2020	5th Feb 2020	1st Feb 2021
Ottosdal	Rep 1	Rain Dependent	13th Dec 2019	-
	Rep 2	Rain Dependent	14th Jan 2020	-
Coligny	Rep 1	Rain Dependent	-	3rd Dec 2020
	Rep 2	Rain Dependent	-	11th Jan 2021
Nampo	Rep 1	15th – 20th Nov 2020	-	2nd Dec 2020
	Rep 2	15th – 20th Dec 2020	-	21st Dec 2020
	Rep 3	13th – 18th Jan 2021	-	13th Jan 2021
	Rep 4	1st – 5th Feb 2021	-	4th Feb 2021

Yield, growth and quality

In the 2020/21 season, plant growth and development showed similar trends to those observed in the previous season where leaf emergence was delayed, and leaf area was smaller for the later planting dates. However, there were also differences observed between the two seasons. In the current season the leaf area of the white cultivars was higher than that of the yellow cultivars, but the inverse trend was observed in the previous season. In the 2019/20 season, all trials across locations revealed that the second planting date produced the best yields. In the current trial, the data from the trials across the different locations, showed that the first planting date produced the best yield for all sites except NAMPO. While the larger agronomic trial in Bloemfontein as well as the NAMPO trial showed higher yields for the second planting date, which is more in keeping with previous observations and what is expected to be the optimal planting time. These varying results indicate that two seasons' data are not sufficient to understand the full impact of the planting dates in terms of growth and yield.

Through the detailed trial in Bloemfontein, the white maize cultivars generally excelled in reaching greater leaf areas earlier than their yellow maize counter parts. This is completely the opposite of what was reported during the previous growing season (2019/2020). Once again, this shows that no clear conclusions can and/or should be made with only two season's data. This could play a major role in the plants' potential to produce grain. Leaf area measurements of the third and fourth plantings were nearly 30% lower than the first two plantings. This could most probably be ascribed to both the late planting dates as well as waterlogged conditions during the early growth stages as a result of high rainfall following planting. Additional seasons will enable further assessment of the factors affecting yield and grain quality at later planting dates.

The grain quality analysis of the grain harvested in 2019/2020 revealed that the content of fat, fiber, protein and starch vary between planting dates. The third planting date (January 2020) showed slightly elevated levels of fat, protein and fiber, while its starch content was drastically reduced when compared to the earlier planting dates. It will be interesting to see if similar trends are observed in the grains harvested in the current 2020/21 season.

Climate and crop modelling

Data from the ARC Agro-climate Database has been obtained for use in carrying out correlations with maize yields as well as climatic variable trend analysis. The weather data spans 32 years (1986-2018) for nine different locations in the major maize growing regions including sites in Mpumalanga, Free State and North West. The site selection was based on the different Koppen climate zones covered by these South African maize growing regions. The climate data is being prepared for analyses. The climate datasets for the six locations were received for Schweizer-Reneke, Standerton, Lydenburg, Bloemfontein, Bethlehem and Klerksdorp. For the other three locations (Vryburg, Boshof and Koster), the datasets are still in preparation. Initially there were ten locations, however, Rouxville has been removed due to the climate data which has many missing values. The yield datasets have been sourced. The next step is to complete the data curation and begin the analysis.

A literature survey has been conducted to assess the various climate change models and their predictions for South African agriculture. The findings of this survey have been compiled into a manuscript titled: "*The impact of climate change on agricultural production and food security: what does the future hold for South Africa?*". This manuscript is in the process of publication.

From this literature survey of crop models incorporating climate change predictions, it was found that in all cases it is predicted that maize production in South Africa will decrease as climate change progresses. The fate of C3 crops, such as potato and sugar cane, is less clear as there is some debate on whether abiotic stresses like temperature and drought might mitigate any potential gains made in the plants due to the elevated CO_2 levels that are anticipated. Our climate change modelling approach at RCP 4.5 and 8.5 focused on the local changes that might occur in important maize growing regions. We found that in both Bloemfontein and Lichtenberg the summers are likely to get longer with receding frost dates and hotter with an increase in number of days over 35°C. Our findings suggest that it could be possible to avoid the hottest part of the summer and the ill effects associated with late planting dates by making use of the earlier start to summers. However, this would likely only be effective in regions where supplemental irrigation is available. To assess the effect of planting date on the short and medium maturity varieties used in the modelling, a trial was established UP. Interestingly, it was found that an interplay between planting date and environmental factors revealed certain interactions related to in pathogen susceptibility between the two cultivars used in the trial. At the third planting date, the short maturity variety was significantly affected by Northern corn leaf blight which caused significant decrease in biomass and yield.

Conclusion

Despite much of the two years of this project occurring under various stages of lockdown due to COVID-19, this project has progressed well and has successfully completed the second planting season and preparations for the 2021/2022 season are underway. An understanding of how late planting dates can affect plant growth leading to lower biomass is starting to be generated. It was also found that planting date can change yield capabilities of different cultivars and affect the grain quality by decreasing starch content. There are some discrepancies between the 2019/2020 and 2020/2021 seasons likely due to different environmental factors, that will be elucidated as more data is added with each new season. This research provides a clear outline of the current views and data on how climate change is expected to affect maize production in the future.

Project 3: Important pests and pathogens in a changing climate

Research conducted by University of Pretoria

Project leaders: Prof Bernard Slippers and prof Cobus Visagie

Introduction

Climate change predictions suggest increased temperature, more erratic rainfall patterns and elevated atmospheric carbon dioxide levels to occur globally. These changing environmental factors have negative effects for crop production. Firstly, it poses an immediate threat to production. It creates unpredictable growing conditions, posing a threat to overall yield through phenological development issues or losses due pest and disease damage. Secondly, climate change will impact the occurrence of pests and diseases in the future. This will cause previously controlled diseases to re-emerge, pests and pathogens to move into new areas and even cause these organisms to adapt to changing climates. Recent studies have also highlighted the fact that developing countries, particularly those in Sub-Saharan Africa, are extremely vulnerable to pest and disease invasions and that climate change is substantially adding to this threat.

Pest and pathogen occurrence, re-emergence and spread are critical factors to support climate resilience in agriculture. This vital information is lacking in South Africa and since it is ever changing, human and infrastructural capacity needs to be developed to understand and address the present and future effects of pests and diseases under a changing climate.

In order to investigate the present and future effects of climate change on the occurrence of economically important pests and diseases in South Africa, the appropriate structures to support this research initiative firstly needs to be put in place. The aim of this initiative is to establish a collaborative relationship pertaining to grain research (as it relates to climate change), postgraduate training, field extension, pest and disease diagnostics and possible policy engagements. The research projects are conducted under the recently launched Grain Research Programme.

As a first step, diagnostics and extension services was put in place to determine the spread and occurrence of pests and diseases affecting grain crops in South Africa. This information will enable relevant research projects to be identified and conducted. Additionally, limited capacity was available to proactively deal with plant health threats. The establishment of the Grain Research Programme has formed a base from which producer-relevant and scientifically sound research is being conducted. Co-funding has already been obtained to include research topics outside of the scope of climate resilience.

Project aim

Establish a research programme to conduct research into the threat of pests and diseases posed by a changing climate.

Objectives

- Establish a formal Grain Research Programme
- Establish a diagnostic facility to aid with timely and accurate diagnostics of established pests and diseases that pose a significant risk to production
- Identification and launch of research activities

Progress

- Establish a formal Grain Research Programme

The Grain Research Programme was established to 1) increase engagements between grain stakeholders to support industry with research and innovation, 2) promote industry-relevant research, and 3) increase collaboration between local universities, industry and government. The Grain Research Programme was formally launched on 21 August 2020.

Following discussions with stakeholders, the programme's constitution is nearing completion and a Board will be appointed. The constitution was discussed with representatives from industry (Grain SA, SANSOR, Maize Trust and the Oil and Protein Seed development Trust) and government (DSI, DALRRD) during a meeting on 2 July 2021. Inputs made by stakeholders who attended the meeting were incorporated into the constitution and a revised draft is being circulated. A follow up meeting is planned for 19 October to finalise the constitution and board members. A meeting between UP and UFS was held on the 29th of July to discuss the participation of the UFS in the GRP. The meeting was attended by leaders in the GRP, as well as Prof Corli Witthuhn, (Vice-rector: Research, Innovation and Internationalisation, UFS), Prof Danie Vermeulen (Dean: Natural and Agricultural Sciences) as well as senior and junior research staff at both institutions. Engagements are ongoing to increase collaboration between these two institutes. Furthermore, engagements were held with Stellenbosch University and a formal meeting is scheduled with North West University for October 2021.

- Establish a diagnostic facility to aid with timely and accurate diagnostics of established pests and diseases that pose a significant risk to production

During this year, significant effort went into securing the buy-in and the support of the DALRRD. This support is crucial to implement a successful partnership. National plant health is sufficiently covered in many pieces of legislation, including the new Plant Health Bill, NEMBA and many other Acts (Health, Environment). The diagnostic and extension support is a critical aspect of this partnership between industry and government.

The diagnostic clinic will play a crucial role in supporting the Department of Agriculture, Land Reform and Rural Development (DALRRD). The diagnostic facility will provide technical support to DALRRD in terms of diagnostics, facilitating safe trade, quicker identification of new pests and diseases and supporting the official quarantine labs. The Department's support is needed to fast track accreditation of independent laboratories.

To establish a Diagnostics Clinic, a grain health component has been incorporated into FABI's existing Diagnostic Clinic where it provides a free disease/pest diagnostic service to all grain producers in South Africa. (see https://www.fabinet.up.ac.za/index.php/hosted-sites/diagnosticclinicm).

Since the turn of the year, 26 field trips have been completed and a total of 71 farms have been visited from the Eastern Cape, KwaZulu-Natal, Mpumalanga, Limpopo, North West Province, Gauteng and the Free State. Pest larvae were collected on 14 of these field trips, with more than 3500 collections made. These form part of a country wide monitoring programme and several research projects. Disease scoring of foliar and head rots were done on farms from the Eastern Cape and results communicated with farmers. Plant material displaying diseased symptoms were collected and included a total of 2674 samples. These samples were represented by 1566 maize, 57 sorghum, 551 soybean, 178 sunflower and various other samples like soil. Ongoing isolations from collected samples are ongoing, but 1348 fungal cultures have already been isolated, preserved and DNA extracted for these. Strains will be sequenced in the coming months to make correct identifications down to species level. At farms where disease scoring was done, results were communicated in the field to the farmer and formal reports (30 in total) completed. In addition to this, South African maize lines were planted in the Eastern Cape at Lukhanyo farms and the University of Pretoria experimental farm at Hillcrest. These were subsequently surveyed for foliar and ear rot diseases. Currently, nine projects benefit from the work done during extension services and we foresee this number to greatly expand during the upcoming growing season.

- Identification and launch of research activities

The Grain Research Programme is growing well and a total of 21 projects is ongoing. This includes one DSI funded, four DSI co-funded and 16 externally funded projects. External funding bodies includes the DSI-NRF Centre of Excellence in Plant Health Biotechnology and DHET through the New Generation of Academics Programme (nGAP), FLAIR (African Academy of Sciences & the Royal Society via the Global Challenges Research Fund), Innovation Africa @ UP, the Maize Trust, the NRF, the Oil and Protein Seed Development Trust, SANSOR, the SARChI Chair in Fungal Genomics and UNICEF.

2. Develop climate change response plans

Within this objective, progress will be provided for projects 4 – 7:

- **Project 4**: Expanding genetic variability for heat and drought stress and multi-locality hybrid evaluation
    - **Project 5**: Development of new maize lines using chemical mutagenesis
- Establishing long term crop rotation trials
    - **Project 6**: Long-term crop rotation and tillage experiment
    - **Project 7**: Development of region-specific crop rotation programmes for the eastern Free State

Project 4: Expanding genetic variability for heat and drought stress and multi-locality hybrid evaluation

Research conducted by Syngenta

Project leaders: Dr Francois Koekemoer and Mr Roean Wessels

Technicians: Mr Samuel Ndweni & Mr Leonard Sithole

The detailed results for this section are provided in **Appendix 3**.

Introduction

The amount of variability in a breeding program is very important when plant breeding populations are considered, ensuring that superior material is selected in the population improvement process. Broadening variability within a breeding population is achieved by introducing exotic germplasm. During drought stress, plants respond and adapt by the induction of morphological, biochemical and physiological responses. Complex genetic responses are responsible for activating a tolerant or resistant reaction and are greatly influenced by gene-gene, gene-environment and gene-development stage interactions (Banziger and Araus, 2007). Heterosis and stress tolerance can thus only be determined by making test-crosses and evaluating the F1 hybrid or superior F2-material over localities by subjecting the population to the desired stress characteristic and subsequent selection of tolerant and superior genotypes. Incorporating historic and improved OPV's, landraces and wild relatives containing the highest levels of diversity into heat and drought tolerant nurseries is a long-term breeding effort requiring years of backcrossing and selection of superior and adapted material and screening. Most maize breeding programs prioritise their efforts toward developing high-potential hybrids for commercial farmers, planted under optimal growing conditions. The development of adapted climate resilient varieties able to reach maximum yielding potential under sub-optimal smallholder conditions is usually neglected and will be prioritised in this project.

Aim

The project aims to release superior hybrids and OPV's (open pollinated varieties) adapted to high temperature and low rainfall conditions for the smallholder producers in South Africa by increasing genetic gain and variability in adapted South African material.

Approach

This project was established to provide smallholder producers with access to high quality heat and drought tolerant maize varieties. Most maize breeding programs prioritise their efforts toward developing high-potential hybrids for commercial farmers, planted under optimal growing conditions. The development of adapted climate resilient varieties able to reach maximum yield potential under sub-optimal smallholder conditions is usually neglected and is a prioritised in this project.

The breeding process was started with locally adapted material from which test crosses were made. By starting the process with locally adapted material, the timeline from initiating the project to commercialisation of hybrids was significantly reduced. In a conventional approach, activities in years 1-7 revolve around identifying adapted inbred lines for the country in question, performing backcrosses to generate hybrids with desired traits (e.g. adaptability to the environment and heat/drought tolerance). Thereafter, hybrids are selected (years 7-8) and evaluated across multiple localities to evaluate agronomic traits and yield potential (years 9-12). Subsequently, production and marketing (years 13-14) are conducted to introduce new varieties into the market. As hybrids were selected for the project which already contain the desired traits, test crosses were made to introduce desired traits into locally adapted germplasm and multi-locality testing is in progress. During the preceding three years, significant effort was made to expand genetic variability within the breeding programme and therefore a sub-project was initiated to use chemical mutagenesis (CM) to further expand genetic variability. Lines from this programme will feed into the maize breeding efforts. We expect that within the next three years, five new hybrids will be developed with increased resilience to drought and heat stress and production research conducted on the developed hybrids.

Objectives

The objectives for the reporting period are provided below whilst the full list of objectives of the project can be found in appendix 3.

Year 3 (2020-2021)

- Advancement of phase 1 (2019) and 2 (2018) test hybrids.
- Field evaluation and maintenance of chemical mutagenesis breeding lines (produced as part of Project 5).
- Parental seed increases of promising test-hybrids.
- Small-scale productions and production research of promising test-hybrids.

Progress

- Advancement of phase 1 (2019) and 2 (2018) test hybrids.

A total of forty-eight (48) entries were selected based on yield and agronomical performance for advancement to phase 3 trials and eight to phase 2 evaluation (Refer to Appendix 3 – attached).

The phase 3 trial entries are in the final cycle of agronomical, yield and stability evaluation. The 2019 phase 2 and 2018 phase 3 test-hybrids were evaluated under small holder production practices in the major small holder represented maize areas including, Groblersdal (Limpopo), Carolina (Mpumalanga), Elliot and Ugie (Eastern Cape).

- Field evaluation and maintenance of Chemical Mutagenesis (CM) breeding lines.

A total of 123 inbred lines were multiplied at the Bethlehem research facility where after 400 seeds were submitted to the Cereals Genomics Department of Stellenbosch University (SU) in June 2020. These lines were subjected to chemical mutagenesis to induce mutations for heat and drought tolerance and returned to Syngenta in December 2020. The subjected lines did not germinate and a second batch of seed were then subjected to chemical exposure of which 43 entries survived and are being increased at the SU facilities. Depending on progress and success rate of CM project, the mutant lines produced by SU will be subjected to field screening in Bethlehem in the 2021 season for heat and drought tolerance. Maintenance of these lines will be conducted during the evaluation process. Four to five inbred populations will be developed by means of doubled haploid (DH) technology. DH technology offers the fastest and cost-effective route to produce homozygous lines for maize breeding programs.

- Parental seed increases of promising test-hybrids.

Parental components and test hybrids were produced at the Bethlehem research facility (Appendix 3). Parental lines were maintained and increased. Producibility was determined on test hybrids. Due to continued rain during the flowering period hand pollinations were limited with poor seed set.

- Small-scale productions and production research of promising test-hybrids.

Two trials were planted over four localities (Groblersdal, Elliot, Ugie and Carolina) to evaluate 56 test-hybrids (Table 1, Appendix 3). Trial localities were extended to Eastern Cape in the 2020/21 production season (Appendix 3). Eight local checks, representing the WEMA project hybrids and major role players in conventional maize breeding, were included in the trials. One insect and herbicide tolerant stacked hybrid (DKC78-79BR) was also included.

Test-hybrids showed promising results in the field trials. Three of the trials are progressing well, unfortunately, the trial in Elliot suffered from poor germination due to flooding before and during germination. In addition, the trial was subjected to frost during flowering in March and April which led to the trial being discarded. Disease ratings were obtained in the Eastern Cape trials for Rust (*Puccinia sorghi*), Grey Leaf Spot (GLS) (*Cercospora zeina*) and Phaeosphaeria Leaf Spot (PLS, *Phaeosphaeria maydis*).

Conclusion

Current breeding and crossing nurseries will ensure a breeding pipeline with a continuous supply of new inbred and test-hybrid material. The diversity of germplasm in this program is expanding and will reach a high as soon as the CM lines are in a homozygous state and ready for use in crossing combinations. Including more lines in the genetic study will result in a better understanding of heterotic groups and genes available for heat and drought tolerance. Parental seed increases for superior test hybrids suffered a minor set-back during the Bethlehem research facility due to continued rains limiting pollinations and ultimately leading to poor seed set. Test-hybrids shows good yielding capability under drought and heat conditions but are also able to compete with commercial varieties under normal high potential conditions. Nine hybrids are being evaluated and increased of which five will be commercialised.

Project 5: Development of new maize lines using chemical mutagenesis

Research conducted by Stellenbosch University

Project leader: Prof Anna-Maria Botha-Oberholster

The detailed results for this section are provided in **Appendix 4**.

Introduction

The maize genome has undergone several rounds of genome duplication, including that of a paleopolyploid ancestor ~70 million years ago (mya) and an additional whole-genome duplication event about 5 to 12 mya, which distinguishes maize from its closest relative, *Sorghum bicolor*. The 10 chromosomes of the maize genome are structurally diverse and have undergone dynamic changes in chromatin composition. Maize is considered to be an ancient allotetraploid with regions of the genome present in duplicate copy. As a result, the mutant phenotypes of some genes are not visible unless both copies are mutated. For other genes, one of the duplicate copies is often missing or the two copies have sub-functionalized. Also, as with many other domesticated crops species, maize also experience positive selection and genetic bottlenecks limiting diversity in its genome. Chemical mutagenesis, using certain chemicals such as ethyl methane sulfonate (EMS), allows for the random conversion of single nucleotide bases resulting in increased genetic diversity but still maintaining most of the beneficial traits of commercial lines. Thus, to develop new lines alternative strategies for the development of inbred lines are required, hence the aim to develop new inbred lines making use of chemical mutagenesis.

Project aim

The aim of the research is to develop new genetic resources for maize inbred lines specifically for use by African smallholder farmers. The maize germplasm (i.e. high yielding maize inbred lines) will have improved resilience to climate variability.

Objectives

1. Compare the efficacy of different chemical mutagens to induce mutations in *Zea mays* seed.
2. Phenotyping of the M1 mutants in the greenhouse.
3. Phenotyping of the M2 mutants in the field.
4. Functional characterisation of high yielding M3 mutants expressing enhanced resilience to environmental stressors. This will be done using LC-MS/MS proteome analysis as well as expression analysis.

Approach

Different chemical mutagens were tested to identify the most efficient chemical mutagen to induce mutations in maize seed. Thereafter, the mutants will be screened to identify those with enhanced resilience to environmental stressors, through screening in both glasshouse (conducted at Stellenbosch University) and field (conducted by Syngenta, see Project 4) conditions. Proteomes of promising lines will be characterised.

Progress

1. *Compare the efficacy of different chemical mutagens to induce mutations in Zea mays seed. (Completed)*

In a preliminary study, seed was treated with only buffer or buffer containing different concentrations of EMS (i.e., 0.1%, 0.5%, 1.0% v/v) at different exposure times (i.e., 2h, 4h and 8h), respectively. It was found that treatments below 1% EMS (i.e., exposure to 0.1% or 0.5% EMS for 2h, 4h or 8h, respectively), described in **Appendix 4**, had no effect on germination or plant growth. Thus, another set of experiments were then conducted with increased EMS concentrations (i.e., 1%, 2% or 5% EMS for 2h, 4h or 8h, respectively), and it was found that EMS concentrations at 1% for 2h or 2% for 1h produced the best results, as measured on germination rate and plant growth.

2. *Phenotyping of the M1 mutants in the greenhouse (in progress)*

In December 2020, an additional 900 seeds (representing 15 CMN-USB-SNK20 entries) were treated with 1% EMS and of these, 70 CM lines were obtained from three entries. Of the entries in the trial, CMN-USB-SNK20 ENTRY 8 performed best in terms of ear and seed production. This entry produced 51 CM lines, while only 2 CM lines were produced from CMN-USB-SNK20 ENTRY 88 and 17 CM lines from CMN-USB-SNK20 ENTRY 96. Unfortunately, while CMN-USB-SNK20 ENTRY 32 produced ears and cobs, seed were lost during maturation due to fungal infection. The latter experiment will be repeated to ensure that CMN-USB-SNK20 ENTRY 32 material is available for field trials. The visible quality (as measured in size and weight) of the seed varied significantly ($P < 0.01$), with the best performer being CMN-USB-SNK20 ENTRY 8 (average seed weight = 0.28 g ± 0.08) and the poorest performer being CMN-USB-SNK20 ENTRY 96 (average seed weight = 0.09 g ± 0.01). Currently, multiplication of seed from the newly developed 70 mutant lines are in process to enable planting by Syngenta during the 2021 season. Due to seasonal growth cycles, the material may only be available for planting in Malelane early in 2022.

3. *Phenotyping of the M2 mutants in the field (not started)*

This activity can only start when sufficient M2/M3 mutants are obtained after treatment with chemical mutagens. The phenotyping of M2/M3 plants were initiated in the greenhouse. Once more seed are available, they will be delivered to the industry partner for field trials.

4. *Functional characterisation of high yielding M3 mutants expressing enhanced resilience to environmental stressors. This will be done using LC-MS/MS proteome analysis as well as expression analysis (not started)*

This activity can only start when sufficient M2/M3 mutants are obtained after treatment with chemical mutagens.

Conclusion

Chemical mutagenesis provides a unique opportunity to introduce new agronomic attributes (e.g. drought tolerance) through selection into breeding material within a relatively short timeframe (i.e. 3 years). The project was delayed due to the national lockdown, but progress was subsequently made. The most effective mutagen has been identified and testing of M1 mutants in the greenhouse is in progress. Of the 15 entries induced with the mutagen, 3 entries produced viable seed which were subjected to phenotypic screening. These three entries produced 70 CM lines which will be screened, multiplied and provided to Syngenta for field trials.

We are excited to share the exciting news that this project received funding from the National research Foundation, which will be used to fund all future activities.

Project 6: Long-term crop rotation and tillage

Research conducted by the University of the Free State

Project leader: Dr Gert Ceronio

Introduction

Crop rotation trials forms the basis of building resilient production systems. The complex nature of agriculture means that application of building resilience systems is not a *one size fits all* solution, but rather that these trials need to be region-specific and long-term. The advantages of crop rotation have been known for centuries; these include to help build up soil diversity and fertility levels enabling these systems to buffer against variable environmental conditions. Furthermore, it has been shown to manage weeds, pest and disease pressure through the careful selection of specific cropping sequences. Climate change and variability is putting immense strain on producers' profitability, particularly for subsistence and emerging commercial producers, and thus challenging the food and nutrition security status of South Africa. Through crop rotation, complex interactions between production and the environment can be elucidated to build resilient production systems.

In South Africa, the Western Cape Department of Agriculture has set a golden standard in terms of the value of long-term trials. However, long-term crop rotation and tillage trials are severely lacking for the summer grain production region. Therefore, this project was initiated to develop long-term crop rotation trials in the summer grain production regions to enable building of resilient production systems.

Project aim

This study aims to investigate crop response to different crop sequences (rotations) and tillage practices with and without a cover crop.

Approach

Two long-term crop rotation trials will be established. The first will be a long-term trial established as part of an Agronomy Hub. The target here is to develop a hub for research and training at the University of the Free State. Therefore, a crop rotation trial has been established at the Kenilworth Field Research Facility, north-west of Bloemfontein. This initiative will investigate crop response to different crop sequences (rotations) and tillage practices with and without a cover crop in a low-rainfall, high-risk region. The trial layout will consist of different crop rotation systems and the inclusion of a cover crop treatment. Crops will include grain and oilseed crops suitable to that region as well as investigating cover crops. Special focus will be on evaluating soil water content, biological, physical and chemical responses as well as the economic viability of sustainable cropping systems. The Agronomy Hub will aim to deliver research outputs and expertise that is targeted to the industry.

The second is conducted in partnership with Potato SA (project 7), consisting of four five-year crop rotation systems was initiated in the Eastern Free State during the 2015/16 summer cropping season. Crops within the rotation system includes maize, potatoes, sugar beans, soybean, sunflower and teff.

Objectives

1. Evaluation of soil water content and risk management (improvement of SWAMP model).
2. Evaluation of soil biological, chemical and physical response to the treatment combinations.
3. Evaluation of weed population dynamics of the different systems.
4. Evaluation of disease and insect response.
5. Evaluation of crop yield and quality response.
6. Economic analysis of/and recommendation of economic sustainable systems.

Progress

This has been the first year of this trial. Yield data from the trial will be reported in this progress report as further data analyses is still ongoing. System 2 (Figure 1) includes wheat plots which were planted in the winter period and is yet to be harvested for this season. Therefore, only the yield data of the summer grain and oilseed crops as well as the cover crop will be presented here.

		2020/21	2021/22	2022/23	2023/24	2024/25
Conventional	System 2	1-Maize	Sunflower	Wheat	Fallow	Maize
		2-Fallow	Maize	Sunflower	Wheat	Fallow
		3-Wheat	Fallow	Maize	Sunflower	Wheat
		4-Sunflower	Wheat	Fallow	Maize	Sunflower
	System 1	5-Maize-9	Maize	Maize	Maize	Maize
		6-Maize-36	Maize	Maize	Maize	Maize
		7-Maize-18	Maize	Maize	Maize	Maize
		8-Maize-27	Maize	Maize	Maize	Maize
	System 3	9-Soya bean	Cover crop	Soya bean	Sunflower	Maize
		10-Maize	Maize	Cover crop	Soya bean	Sunflower
		11-Sunflower	Sunflower	Maize	Cover crop	Soya bean
		12-Cover crop	Soya bean	Sunflower	Maize	Cover crop
No-till	System 2	13-Maize	Sunflower	Wheat	Fallow	Maize
		14-Fallow	Maize	Sunflower	Wheat	Fallow
		15-Wheat	Fallow	Maize	Sunflower	Wheat
		16-Sunflower	Wheat	Fallow	Maize	Sunflower
	System 3	17-Soya bean	Cover crop	Soya bean	Sunflower	Maize
		18-Maize	Maize	Cover crop	Soya bean	Sunflower
		19-Sunflower	Sunflower	Maize	Cover crop	Soya bean
		20-Cover crop	Soya bean	Sunflower	Maize	Cover crop
	System 1	21-Maize-36	Maize	Maize	Maize	Maize
		22-Maize-9	Maize	Maize	Maize	Maize
		23-Maize-18	Maize	Maize	Maize	Maize
		24-Maize-27	Maize	Maize	Maize	Maize

Figure 1:A representation of one block (replication) indication the treatment combinations as well as the sequence of the following five (5) years.

Results and discussion from year 1

Rainfall

The total rainfall for the summer growing season 2020/21 from November to April was 723 mm. For the period 15-01-2021 to 27-01-2021 a total of 170 mm of rain was received.

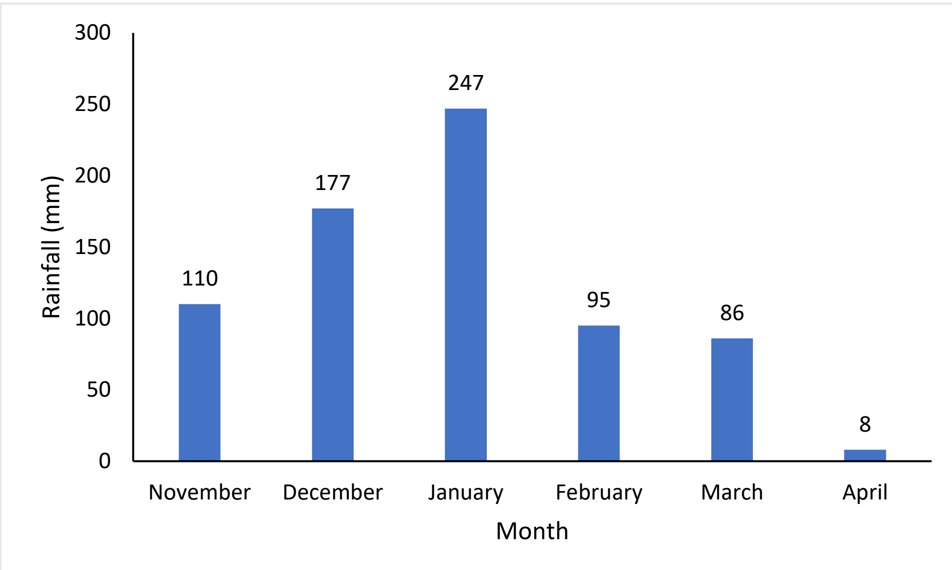

Figure 2. Rainfall data for the period November 2020 to April 2021

Yield data

Only yield data of the harvested crops will be presented and discussed since the first cycle of the experiment will only be completed by the end of November 2021 following harvesting of wheat. Unfortunately, guinea-fowls caused extensive damage to the six wheat plots. This is mainly the consequence of wheat being the only green material in the entire area and following a season with extremely high rainfall, the guinea-fowl population increased beyond expectation. These animals dug out the emerging seedlings as well as destroyed that what remained thereafter. Therefore, the stand is poor and extremely low and no wheat yields are unfortunately expected. In subsequent years, efforts will be made to protect the crop against damage.

Maize, sunflower, soybean (grain) and cover crop (biomass) yields (Table 3) varied to some extent for the different treatments. This variation cannot solely be attributed to the treatments *per se*. The greater picture of establishing the trial during the first season should be the focus of this exercise. With this in mind, the following was observed: Comparing the average maize yield, that is of all maize plots, of the conventional tilled plots (3 437 kg ha-1) to that of the no-tilled plots

(3 847 kg ha-1) the no-till plots yielded on average 410 kg ha-1 (12% increase) more than that of the conventional plots.

Table 3. The effect of tillage and crop rotation systems on the yield (kg ha^{-1}) of field crops

Tillage system	Rotation system	Crop sequence	Yield (kg ha^{-1})
Conventional	1	Maize (9 000 plant ha^{-1})	2928
		Maize (18 000 plant ha^{-1})	2738
		Maize (27 000 plant ha^{-1})	3324
		Maize (36 000 plant ha^{-1})	3000
	2	Maize	3642
		Fallow	-
		Wheat	-
		Sunflower	1855
	3	Soybean	867
		Maize	4367
		Sunflower	1417
		Cover crop	1340
Conventional	1	Maize (9 000 plant ha^{-1})	3180
		Maize (18 000 plant ha^{-1})	3517
		Maize (27 000 plant ha^{-1})	3867
		Maize (36 000 plant ha^{-1})	4167
	2	Maize	4597
		Fallow	-
		Wheat	-
		Sunflower	1361
	3	Soybean	741
		Maize	3756
		Sunflower	1830
		Cover crop	3320

Comparing all maize plots, including those with different plant densities of the conventional tilled plots the greatest yield (4 367 kg ha^{-1}) was obtained with rotation system 3 (Table 3). For the no-till maize plots the greatest yield (4 597 kg ha^{-1}) was obtained for crop rotation system 2. Inspection of the different planting densities of the conventional tilled system showed that 27 000 plants ha^{-1} yielded 3 324 kg maize per hectare (Table 3). This was 300 kg ha^{-1} more than that of 36 000 plants per hectare (3 007 kg ha^{-1}) and 600 kg ha^{-1} more compared to that obtained with 18 00 plans per hectare. For the no-tilled system a near linear increase from 3 180 kg ha^{-1} for the 9 000 plants per hectare to 4167 kg ha^{-1} for 36 000 plants per hectare was found. Sunflower yields of the conventional tilled plots (1 636 kg ha^{-1}) were nearly 80 kg ha^{-1} greater than that of the no-tilled plots (1 560 kg ha^{-1}). For the conventional tilled plots, the late planted sunflower yielded approximately 400 kg ha^{-1} more than the early plantings. For the no-tilled plots the inverse was observed with the late sunflower planting yielding nearly 500 kg ha^{-1} less than the early planting. Soybean showed no significant difference in yields for the conventional and no-tilled systems (Table 3).

Conclusion

In general, the 2020/21 growing season was completed successfully. Variation in the different replications were high which is expected in a newly established experiment. However, the exceptional high precipitation of 247 mm in January and especially the period 15-01-2021 to 27-01-2021 where a total of 170 mm of rain was received resulted in waterlogged conditions and all crops generally showed typical nitrogen deficiency symptoms. Although additional nitrogen, to the equivalent of 28 kg ha^{-1}, was applied to all plots the plants did not recover fully and this was clearly observed from the yields obtained which were less than the initial set potential yields with the exception of the early sunflower plantings.

Project 7: Development of region-specific crop rotation programmes for the Eastern Free State

Research project is in collaboration with Potato South Africa and conducted by the University of Pretoria

Project leaders: Prof Martin Steyn and Prof Jacquie van der Waals

Detailed results are provided in **Appendix 5**.

Introduction

The drive towards a food secure future has prompted research into climate resilient cropping systems that will stand the test of time, be sustainable and equally equitable to the farmer. Among these proposed cropping systems is crop rotation, an age-old practice that was initially introduced as an attempt to attain sustainable agriculture. Ideal or effective crop rotation systems coupled with optimal tillage practices have been reported to significantly improve soil health properties, such as soil fertility levels and control of weeds, pests and diseases. Moreover, the extent of these improvements has been suggested to depend on the specific crops within the crop rotation sequence, the order in which they are grown seasonally and other location-dependent factors, i.e., ecosystem interactions and the prevailing climate and soil conditions. These findings suggest that certain crop rotation systems are more suited to particular locations. As a result, the use of crop rotation to enhance profitability and reduce disease and financial risk of grain crops has lately received renewed interest in the eastern Free State. The long-term objective of this study is to optimise crop rotation systems for grain crop production in the Eastern Free State in order to improve soil health, soil physical and chemical conditions and profitability of dryland grain crop production in the region. Furthermore, the long-term trial also offers the ideal opportunity for additional secondary studies, such as to assess the effect of different crop rotation systems and sclerotia burial depth on the survival, viability and germination of *Sclerotinia sclerotiorum* survival structures called sclerotia (which is part of the Plant Health Consortium and funded by the Department of Science and Innovation).

Project aim

To optimise crop rotation systems for potato and summer grain crop production in the Eastern Free State in order to improve soil health, soil physical and chemical conditions and profitability of dryland potato and summer grain production in the region.

Objectives

The long-term objective of the study is to optimise crop rotation systems for potato production in the Eastern Free State in order to improve:

- soil health,
- soil physical and chemical conditions and
- profitability of dry land potato production in the region

Approach

The long-term crop rotation trial was initiated in the Petrus Steyn district of the eastern Free State during the 2014/15 summer cropping season and consists of four five-year crop rotation systems (Table 4). Each of these treatments are replicated eight times, giving a total of 32 plots which are 766.85 m2 (35 m x 21.91 m) in size each. Potatoes were followed by maize on all plots in 2016/17 (Year 1), when the soil physical, chemical and microbial observations commenced. The second year rotation crops were planted in 2017/18 and the 2018/19 summer growing season was year 3 of the 5-year rotation. The 2019/20 growing season consisted of a fallow period for all four the crop rotation systems under investigation. The 2020/21 season representing the fifth and final year of the crop rotation cycle was grown to potatoes across all the crop rotation treatments. During each season, soil physical, chemical and microbial observations are made.

Table 4: Crop rotation treatments in the long-term eastern Free State trial.

Year	Growing season	Rotation system number			
		1	2	3	4
0	2015/16	Potatoes	Potatoes	Potatoes	Potatoes
1	2016/17	Maize	Maize	Maize	Maize
2	2017/18	Maize	Sugar beans	Soybeans	Sunflower
3	2018/19	Teff	Maize	Maize	Maize
4	2019/20	Fallow	Fallow	Fallow	Fallow
5	2020/21	Potatoes	Potatoes	Potatoes	Potatoes

Progress

An update on the results from the 2019/20 and 2020/21 seasons will be presented here. The 2020/21 season marked the end of the first 5-year cycle of the trial and the second cycle will begin in the upcoming season. Data analyses for certain parameters from the 2020/21 season is still ongoing such as yield and soil biological properties.

The soil environment seemed to stabilise in the 2020/21 season, grown to potatoes across all treatments. There were no significant differences to report in most of the soil physicochemical properties assessed this season. It was, however, interesting to note that, for the better part, a similar trend persisted between the 2019/20 and 2020/21 season with the nutrient concentrations in the different crop rotation treatments. The soil biological assessments from the soil collected at harvest is still being analysed. Coupled with the disease severity data and potato yields, it is envisaged to generate a preliminary overview of the long-term trial in terms soil health improvements resulting from the individual crop rotation sequences being studied.

Physicochemical factors

From the soil chemical analyses done at the end of the 2019/20 fallow period, some significant treatment effects were observed. However, some of these effects seemed to have been cancelled out in the following 2020/21 season, since there were generally no significant differences between treatment means for the various soil chemical properties analysed, regardless of sampling depth. It was, however, observed that there were a few outliers from the data presented in this report (see appendix 5). Various reasons can be attributed to this, unfortunately since this is still only the first full rotation cycle, there are not any obvious reasons for these inconsistent results. We do expect this to change in the coming future, since literature clearly suggests that positive changes in soil health can take up to 15 years to realise.

The pH between the two seasons ranged between 5.0 and 6.0, which translates to strongly acidic (5.1-5.5) and moderately acidic (5.6-6.0) (Foth and Ellis 1997), which led to the assumption that there were no nutrient elements that were toxic or unavailable in any of the treatments as a result of the soil pH levels. It will be interesting to assess the final findings after most of the biological analyses are completed from soil collected at the end of the 2020/21 season. This may paint a better picture of the influence of soil pH and soil organic matter (SOM) content on the selected biological indicators that will be assessed. Since soil biological indicators are regarded as the most sensitive soil health indicators, we t expect to provide more feedback once these results are available and a better angle on which crop rotation sequence seems to at least provide some form of soil health improvement after the full crop rotation cycle.

Regarding soil organic matter (SOM) content, there were no significant differences ($P < 0.05$) between the crop rotation treatments in the 2019/20 nor the 2020/21 season. A similar trend was observed between the 2019/20 and 2020/21 seasons, where the ROT1 and ROT2 treatments (Table 4) recorded relatively higher SOM content compared to the other treatments. It is interesting to note that this trend was observed in the top 0-15 cm of the soil in the 2019/20 season, whereas it was observed in the deeper depths of 25-50 cm in the 2020/21 season. This could possibly be attributed to cultivation practices, which through soil disturbance may have caused inconsistent concentrations of SOM across the soil profile of the different crop rotation treatments. It has been suggested that continuous tillage results in the break-up and re-distribution of aggregates and fresh organic matter added to the plough layer, in addition to accelerating SOM decomposition through microbial attack (Grandy and Robertson 2007, Moebius-Clune et al. 2011, Shah et al. 2017). This could possibly explain the inconsistent SOM content across seasons even though residue retention is practiced.

The 2020/21 season resulted in the improved contents of both nitrate- and ammonium-N content across all treatments compared to the respective content recorded in the 2019/2020 season. A simple explanation for this could be that in the 2020/2021 season, fertilisers were applied to the potato crop grown next in line in the rotation, while for the 2019/2020 season, no fertilisers were applied since this was the fallow season. There were however no significant differences in these residual N contents between the various crop rotation treatments and there did not seem to be any trend worth reporting from the results recorded.

There were no significant differences in Phosphorous levels in the 2020/21 season between treatments because of the characteristic immobile trait of P in the soil. It is also worth mentioning, however, that the mean P concentration seemed to occupy the same range in all treatments in the 2020/21 season, relative to the 2019/20 season, further emphasizing the immobile nature of P in the soil.

Some of the soil chemical properties were not significantly influenced by crop rotation treatments in our eastern Free State long-term study after the 2019/20 season. This was demonstrated by statistically similar levels of Cu and Zn in the different crop rotation treatments. The various concentrations of micronutrients in the different crop rotation treatments are not regarded as a problem in cropping systems because with the pH being below 6.5, deficiencies for any crop are unlikely if adequate fertilisation is applied (Horneck et al. 2011, Murphy and Hazelton 2016).

All the micronutrient content levels tended to stabilize in time (2020/21 season) and as a result, no significant differences were recorded between treatments. It is still difficult to provide a possible reason for this outcome since all the micronutrients stabilized more or less about the same mean for each indicator assessed, regardless of the depth.

There were no significant changes in bulk density (BD) across the soil profile in the first five years of the crop rotation study, it is therefore assumed that the crops grown in rotation did not have a major effect on the BD. At deeper depths however, bulk density seemed to get higher and as a result the penetration resistance was also higher, as was recorded by the penetrometer readings. What was interesting to note was a spike in penetration resistance readings around the 5-7 cm depth, which could suggest a hard layer around that region across the field. This may be due to several factors, the most obvious being traffic from heavy machinery during mid-season activities (e.g., fertilisation). There was not much to separate the four treatments in terms of penetration resistance deeper into the soil profile since the penetration resistance followed the same pattern. Similarly, it is proposed that it may still be too early to observe significant changes in soil physical properties over a five-year period and with one rotation cycle just completed, especially since the same tillage practices are followed for the entire trial.

Conclusion

The soil environment seemed to stabilise in the 2020/21 season, grown to potatoes across all treatments. There were no significant differences to report in most of the soil physicochemical properties assessed in this season. It was however interesting to note, for the better part, that a similar trend persisted between the 2019/20 and 2020/21 seasons with the nutrient concentrations in the different crop rotation treatments. Biological assessments still need to be conducted from the soil collected at harvest. Coupled with the disease severity data and potato yields, we hope to generate a preliminary overview of the long-term trial in terms of soil health improvements resulting from the individual crop rotation sequences being studied.

DELIVERABLES

Deliverable	Update
Knowledge on the impact of climate change and variability on grain production.	- The assessment of climate risks for producers has been completed and the final report is attached in appendix 1. This project focussed on working closely with producers and provided information directly to the producers who participated. Following from this, further information sheets have been developed to share with all producers through digital and print media. - The study on the maize planting window is progressing well. All three detailed trial sites have been established for the second season. The on-farm trial has moved from Ottosdal to Coligny and a demonstration trial established at NAMPO. Data was collected for the 2019/20 season and data analysis is in progress. Furthermore, there is an article on the crop modelling that is being prepared for publication.
Maize hybrids developed with increased resilience to drought and heat stress	- Test-hybrids show good yielding capability under drought and heat conditions but are also able to compete with commercial varieties under normal high potential conditions. Trials were expanded to the Eastern Cape during the 2020/21 season. - The use of chemical mutagenesis to support expansion of genetic variability has produced several promising M1 mutants that are being screened.
Establishment of long-term crop rotation trials	- The long-term crop rotation trial has been established at the University of the Free State. This is an important step in building resilient production systems. Yield data is provided in this report as further data analyses of the first season is ongoing - The first full cycle of the crop rotation trial in collaboration with Potato SA has been harvested and final data analyses is ongoing. Results from the 2019/20 and 2020/21 seasons have been provided. Planning for the upcoming season is underway. This work is being conducted by the University of Pretoria.

CONCLUSION

The Climate Resilience Consortium has been funded by the Department of Science and Innovation (DSI) in partnership with the Technology Innovation Agency (TIA) through the Agricultural Bio-economy Innovation Partnership Programme (ABIPP) since 2017. The Consortium was subsequently co-funded by the Maize Trust since 2018. As such, research projects are formulated to address national priorities which are aligned between government and industry. Since inception, the Consortium has grown to strengthen current projects and address needs identified from all grain producers.

The consortium is progressing well. A key highlight is the climate risk study coming to an end. This project focused on developing knowledge through engaging with producers in study groups and incorporating climate data into the discussions. These were smaller focused study groups and the information developed within this study will be shared with all producers.

The overarching goal of the Climate Resilience Consortium is to investigate the effects of climate change (such as increased heat and erratic rainfall) on production in South Africa and explore strategies for adaptation. Special focus areas of this consortium are to build resilience of smallholder producers in South Africa, as well as to strengthen available capacity to address industry's climate-associated research needs.

FUNDING

A total amount of R5 500 000 is available for this consortium from two main funding institutions: namely, the Maize Trust (R3 000 000) and the Department of Science and Innovation (R2 500 000). Although all projects (whether funded by the Maize Trust or DSI) are reported on, only payments made with the Maize Trust money are indicated in this section.

Grain SA received R2 100 000 from the original R3 000 000 that was approved from the Maize Trust. There was a small discrepancy from the amounts received and Grain SA constrained spending until the discrepancy was resolved.

Actual Year to Date 31 August 2021

MAIZE Climate Resilience

Description	**Actual Year to Date 31 August 2021**		**Approved Budget 20/21**		**Remaining**
Income	-	2 100 000,00	-	3 000 000,00	900 000,00
Expenditure		836 766,00		3 000 000,00	- 2 163 234,00
Net Amount	**-**	**1 263 234,00**		**-**	**- 1 263 234,00**

Although the table above indicates the actual figures till end Aug the estimated figures till end of September are indicated below. From the R2 100 000 received an amount of R 1 820 717 was allocated towards research projects. These figures has not yet been verified by Grain SA's Financial Department, it will be communicated after Grain SA's year-end.

Estimated Summary of Expenditure as estimated till end of September 2021

MAIZE Climate Resilience						
Description	**Actual Year to Date**		**Approved Budget 20/21**		**Remaining**	
Income	-	2 100 000,00	-	3 000 000,00		900 000,00
Expenditure		1 820 717,00*		3 000 000,00	-	1 179 283,00
Net Amount	**-**	**279 283,00**		**-**	**-**	**279 283,00**

*Estimated spending as till end of Sept 2021

The table below shows a summary of the payments Grain SA made towards projects. Annually, contracts are signed between Grain SA and the various research institutions.

Climate Resilience (Expenses)	**Project (R)**
The effects of a changing environment and late-planting dates on maize plants development and yield in South Africa (Year 3) - 4 localities	R233 951
	R310 450
	R526 316
Development of region-specific crop rotation programmes for the Eastern Free State	R150 000
Long-term crop rotation and tillage	R600 000
Total expenses to date	**R1 820 717**