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Sorghum Cluster INITIATIVE

Progress Report

SORGHUM CLUSTER INITIATIVE

EVALUATION OF EXOTIC GERMPLASM AS A PRECURSOR TO SORGHUM PRE-BREEDING

June 2024

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EVALUATION OF EXOTIC GERMPLASM AS A PRECURSOR TO SORGHUM PRE-BREEDING

Research conducted by UFS, UKZN, Sorgho
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Other Collaborating institutions: ICRISAT, ARC-SG

1. INTRODUCTION AND BACKGROUND

Although sorghum only represents 1% of the total summer crop output of South Africa, it is the fourth largest summer crop in South Africa and the fifth most important crop worldwide. Sorghum is seen as a local staple in South Africa, and approximately 91% of the sorghum produced is used for human consumption. Yet South Africa's sorghum production has decreased dramatically over the last 30 years. An all-time low was reached in the 2017/18 production season, while production area decreased to 37 000 hectares in the 2021/22 season. Limited pre-breeding and breeding have led to low growth of sorghum yield potential. Due to the lack of sorghum genetic improvement in South Africa, commercial sorghum producers have been planting the same cultivars for more than 20 years. Only one company (Sorgho [Pty] Ltd) is actively breeding and maintaining elite lines and sorghum hybrids in South Africa. The ARC-Grain Crops has an aged germplasm bank of open-pollinated varieties (OPVs), with minimal breeding activities. The other seed companies in South Africa source and screen international hybrids to find suitable hybrids for the country's unique climate conditions. Therefore, South Africa urgently needs dedicated sorghum breeding to revive the sorghum production and commercialisation in the country.

2. PROJECT OVERVIEW

Aim The long-term aim of this initiative is to establish a sustainable pipeline of high-performing sorghum hybrids bred under local conditions for all producers. These high-performing hybrids will mainly be bred for higher yield, better disease resistance and better quality for the processing sector.

Objectives

Phase 1 – to be executed by UFS, UKZN and Sorgho

- Investigating current pre-breeding activities (including pre-breeding capacity) and sorghum related research.
- **Progress in quarter 1 (recap from first report)**

- Kwame Shamuyarira (UFS) has completed this report, which was reviewed by all team

members and which will be disseminated to industrial role players.

- Initiate pre-breeding activities: sourcing of germplasm for screening and line development, and multiplication of this material. Screening for drought and heat tolerance, disease and insect resistance (all aimed at maximizing yield) and quality characteristics. The breeding program can already test the best of these lines in hybrid development to save time.

Progress in quarter 1 (recap from first report)

- The 169 sorghum genotypes obtained from Prof. Shimelis Hussein (UKZN), including accessions from the US Department of Agriculture, Ethiopia, ICRISAT, Agricultural Research Council Grain Crops, Plant Genetic Resources SA, Malawi and Mexico were planted at the UFS in the greenhouse, and 120 accessions with sufficient seeds were planted in the field in a replicated trial. The same 169 accessions were planted in a net house at Ukulinga farm at UKZN in Pietermaritzburg in a replicated field trial. All entries at UKZN and UFS were planted in 5 m single rows.
- Partners met at UKZN on Wednesday, 6 March, to see the field trial and to discuss progress and challenges. The UFS team also visited the Sorgho program close to Krugersdorp late in February. The team met again on Wednesday, 13 March in Bloemfontein, when they visited the trials in the greenhouse and field and had discussions.
- Dr. Shamuyarira arranged meetings with Dr. Tesfaye Tesso (Purdue University), Dr. Ramasamy Perumal (Kansas State University), Dr. Bright Jumbo (ICRISAT, Mali), Dr. Janila Pasupuleti (ICRISAT, India), and Dr. Rod Snowdown (sorghum breeder, Giessen University), which have been very informative. They have all offered to collaborate with us, and we are following up on this.
- A sorghum breeder from IIAM in Mozambique (Sheila Juma, 2024913333) has also joined the UFS as a PhD student. She will be studying carotenoids in sorghum, their expression and effects in sorghum, as well as their heritability.
- Two South African students, one MSc (Karabo Pule, 2016423275) and one PhD (Sisipho Platyi, 2015235431) has also joined the team at UFS (Sisipho will register for her PhD in July. Karabo will investigate sorghum seed colour, how it is inherited and how it relates to morphological and nutritional characteristics of sorghum. Sisipho will do phenomics in sorghum for both morphological and nutritional traits. He is also appointed as a research assistant in the program
- UKZN has enrolled two postgrdaute candidates - Asande Ngidi (MSc Plant Breeding, Student No. 218013830) and BL Zabuloni (PhD Crop Science, 219076497).

Progress from March to end of May 2024 (quarter 2)

- Morphological data were obtained from the two field trials and harvesting is currently underway. The greenhouse trial at the UFS has already been harvested, and threshing is underway.
- A trial of the same material (the original 169 accessions) was planted in March in the Lowveld for the winter season by Sorgho (Elize Botha)
- The same 169 entries were planted out for DNA fingerprinting, and primers have been ordered for microsatellite (SSR) analysis to determined genetic relationships within the germplasm (part of the MSc project of Karabo Pule).
- The pre-breeding team visited Namibia's Ministry of Agriculture, Water and Land Reform sorghum research team at the Mannheim Crop Research Station situated on the outskirts of Tsumeb from 24 to 28 March 2024. The mission allowed the team to share the sorghum research experience based on scheduled field visits and discussions on the needs and requirements of the industry in Namibia.
- Prof. Labuschagne, Ms. Elize Botha and Dr. Albie du Toit (responsible for sorghum product development) visited the sorghum breeding program of ICRISAT (Bulawayo) from 15-17 April. We had extensive discussions with the sorghum breeder, Dr. Henry Ojulong, and we visited the breeding facilities. We also visited the product development section as well as the germplasm bank.
- We are in the process of signing the material transfer agreement with ICRISAT to access their whole sorghum germplasm collection (372 accessions) in order to access as much as possible genetic variation for the pre-breeding program. This material will be multiplied in the UFS greenhouse as soon as we receive it and will then be evaluated at the facilities of all three partners.
- The germplasmbank curator and part of the breeding team of ICRISAT (Bulawayo) has joined the UFS for a PhD in Plant Breeding (Tanyaradzwa Tenesi, 2024907673) which has strengthened our interaction with ICRISAT. She will be working on fall armyworm resistance in sorghum.

Milestones: Year 1

1. Make an inventory of seeds available at UKZN (Shimelis).
   This has been completed and seed and lists were sent to all partners.
2. Make a full inventory of all seeds in South Africa, with as much information as possible included (Kwame).
   We are populating this list with data from the field trials and the greenhouse currently.
3. Determine which entries have sufficient seed for multilocation planting in 2023 (all).
   All 169 entries were planted in the greenhouse at the UFS, and in the nethouse at UKZN, and 120 entries with sufficient seed were planted in the field in a replicated trial on the UFS experimental farm. The same entries were planted in March in the lowveld by Sorgho. The material has already flowered.

4. Plant these entries at UKZN, UFS and Sorgho using standardized procedures in October/November (will be coordinated between partners) (Maryke, Shimelis, Elize) (group 1 material).
   All material has been planted at UFS and UKZN as discussed in point 4. The greenhouse trial has already been completed and harvesting of the field trials are underway. Sorgho has planted a trial in March in the lowveld for multiplication in the winter season.
5. Phenotype these entries using standardized sorghum descriptors (Maryke, Shimelis, Elize).
   A descriptor list has been sent to all collaborators, which we have all used to do phenotypic screening. Phenotyping is being completed now and data will be shared between partners.
6. Screen all three sites for diseases (Lisa).
   We have decided to postpone disease screening to next season, as the current trials were mainly for initial screening and seed multiplication.
7. Preliminary quality screening on NIR of harvested seed (Maryke).
   As soon as the trials at UFS and UKZN are harvested we can start with quality screening. We will use near-infrared reflectance analysis, followed by tannin, phytic acid, mineral, carotenoid and starch analysis.
8. The MSc student will do SSR fingerprinting of all material.
   MSc student Karabo Pule has planted all 169 accessions in planting trays, and the necessary primers have been ordered. DNA extractionhas commenced.
9. Complete report on current pre-breeding activities (including pre-breeding capacity) and sorghum related research (Kwame).
   This has been completed. The report was circulated to all partners, and the report was made available to industry.
10. Seed multiplication of entries with insufficient seed (UKZN).
    Seed multiplication of all 169 entries have been done at both UKZN and UFS (harvesting in progress). A nursery with the same material was planted in March in the lowveld by Elize Botha (Sorgho).
11. Write report on all data collected in the 2023/2024 season (Maryke).
    As soon as all the data is collated from the trials at UFS and UKZN, this will be written up. When the winter trial is completed, that data will be added.
12. Make the first requests for importation of sorghum germplasm from abroad (Maryke/Shimelis/Kwame).
    We are in the process of signing the material transfer agreement with ICRISAT to import small amounts of seed from their total germplasm collection (372 accessions) which will be multiplied at the UFS, and then made available to all three partners for evaluation. The material from Namibia will be multiplied at UKZN and also made available to all three partners.

Table 1: Overview of research project

Milestone	Activities	Deliverables	Partners	Expected output
Year 1				
P1.1 Investigating current pre-breeding activities (including pre-breeding capacity) and sorghum related research	A desktop survey of current pre-breeding activities in South Africa	A report with all information	All role players in the sorghum industry.	The report has been completed and is available.
	Determining which projects are/have been done on sorghum, and where	An inventory of seed available with detailed information on endosperm type, genetic type and related information on pest and disease resistance etc.		
	Determine capacity for pre-breeding activities			
	Make an inventory of current seed available in South Africa			
P1.2 Multiplication of SA seed sources with limited seed (UKZN) from germplasm resources	Preparation for planting (seed preparation from germplasm bank, preparing nethouse, soil, fertilizer, insecticides, technical help etc.)	Sufficient seed generated for next season	UFS, UKZN and Sorgho have planted four trials in all, three in the field, and one in the greenhouse. The summer trials have been completed.	UKZN planted the full set of 169 entries in a net house in a replicated trial. The same set was planted in a replicated trial in the greenhouse at UFS, and 120 of these were planted as a replicated field trial. Sorgho has planted a winter nursery with all 169 entries.
	Management and harvesting of material		UFS and UKZN have completed the summer trials. The greenhouse trial is being threshed currently, and harvesting of the field trials are underway. Sorgho will harvest the winter trial by October.	Sufficient seed for 2024/25 trials.
P1.3 Preliminary field trials at UFS and Sorgho	Preliminary field trial preparation at UFS (consumables, land preparation, fertilizer etc.)	A first field evaluation and preliminary database of accessions	One trial was planted in the greenhouse and another in the field at the UFS. Both were replicated trials. Fertilizer, herbicides and insecticides were used to create the best possible growing conditions.	Sufficient seed for 2024/25 trials.
	Preliminary field trial preparation at Sorgho		This has been done, and a winter nursery (with the 169 entries that were used by all partners) was planted in the lowveld in March	Sufficient seed for 2024/25 trials.
	Management and harvesting of material UFS		The greenhouse trial has already been harvested, and the harvesting of the field trial has just started.	Sufficient seed for 2024/25 trials.
	Management and harvesting of material at Sorgho		A winter nursery with 169 entries was planted in the lowveld.	Sufficient seed for 2024/25 trials.
P1.4 Initial disease resistance screening	Screen material at UKZN for disease resistance	Preliminary disease resistance data	We have decided to postpone disease screening to the next season as the last season was mainly focussed on initial screening, and some of the forage types and very late maturing types will be excluded in the coming season.	A database on disease response in 169 entries.

	Screen field trial at UFS for disease resistance		We have decided to postpone disease screening to the next season as the last season was mainly focussed on initial screening, and some of the forage types and very late maturing types will be excluded in the coming season.	A database on disease response in 169 entries.
	Screen field trial at Sorgho for disease resistance		This will be done in the winter on the lowveld trial	Sufficient seed for 2024/25 trials.
P1.5 Initial phenotyping	Phenotype material at UFS	Preliminary phenotyping dataset	Phenotyping has been completed in all the summer trials using a standardized descriptor list, and the winter trial evaluation is still underway.	A database of all traits of the 169 accessions.
	Phenotype material at UKZN			
	Phenotype material at Sorgho			
P1.6 Importation of foreign germplasm	Obtain foreign germplasm (UKZN and UFS). This will be a continuous process.	First international germplasm set	The UFS is in the process of signing a material transfer agreement to obtain 372 accessions from the ICRISAT germplasm collection housed in Bulawayo. UKZN is arranging to access sorghum germplasm developed by the Namibia team through the International Atomic Energy Agency (IAEA)-supported mutation breeding project. The mutants will be evaluated for their adaptation and selection under South African conditions.	New germplasm to plant in the 2024/25 season.
P1.7 Initial quality screening of harvested mater	Clean and prepare harvested material (UFS)	First basic quality dataset	This will commence when all summer trials have been harvested and threshed. When the winter trial is harvested, analysis of that trial will also commence.	Part of an MSc study.
	Evaluate all material with NIR for basic quality characteristics (UFS)			

3. PROGRESS

Within this project, progress will be provided on the following objectives, that being:

- Explore current local sorghum pre-breeding and breeding expertise, resources, and initiatives to identify suitable role-players and investigate the establishment of a pre-breeding program.
- Explore all current sorghum breeding activities.
- Establish a sorghum pre-breeding program.
- Support local breeding programs.

We are very satisfied with the progress we have achieved with the sorghum pre-breeding project since November 2023.

- The report on sorghum pre-breeding and breeding expertise, resources, and initiatives to identify suitable role-players and investigate the establishment of a pre-breeding program has been completed.
- A total of 169 sorghum entries from all over the world were made available to all three partners by UKZN. These entries were planted in replicated trials at UKZN (in a net house) and at the UFS in the greenhouse, and the field (120 accessions) in replicated trials. These trials are have been used for the first screening for morphological traits, using a standardized descriptor list. The greenhouse trial has been harvested, and harvesting of the two field trials are underway. A winter nursery of the same material was planted in the lowveld by Sorgho in March.
- At the UFS, Tanyaradzwa Tenesi (ICRISAT Zimbabwe), Sheila Juma (IIAM in Mozambique) joined as PhD students on the sorghum project, and Sisipho Platyi (South African) will join us in July as PhD student. Karabo Pule (South African MSc student) was appointed as a research assistant in the sorghum program and is doing his project on seed colour and nutritional value in the collection. The other student projects revolve around the genetics of seed quality and nutritional value, and one student is working on fall armyworm resistance. At UKZN a full time post-doctoral fellow is working on the sorghum project (Seltene Tesfamariam) as well as two post-graduate students.
- We've had online meetings with ICRISAT (Zimbabwe, Mali and India) as well as sorghum breeders at Kansas State University, Purdue University and Giessen University and they were all positive to give us access to seed and to collaborate with us early in the year.
- We have visited the Ministry of Agriculture in Namibia (Tsumeb) to see their sorghum breeding program, in order to source germplasm. Dr. Athon Wanga will send us germplasm for multiplication (UKZN) as soon as a material transfer agreement is in place.

- We visited the sorghum breeding program of ICRISAT in Bulawayo to see their breeding program and germplasm bank as well as the product development division. We had discussions with the sorghum breeder, dr. Henry Ojulong.
- We are in the process of signing a material transfer agreement with ICRISAT to obtain 372 accessions from their germplasm collection for multiplication by the UFS, which will be made available to the other partners for evaluation.

Figure 1. Photos showing the sorghum pre-breeding activities and research team at the Ukulinga research site of UKZN (top left and right) and UFS greenhouse (bottom). (Photos supplied by Shimelis and Maryke).

Figure 2. Sorghum screening trial at Ukulinga site of UKZN under bird-protected nethouse conditions

Figure 3. Visit to sorghum breeding program of ICRISAT (Bulawayo) which resulted in a material transfer agreement for the full germplasm collection (372 accessions).

Figure 4. Harvested panicles from greenhouse trial (top) and Sorgho winter nursery (below)

4. DELIVERABLES

Table 2: Update on key deliverables

Deliverable	Update
Explore current local sorghum pre-breeding and breeding expertise, resources, and initiatives to identify suitable role-players and investigate the establishment of a pre-breeding programme.	This has been completed in the form of the report compiled by dr. Shamuyarira.
Complete case study of the current sorghum genetic improvement activities;	This was part of the above report.
Complete case study on the possibility and feasibility of establishing a pre-breeding program with recommendations on how to proceed.	This was part of the above report.
A local pre-breeding programme to support the development of higher yielding sorghum cultivars	Sorgho is the only sorghum breeding program in South Africa currently, and they will take responsibility for line development and hybrid breeding.
Breeding of higher yielding cultivars suitable for the sorghum industry (year 10-15)	This will be part of the Sorgho program responsibility.
Capacity building: Training of students in pre-breeding and breeding initiatives	At UFS two PhD students, and one MSc student is also involved (he is also a research assistant on the project). At UKZN one post-doctoral fellow is involved as well as two post-graduate students.

The table below shows the overarching objective, deliverables and ABIPP KPI's for the Sorghum Cluster initiative to date.

Objectives	Deliverables	ABIPP KPI
Explore local sorghum pre-breeding and breeding expertise, resources, and initiatives to identify suitable role-players and investigate the establishment of a pre-breeding programme.	- Report outlining available pre-breeding/breeding capacity and equipment within SA. - List of local expertise and potential role-players - Explore all current sorghum breeding activities. - Complete case study of the current sorghum genetic improvement activities. case study on the possibility and feasibility of establishing a pre-breeding program with recommendations on how to proceed	**Want to achieve:** - Number of new plants/animal lines & cultivars developed (10) - Training support/students/technicians etc (2) **Achieved to date?** - Number of new plants/animal lines & cultivars developed (10) - Training support/students/technicians etc (2) -

5. CONCLUSION

The project is well underway, and we have reached the goals we set for the first season (with the exception of disease screening, which we will do in the next season). We will be able to do even more than we planned for, for example, DNA fingerprinting. The material transfer agreement with ICRISAT for their full germplasm collection of 372 entries is with the UFS lawyers currently, and as soon as the paperwork is done, we will receive the material. We are in the process of screening all of the current 169 accessions for morphological and nutritional traits. A selection of the best of the entries will be planted in November 2024 in replicated trials at three locations (UKZN, UFS and Sorgho). The first abiotic stress tolerance screening will then commence at UKZN in the summer 2024/25 with a selected number of entries. The 372 entries from ICRISAT will be multiplied, and preliminary screening will be done as soon as the material is received.