APPENDIX 1

PROGRESS REPORT

Farmer innovations in Conservation Agriculture (CA) systems for sustainable crop intensification in semi-arid, sandy soil conditions, North West Province

For the period:

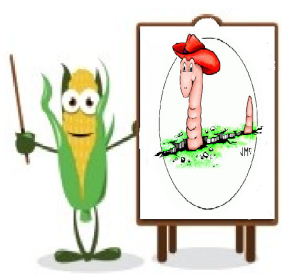
OCTOBER 2018 TO SEPTEMBER 2019

Compiled by:

HJ Smith, AA Nel and G Trytsman

September 2019

GRAIN SA
GRAAN SA



The Maize Trust

Ottosdal No-till Club

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1. Coordination and management

Work Package title	**Coordination and management**
Work Package period	October 2018 to September 2019
Lead partner	Ottosdal No-till Club (Mr Hannes Otto) and Grain SA (Dr Hendrik Smith)
Involved partners	All
Objectives	Coordinate activities among all partners Ensure timely reporting to Grain SA / The Maize Trust Promote synergy among project activities
Justification	Project size, complexity and level of integration/interdependency among different project actions require strict delivery and adherence to project timelines as essential. Partners must often work together to achieve specific project outputs.
Description of work	**Activity 1: Project inception workshop**. **Progress and Results achieved:** A one-day project planning and inception workshop was held on 20 August 2013 (at the Ottosdal country club) at the beginning of the project to enable all project partners to define work packages and procedures to achieve the project outputs and objectives. These WP's are used for the financial control and payment of the project and for the monitoring of the agreed tasks and deliverables. Work package managers were identified at this meeting and will present/follow strategies and protocols which are frequently monitored by all partners. **Activity 2: Frequent coordination meetings**. The purpose of these meetings is to establish an Innovation platform for improved communication, integration and sharing. The essence or key action in these meetings will be social learning, characterised by feedback, reflection, planning and coordination between different work packages and stakeholders. A secondary activity is the creation of a wider network in support of communication, sharing, learning and scaling out. **Progress and Results achieved:** Project meetings has taken place involving all the key partners (project team members) in the project. Those include farmers, researchers, input suppliers, Grain SA/MT and manufacturers. These meetings are instrumental in the running of the project, serving as a platform for collective and adaptive project management. Some of the key project events, such as the farmer-led trials and the conference, have been planned and coordinated form this platform.

	Activity 3: Annual Reference Group Meetings Formal reference group meetings will be organised each year with representation from each work package. In order to provide the project with independent monitoring, advice and support and to ensure communication with key stakeholders, a group of experts and end users (reference group) will be formed and invited to participate. Presentations from each work package leader will summarise achievements. Discussions about progress, potential deviations from the work plan and forward planning will be standing items at each meeting. **Progress and Results achieved:** The annual reference will take place on ***10 October 2019***. **Activity 4: Organise and Coordinate annual awareness event(s)** **Progress and Results achieved:** The annual Ottosdal CA conference was successfully held on 13 and 14 March 2019 in collaboration with *Landbouweekblad*. Around 300 people attended the event. **Activity 5: Reporting** All partners participate in the preparation of a six-monthly progress report. The lead applicant and work package managers' report on results and work progress, as well as actions taken to minimise the effects of delays on other project activities. **Progress and Results achieved:** Reporting has been done according to the standards and format required by The Maize Trust. **Activity 6: Annual progress reports** The annual report has been done according to The Maize Trust / CA-FIP guidelines. Work package managers were responsible for collating information and making a single work page report. The lead applicant has been responsible for integrating these into a single full report. A similar approach will be used to prepare the final project report covering information from all project years. **Progress and Results achieved:** The annual report has been completed in September 2019.

Deliverables	• Project actions and reporting delivered on time

Risks	The project study area is experiencing a major drought period and trial results might be affected.

2. Assessment of soil quality

2.1. Work package

Work Package title	**Assessment of soil quality under Conservation Agriculture (CA) systems in the semi-arid cropping areas of the North-West Province**
Work Package period	October 2018 to September 2019

Lead partner	Independent agronomist - Dr. A. A. Nel
Involved partners	Ottosdal No-till Club, Grain SA,

Objectives	• To characterize the soil types and soil physical & chemical parameters, such as particle distribution, pH, Soil Organic Matter and macro-, micro-nutrients as well as soil health on selected trials • To compare the effect of different CA treatments on soil quality/health

Justification	A number of studies suggest that a soil and nutrient management strategy based on a broader range of ecosystems processes is worth further investigation. The approach shifts the emphasis of soil nutrient (fertility) management away from soluble, inorganic plant-available pools to organic and mineral reservoirs that can be accessed through microbial and plant mediated processes. However, a relatively poor understanding and capacity exist among the local research fraternity to investigate these crucially important subjects.

Description of work	Characterise the effects of different CA practices (treatments) on soil nutrient and physical dynamics (soil health). The work will involve regular field visits, sampling of soil on selected trails of fields, laboratory analyses of the samples by a service provider, data processing, statistical analyses and report writing.

Activities	1. Monitoring and Sampling 2. Lab Analyses 3. Monthly meetings (project team) 4. Annual reference group meeting (advisory committee) 5. Annual report and documentation of results 6. Participate in Awareness events

Risks	• Being a dryland experiment, low and erratic rainfall may delay or prevent sampling; • Weather events such as hail, wild animals and birds may jeopardise crop performance and yields;

2.2. Deliverables, progress and results achieved per activity

Activities	Deliverables	Progress and Results achieved
1. Monitoring and Sampling	Detailed sampling at selected sites; Selected samples as required	A total of fifty soil samples was taken in2018/2019 on the crop rotation and cultivar trials at Humanskraal, on the crop rotation plant arrangement trial at Korannafontein.
2. Lab Analyses	Organic C (%) Standard soil analysis: 4 basic cations, P, pH, ratios, micro-elements Soil health through the Haney and PLFA analyses	Thirty-eight samples were delivered to Nvirotek for inorganic chemical analyses. Twelve samples were sent to Soil Health Solutions for soil health analyses.
3. Regular meetings with project team	Participate in club meetings, discussing problems and possible solutions to that	Participated in meetings that were held on 16 October 2018, 5 February & 27 June 2019.
4. Annual reference group meeting (advisory committee)	Report progress and findings at forum meeting.	Maize Trust Form meeting scheduled for 18 September 2019
5. Annual reports and admin (technical data)	Written technical report covering trial procedures, results and progress.	Submitted as required in March and September 2019. -
6. Participate in Awareness events	Trial visits with stakeholders; participate in awareness events, such as the annual conference and/or cross-visits	Results were presented at a club members on16 October 2018. Some results were discussed during the Ottosdal No-Till Club conferenc on 13 & 14 March 2019.

2.3. Summary of soil quality work package 2017/2018 and 2018/19

ACTIONS TAKEN TO DATE

2017/2018

Soil samples were collected during July 2018 on the crop rotation trial and cultivar trials at Humanskraal and the trial where two no-till systems are compared with a conventional tillage system at Doornspruit as well as on three farms where conservation agriculture is practiced. The objectives and materials and mehods of these trials are described under work package 5. A total of 12 samples from the trial at Doornspruit was send to two companies (Agrisol and Soil Health Solutions) for a soil health assessment. Sixty samples were sent to Envirotek for conventional soil analyses.

2018/2019

Soil samples were collected on a newly implemented trial *"Grain yield and soil health as affected by a cover crop – sunflower – maize rotation system and monoculture with maize and sunflower in two plant arrangements"* on the farm Korannafontein. These samples were sent to Envirotek for conventional soil analyses. During July 2019 selected treatments of the crop rotation trial at Humanskraal were sampled and send to Soil Health Solutions for a soil health assessment. Due to the intention of the NWU to monitor the nematode dynamics on the new trial at Korranafontein at their own cost, soil samples were taken in July at Korranafontein and send to Soil Health Solutions for a soil health assessment.

PROGRESS MADE

Selected plots of the following trials and selected lands on farms were sampled in 2017/2018.

Trial or site	Sample details
Crop rotation systems trial at Humanskraal	Six plots each from the maize and sunflower crops respectively, plus one forage sorghum plot, at 0 – 5 and 5 – 15 cm depths
A comparison of conventional and conservation agriculture (CA) cropping systems at Doornspruit	Nine plots at two depths plus one reference point next to the fence representing natural veld
Maize cultivar evaluation trial plus adjacent field as reference at Humanskraal	Two samples, 0 – 5 and 5 – 15 cm depths
Four locations on farms to compare the organic material content of adjacent CA and conventional tillage soils	Ten samples, 0 – 5 cm depth

Selected plots of the following trials and selected lands on farms were sampled in 2018/2019.

Trial or site	Sample details
Crop rotation systems trial at Humanskraal	Six maize plots, one sunflower and one cover crop plot were sampled (0 - 20 cm depth)
The newly established crop cover crop rotation trial on the farm Korannafontein	Twenty-four samples (12 x 0 – 5 cm depth + 12 x 5 – 15 cm depth) at the onset of the trial and 12 samples (0 – 20 cm depth) in July 2019 after the first cropping season
Two locations on farms the farms Humanskraal to compare the organic material content of adjacent CA and conventional tillage soils One field on the farms korannafontein where crop rotation caused a difference in grow in 2017/2018	Four samples, 0 – 5 cm depth Two samples

RESULTS ACHIEVED TO DATE

The following gives a short description of the different Objectives and the conclusions. The addendum gives a more comprehensive description of the results.

Crop rotation systems: Results from the five seasons of crop rotation suggest that some crops are affected by the preceding crop as indicated under Work Package 5. Soil nutrient content varied among the rotation systems in 2018. If this variation is due to the crops involved will only be clear in due course as change of the soil nutrient content is a slow process. Soil samples taken in 2019 are analysed for soil health and PLFA to get an indication of the microbial composition. These analyses are still in progress by the service provider at the time of writing this report.

A comparison of conventional and conservation agriculture (CA) cropping systems: Due to a local lack of scientifically based results and for demonstration purposes the need existed to collect results on the success of CA crop systems in comparison with conventionally tilled systems in field trials. To compare the yield of maize in conventional and CA production systems with both 0.52 and 0.91 m spaced rows in the CA systems. A statistically laid-out trial was done on the farm Doornspruit. The inorganic nutrient contents of the soil were unaffected except for phosphorus which were higher in the conventional than the CA soil. Contrary to what was expected, most soil health indicators were higher for the conventionally tilled soils than the CA soils.

Grain yield and soil health as affected by a cover crop – sunflower – maize rotation system and monoculture with maize and sunflower in two plant arrangements: The aim of this trial is to determine how soil health and crop yields are affected by the rotation systems and plant arrangements. Soil samples were taken and analysed at the onset of the trial and again at the end of the season. Analyses of the latter is still in progress.

S**oil sampled from farms for C comparisons and explanation for a difference in growth:** In 2018 conventionally, tilled soils had a higher organic carbon content than CA soils. It is probably due to an error at the service providing laboratory. Samples taken in 2019, however, confirmed that the organic carbon content of CA soils are similar or higher than that of conventionally tilled soil.

PROBLEMS ENCOUNTERED AND MILESTONES NOT ACHIEVED

No serious problems were encountered and all milestones were reached.

2.4. Results 2017/2018

2.4.1. Suitable crop rotation systems for CA

Introduction

The aim is to investigate the influence of six crops on the grain yield of each other for a number of years to find the best crop sequence in CA cropping systems. Cowpeas, grain sorghum, forage sorghum, soybean, maize and sunflower are grown in rotation with each other. All crops are also grown in monoculture. The trial is not replicated and consists of only one plot per season for each rotation system. It is expected that the soil composition and health of the upper layers of the soil will change over time among the rotation systems. These changes are usually slow and analyses of the soil only started after harvesting of the fourth season of crop rotation where maize and sunflower are the principle crops.

Soil samples (0 – 5 and 5 – 15 cm depths) were collected during August 2018 by taking eight subsamples on an area of 10 x 10 m per plot and mixing it into one compound sample for the 0 – 5 and 5 – 15 cm soil layers. All maize and sunflower plots were sampled while the monoculture forage sorghum system was included due to the relative high amount of crop residue left on the soil surface by this crop which might accelerate changes in the soil.

Soil samples (0 – 20 cm depth) of the above-mentioned plots, were taken on 6 August 2019 and send to Soil Health Solutions for a soil health (Haney and PLFA) analyses. The analyses were still in progress during writing of this report.

Results and discussion

Results for the soil analyses are shown in Table 2.1. As this trial is not replicated it is unknown if differences among values are due to the rotation system or not and only general comments is possible. Soil analyses in time will show if apparent difference will increase indicating which rotation systems need addition fertilisation. The soil organic material, pH and nutrient content of the monoculture forage sorghum were all within the range of that found for the maize and sunflower rotations and is not shown in Table 2.1.

The organic material content of the upper layer is lower than the content of the deeper layer on the maize crop for all preceding crops while that of the sunflower crop changes. The Ca, Mg and especially the K content of the upper layer was higher than that of the deeper 5 -15 cm layer across all rotations. This is likely due to the application of lime in the past or it may be due to the enrichment of the upper soil that is often found under no-till

Table 2.1. Soil organic material, pH, Ca, Mg, P and K content of maize and sunflower preceded by different crops since 2014/15 at Humanskraal in 2018/2019

Parameter	Preceding crop					
	Cowpea	Forage sorghum	Grain sorghum	Maize	Soybean	Sunflower
	Maize 0 – 5 cm depth					
OM* (%)	0.62	0.49	0.49	0.55	0.63	0.53
pH (H_20)	6.89	6.49	6.39	6.36	6.46	7.27
Ca (mg kg^{-1})	1304	1145	1038	717	849	1110
Mg (mg kg^{-1})	189	238	216	156	180	220
P (mg kg^{-1})	89	77	103	53	60	89
K (mg kg^{-1})	328	424	438	346	292	450
	Maize 5 – 15 cm depth					
OM (%)	0.82	0.87	0.61	0.71	0.95	1.04
pH (H_20)	6.33	5.94	5.85	5.66	5.85	5.93
Ca (mg kg^{-1})	640	741	644	467	534	482
Mg (mg kg^{-1})	139	186	156	108	126	107
P (mg kg^{-1})	27	71	88	58	31	96
K (mg kg^{-1})	254	220	294	232	199	307
	Sunflower 0 – 5 cm depth					
OM (%)	0.44	0.52	0.56	0.35	0.47	0.24
pH (H_20)	7.99	7.94	6.84	6.15	6.64	6.31
Ca (mg kg^{-1})	988	1337	876	824	797	776
Mg (mg kg^{-1})	171	208	180	158	146	150
P (mg kg^{-1})	77	72	75	59	62	58
K (mg kg^{-1})	497	466	409	469	395	467
	Sunflower 5 – 15 cm depth					
OM (%)	0.48	0.49	0.47	0.30	0.47	0.38
pH (H_20)	7.78	7.43	5.75	5.87	5.63	6.00
Ca (mg kg^{-1})	469	572	909	494	441	496
Mg (mg kg^{-1})	105	125	119	107	93	110
P (mg kg^{-1})	40	49	87	75	73	43
K (mg kg^{-1})	266	282	250	241	185	334

* Organic material

2.4.2. A comparison of conventional and conservation agriculture (CA) cropping systems (completed)

Introduction

The aim of this trial on the farm Doornspruit is to compare the yield of maize in conventional and CA production systems with both 0.52 and 0.91 m spaced rows in the CA systems. Due to a local lack of scientifically based results the need existed to collect results on the success of CA crop systems in comparison with conventionally produced crops in a field trial. This trial also served as demonstration of CA to farmers and visitors.

The cropping systems which are replicated three times, consisted of no-till maize in 0.52 and in 0.91 m spaced rows at higher plant populations and a conventional system of 2 row spaced at 2 x 2.3 m + 1.5 m with rip-on row to a depth of 0.45 m. Soil samples (0 – 5 and 5 – 15 cm depths) were collected during August 2018 by taking eight subsamples on an area of 10 x 10 m per plot and mixing it into one compound sample for the 0 – 5 and 5 – 15 cm soil layers. These samples were submitted for conventional inorganic nutrient analyses and for a soil health analysis.

Results and discussion

Results of the conventional soil analyses from this trial which is in its third season, are shown in Table 2.2. In the 0 – 5 cm layer, only phosphorus was affected by the cropping system with the conventional system having a higher content than the two no-till systems. Values for the pH, organic material and all nutrients were similar in the 5 – 15 cm layer. The reference point was sampled below the fence next to the trial and is assumed to be undisturbed natural veld. In respect of potassium, calcium and magnesium the reference point had much higher values than any of the cropping systems. This is most likely an indication of under fertilisation in the past.

The soil respiration, water extractable organic carbon, water extractable organic nitrogen, organic nitrogen to carbon ratio, organic nitrogen to phosphorus ratio, microbially active carbon and the calculated soil health score of the 0 – 15 cm soil layer are shown in Table 2.3. As the soil samples were compounded from three replicates, no statistical comparison was possible and if differences among values are significant, is unknown. The aim however is to determine how the soil health will change with time. However, with the exception of the organic nitrogen to carbon ratio, all parameters as well as the soil health score of the conventional crop systems were higher than the values found for the two no-till systems. This is contrary to what was expected and most likely due to the short duration of the application of CA principles.

Table 2.2. The mean pH, organic material, potassium, sodium, calcium, magnesium and phosphorus contents, and percentage hydrogen saturation for the cropping systems and a reference point (natural veld) at two soil depths, at Doornspruit 2018

System	pH	Org Mat	K	Na	Ca	Mg	P	H
	(H2O 1:1)	(%)	(mg kg^{-1})	(mg kg^{-1})	(mg kg^{-1})	(mg kg^{-1})	(mg kg^{-1})	(%)
			Depth 0 - 5 cm					
Conventional	5.0	0.44	100	13	110	32	42	44
No-till 0.5	5.0	0.55	122	14	124	43	38	44
No-till 0.9	5.0	0.62	127	16	143	46	36	43
Significance#	ns	ns	ns	ns	ns	ns	*	NS
Reference	5.5	0.54	271	18	264	124	46	31
			Depth 5 - 15 cm					
Conventional	4.9	0.56	88	15	137	34	41	48
No-till 0.5	5.0	0.70	88	16	125	32	39	45
No-till 0.9	5.1	0.42	97	20	147	40	42	41
Significance	Ns	ns	ns	ns	ns	ns	ns	ns
Reference	5.1	0.84	244	21	276	66	31	42

ns = not significant; * = significant at $P \leq 0.05$.

Table 2.3. Soil respiration, water extractable organic carbon, water extractable organic nitrogen, organic nitrogen to carbon ratio, organic nitrogen to phosphorus ratio, microbially active carbon and the calculated soil health score of the 0 – 15 cm soil layer at Doornspruit for three crop systems

Parameter	Conventional	No-till 0.5	No-till 0.9
Respiration (Solvita CO_2-C) (mg kg^{-1})	43.5	36.4	22.1
Water extractable organic carbon (mg kg^{-1})	88.4	97.9	96.5
Water extractable organic nitrogen (mg kg^{-1})	7.8	2.5	3.7
Organic nitrogen to carbon ratio	11.3	39.0	26.0
Organic nitrogen to phosphorus ratio	0.2	0.1	0.1
Microbially active carbon (%)	49.2	37.2	22.9
Soil health score	6.0	4.9	3.5

2.4.3. Maize cultivar evaluation trial

Introduction

The purpose of this trial is to evaluate maize cultivar annually in no-till, with a mulch of residue at a row width of 0.52 m and at a plant population density of 40 000 ha^{-1}. No crop rotation is applied. Next to this trial is a commercial no-till field where maize and sunflower are grown in rotation with residues left on the soil which serves as reference point. The row width is 0.76 m and the seeding density is 40 000 ha^{-1}. All residue are left on the soil surface. It is expected that a difference between the trial and the field will develop in time. Soil samples were taken in August 2018 as described above. Due to the slow change of the nutrient content of the soil, this trial will sampled again 2020.

Results and discussion

The results are shown in Table 2.4. Although no statistical comparison can be made, the potassium content (0 5 cm depth) of the land is higher than that of the trial area while the opposite is true for sodium, calcium magnesium and phosphorus contents. For the 5 – 15 cm layer, all measured variables were higher in the cultivar area than in the adjacent land with the exception of the hydrogen ion percentage.

Soil sampling and analyses of this trial will be done in 3 years-time to determine if the current fertilisation program needs any adjustment.

Table 2.4. The pH, organic material, potassium, sodium, calcium, magnesium and phosphorus contents, and percentage hydrogen saturation for the maize cultivar trial area and adjacent CA land at two soil depths, at Humanskraal 2018

System	pH	Org Mat	K	Na	Ca	Mg	P	H
	(H2O 1:1)	(%)	(mg kg^{-1})	(mg kg^{-1})	(mg kg^{-1})	(mg kg^{-1})	(mg kg^{-1})	(%)
			Depth 0 - 5 cm					
Cultivar area	6.76	0.64	455	22	961	233	50	3.6
Adjacent land	7.00	0.60	519	16	915	189	29	0.0
			Depth 5 - 15 cm					
Cultivar area	6.51	0.95	321	22	745	205	61	7.35
Adjacent land	6.47	0.78	224	17	691	178	31	8.03

2.4.4. Adjacent CA and conventional tilled soils 2017/2018 and 2018/2019

Introduction

The organic material content of soil is an important indicator of soil quality and health. It known that the organic material of CA soils improves with time, especially in the upper part of the profile. The purpose of this investigation was to determine if the organic material content of the 0 – 5 cm layer of soils where CA are practiced are higher than that of conventional tilled soils. The Ottosdal No-till club needed proof that their soil show improvement as a result of their CA effort.

Soil samples were taken on four farms where the CA and conventional lands are adjacent in 2017/2018 and two paired samples on Humanskraal in 2018/2019. Soils were sampled as described previously with the sampling points between 30 and 50 m apart. These samples were analysed for their organic material content only.

Two soil samples (0 – 10 cm depth) were taken from a maize land which was split in 2017/18 with forage sorghum on part of it and maize on the rest of the field. Growth of maize in 2018/2019 on the forage sorghum side was visibly poor compared to growth on the maize side. The two soil samples taken were analysed for their health indicators (Haney analyses).

Results and discussion

The results of the soil analysed for their organic material contents are shown in Table 2.5. The organic material content of the conventional tilled soils was between 23 and 71% higher than that of the CA soils in 2018. This is completely opposite of what was expected. It is suspected that the two sets of samples got switched at the service providing laboratory.

The 2019 results confirmed that the organic material content can improve soil under CA practices improves above that of neighbouring conventionally tilled soils (Table 2.5). The organic material content of land 1 was 2.9 times higher than that of the adjacent conventionally tilled soil. Soil from Land 5 had a slightly higher organic matter content than the adjacent conventionally tilled soil.

Table 2.5. The organic material content (%) of the 0 – 5 cm soil layer on farms where CA and conventional tillage are practiced on adjacent lands in 2018 and of the 0 – 10 cm layer in 2019

Season	System	Farm			
		Droëkraal 1	Droëkraal 2	Doornpoort	Humanskraal
2017/2018	CA	0.40	0.34	0.62	0.56
	Conventional	0.63	0.58	0.76	0.80
		Land 1	Land 7		
2018/2019	CA	0.39	0.14		
	Conventional	0.10	0.13		

Results for the maize field soil samples are shown in Table 2.6. Health indicator values were quite similar between the soil with maize that grow well and the soil with maize that show poor growth. The difference in growth is thus most likely not due to a difference in soil health. A possible cause is allelopathy. It is known that sorghum crops can suppress the growth of a following crop while it is not associated with maize.

Table 2.6. Soil health indicators for samples (0 – 10 cm depth) taken on a maize field in 2018/2019 for poor growth (preceded by forage sorghum) and good growth (preceded by maize)

Soil health indicator	Good growth	Poor growth
pH	7.3	8.1
Organic matter (%)	1.2	1.2
Soil respiration CO_2-C (mg kg^{-1})	12	13.5
Microbially active C (%)	12	13
Total N (H_2O extract mg kg^{-1})	23.1	16.4
Inorganic N (H3A extract mg kg^{-1})	11.6	6.6
Total P (H3A extract mg kg^{-1})	43	65
ICAP K (H3A extract mg kg^{-1})	139	140
ICAP S (H3A extract mg kg^{-1})	7	5
ICAP CA (H3A extract mg kg^{-1})	306	384
ICAP Mg (H3A extract mg kg^{-1})	131	127
Soil Health Calculation	4.30	4.34

3. Assessment of cover crop adaptability and suitability

3.1. Work package

Work Package title	**Assessment of cover crop adaptability and suitability** **Crop and Livestock integration**

Work Package period	March 2019 to Sept 2019
Lead partner	Independent Researcher (Mr Gerrie Trytsman)
Involved partners	Grain SA, Ottosdal no-till club, Seed companies

Objectives	• To establish and maintain an on-farm screening trials • Determining the biological production of different cover crops • Measuring the production of crop residues of each cover cropping system • Measure the adaptability of cover crops in different agro-ecological regions • Planting of cocktails that can be used as livestock feed or soil primers • Planting of cash crops on primed soil • Monitor and determine crop yield on mixtures • Established new cocktails from seed companies • Fine turning cover crops mixtures for the agro-ecological region

Description of work	**On-farm, farmer-led screening trials; summer mixture for livestock integration; cash crop (maize) rotation and regenerative trials; sorghum screening trial, 15 varieties + 4 summer mixtures; cooperation with seed company (Agricol, Barenbrug, AGT and K2); Goal: Building a sustainable farming system for the North West province**

Activities	1. Land preparation (finding a suitable location, sourcing materials) 2. Purchase Materials & Equipment 3. Establishing and planting of trials 4. Seasonal management and maintenance of trials 5. Monitoring and Sampling (including harvesting, biomass and yield determination, nutrient analysis) 6. Lab analyses 7. Monthly meetings (project team) & training 8. Annual reference group meeting (advisory committee) 9. Harvesting, biomass and yield determination, nutrient analysis 10. Annual report and admin (production & technical data)

	11. Participate in Awareness events

Risks	Finding a suitable site for a trial of this magnitude Getting the right equipment and seed to do the job well Acts of God (drought, hail, etc.) Labour (weed control, harvesting, etc.)

3.2 Deliverables, progress and results achieved per activity

Activities	Deliverables	Progress and Results achieved
1. Land preparation (finding a suitable location, sourcing materials, action planning)	Description of natural resources. This will include positive and negative factors that can impact on plant growth. Selection of suitable site(s). Drawing up a concept note for livestock integration. An action plan that will include acquisition of seed, inoculum, stickers, implements, chemical inputs, monitoring and evaluation of trial, harvesting, collecting and interpretation of data. The action plan clarify the roll of every party involved.	A plot of 80 ha mixed summer annuals were planted at George Steyn. The seed was source from Barenbrug seed company. This will be used to implement a livestock integration trial. Summer annual ley or cover crop seed was supplied to George to plant the screening trial. A new technical helper was appointed and with assistance the summer annuals were planted. The regenerative trial (green fallow) was planted again and on the previous year's cover crops maize soybean and sunflowers were established (10ha). Summer annual cover crops were planted on the cash crops of 2018 again. Treatments then is rotation between cash crops and cover crops (green fallow; 10ha). A sorghum screening trial was established at Humanskraal. 4 cover crop mixtures were included with the different sorghum varieties.

2. Purchase Materials & Equipment	Acquisition of seed, inoculum, stickers, implements, chemical inputs.	Warm season legume and grass cover crop seed varieties were delivered to farmers after purchasing it from the seed companies.
3. Establishing and Planting of trials	Drawing up a field plan. Establish screening trial December. Established trial according to the field plan. Extended summer annuals area for soil priming and livestock integration was planted.	Cover crop screening trial was planted on the 7/01/2019 and replanted on the 6/02/2019. Regenerative trial 5/01/2019 Integrative trial planted on 5/01/2019 Sorghum trial planted on the 7-10/01/2019
4. Seasonal management and maintenance of trials	Regular visits to the trial site for inspection of weeds and insect damage and control if needed. Treatment of cover crop at appropriate time (usually before seed set) using appropriate equipment. Submission of technical report after each visit. Photos from trial during visits. Harvest trials	Discussed trials with farmers and delivered seed. 16/10/2018 meeting Ottosdal decision was taken to carry on with screening trial. Ground cover was determined before planting trials Fertilizer was applied as discussed in report Photos were taken with every visit of the trials. The trial was harvest for the first time the 15/03/2019 Second harvest took place on the 10/05/2019. Also harvest the green fallow trial and the integration trial.
5. Monitoring and Sampling	Completed data sheets for 1. Input cost 2. Germination 3. Cover %	Ground cover from last year's treatments were done. At every harvest morphological trades were measured and

	4. Height of cover of each addition 5. Biological productivity t/ha 6. Root evaluation:	samples were also analysed for nitrogen and carbon content. Root evaluation was done at Skulpspruit. Plants and tillers per m^2 were counted. The basal cover was determent for every treatment. Samples were dried and the DM was recorded.
6. Lab Analyses	C:N content of plant material.	From the N content the CP % was calculated. CP % can be related to possible animal production
7. Monthly meetings (project team) & Training	Partake in monthly forum meetings, discussing problems and possible solutions to that.	16/10/2018 Meeting at Ottosdal steering com. 8/10/2018 order summer annuals from Barenbrug
8. Annual reference group meeting (advisory committee)	Report progress and findings to advisory committee. Discussion and evaluation of trials. Learning from previous mistakes.	Scheduled in fourth quarter.
9. Annual report and admin (production & technical data)	Written technical report covering trial procedures, results and progress.	On-going process. Annual technical report completed by 3/19.
10. Participate in Awareness events	Trial visits with stakeholders; participate in awareness events, such as information day and/or cross-visits	Enquiries around CC are expanding. Article on the "Enhancing of soil health trough livestock integration." was published in Grain SA and a similar article was published in the *Landbouweekblad*. Ottosdal conference 13-14/03/2019: Manned a field point with Adriaan Dreyer. 27-29/05/2019: A strategic planning session at Bothaville was held where farmer's

		problems and aspirations were discussed.

3.3 Results achieved

Al the trials were harvested and dry matter (DM) for the different treatments were calculated.
1. Green fallow trial
2. Grazing trial (integration trial)
3. Screening trial
4. Sorghum screening trial.

3.3.1. Green fallow (Regenerative trial)

Year 1: A summer annual cover crop mixture was left to develop fully and were left standing (vertical mulch) for the winter. This crops being summer annuals are killed by frost. A small amount of Radish (cool season annual) is mixed with the seed. This ensure that we can keep living roots in the soil for winter. A core principle of conservation agriculture is adhered to by applying this strategy. The root exudes glycoproteins that can attract micro-organisms and soil life can use this sugary substance as food.

Year 2: Sunflower, maize and soybeans were established after the summer CC mixture with good results, which were previously reported on.

Year 3: A summer cover crop mixture was planted which was grazed during March the previous year. The regrowth was grazed in May and June.

Year 4: Cash crops was established once again as in year one. The crops established well as shown in plate 1 below.

Plate 3.1: Cash crop on grazed cover crop of 2018

A plot containing summer annuals (Plate 3.2) was established where cash crops and cover crops are rotated on both pieces of land on a yearly basis.

Plate 3.2: Cover crop mixture established on previous cash crops

The yields for the cash crops remained poor due to the drought. The farmer harvested the cash crops and 0.5, 1.0 and 3 t/ha were realized for soya, sunflower and maize respectively. Sunflower after summer CC annuals containing broadleave species seems to contract Sclerotinia head rot on a regular basis and maize might be a better rotational crop to plant in Ottosdal after summer annuals.

Taking the dry condition into account the summer annuals performed well and a DM of 13.6 t/ha was harvest as can be seen in plate 3.3.

Plate 3.3: Cover crop mixture at harvest

3.3.2. Grazing trial (livestock integration)

The previous year a trial plot of 42 ha summer annual CC mixture was planted by Mr George Steyn. He decided to increase the size of the plot to 80 ha this year. Due to the foot and mouth decease outbreak, prices of weaners dropped considerable this year from R 43/kg to R 24/kg and the fees paid when buying livestock forced George to hold on to his own weaners.

He is hoping that the prices will increase to previous levels in the near future. This year he will put his own livestock onto cover crops. Saving money on agent fees and transport cost will hopefully positively influence economic outcomes.

The same mixture than the previous year was established, due to the good results in terms of meat production and residue cover. Plate 3.4 is an indicator of a well establish stand of maize on the previous grazed cover crop.

The maize was planted using coulters and George express his satisfaction with the less power that was needed to establish the maize. We are looking forward to see the results of this practise in the near future. Livestock integration spread risk and diversification increase the flexibility of a whole farm approach.

Plate 3.4: Well established maize field in a sufficient soil cover of 80%

Maize was harvested during August and the harvest map of the yield is presented in plate 3.5. From the maize that was planted during January on the farm the maize rotation with livestock produced the highest yields at almost 5 t/ha. Maize in rotation with other cash crops produced 2.3 and 2.7 t/ha for sunflower and maize respectively.

Plate 3.5: Havest map of maize planted on cover crops

Again on the 7/01/2019 (as the previous year) summer annuals were establish, using a John Deere 10 row, 76 cm planter as seen in Plate 3.6. The larger seed crops were planted first at a seed density of 110 000 plants/ha and the small seeds were planted at a 30 degree angle at the same density. Weed control include a Round-up treatment with no other pesticides. For fertility management an N application of 42kg/N was broadcast before planting with a mixture that supply; N-11, P-7,6 and K-3,5 kg/ha applied with the planting operation.

Plate 3.6: Planting summer mixture for livestock integration

The sward established well and the photo in Plate 3.7 confirmed a well-established cover crop with good potential. The cost saving on fertilizer this year by George is estimated at R 500 000. Finally, the advantages of soil biology and the "farming in natures image" realization that we need to cut back on external input, is starting to surface.

Plate 3.7: Cover crops that will be grazed, using high density grazing

Plate 3.8: Type of animals used in grazing trials

Animals weighing approximately 280 kg were bought at auctions. Due to problems with lung diseases the previous season, all animals were inoculated to prevent lung infections. In Plate 3.8

the type of animals that were used for grazing the cover crops are shown. The cover crops were grazed for a period of 83 days and a weight gain of 240 kg/ha were realized.

Plate 3.9: Animals gaining weight in the feedlot

Animals gained weight at 1.25 kg/day for the duration of the trial. After grazing the cover crops animals were moved to the feedlot. When reaching the weight and grading that are required by the markets, the animals will be sold. Plate 3.9 is a testimony of their growth. The picture was taken on the 08/08/2019.

3.3.3. Screening trial

On 16/10/2018 during a planning meeting, the screening trial was discussed and it was decided that the trial should be established again for the 2018/19 season. Due to the lack of rain, establishment of the trial was delayed until 7 of January 2019. Soil conditions at that stage was less than ideal, with little plant available soil moisture.

Before planting, soil cover was determined and as reported in previous reports, a certain trend emerges, where winter annuals (such as radish, winter mixtures, grazing vetch) and summer annuals (such as soya) produced soil cover of inferior substance. It is clear form Figure 3.1 that in order to produce cover that can protect the soil against wind and water erosion, winter mixtures that consist of rye, black oats and triticale should be prioritized. For summer cover crops, one legume stood out namely lablab, whilst for the annual grasses maize, sorghum and millet produced excellent cover. These mentioned crops should be seen as primary crops when building a mixture for protecting soil and produce cover.

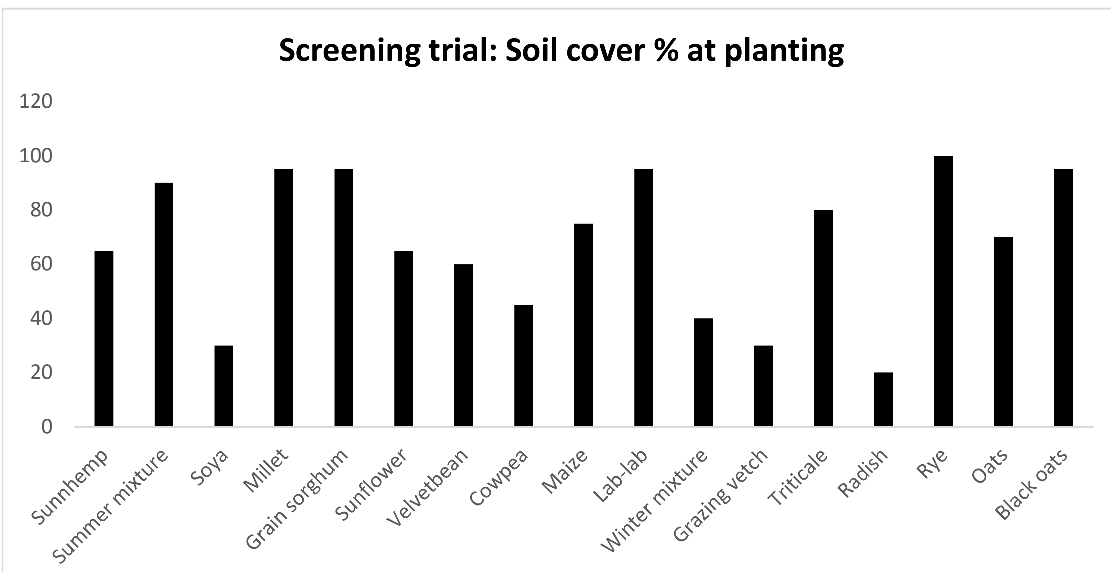

Figure 3.1: Ground cover before planting the screening trial

A Jumil no-till planter was used for the establishment of the trial and this method was fairly successful. Plate 3.10 shows the planter plates and gears being changed.

Plate 3.10: Jumil no-till planter used for the establishment of the cover crop screening trial

The plant densities of crops differ for the different agro ecological regions due to climate and soil conditions. Figure 3.2 is an example of the planting densities that were used in the case of the summer annuals in a screening trial at Ottosdal.

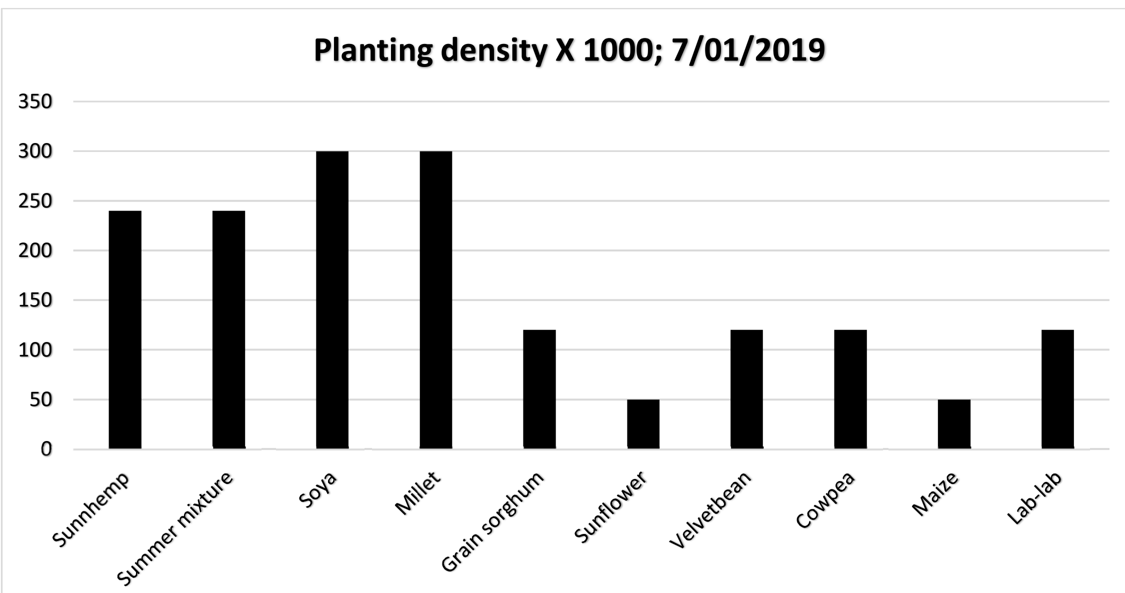

Figure 3.2: Plant densities used in the cover crop trial

The establishment of the trial was not satisfactory and the trial was replanted on the 6/02/2019.

At a steering committee meeting a decision was taken to terminate the trial. Valuable information such as biomass, growing habits etc. were, however, gained for the different treatments during the duration of the trial (5 years).

3.3.4. Sorghum screening trial and summer mixture

After discussing the screening trial with participating farmers at a planning meeting, it was decided to go ahead and plan a new trial. Mr George Steyn planted the trial on his farm, Humanskraal.

3.3.4.1. Background

Four seed companies were approached and requested to provide (sell) us their best performing sorghum type varieties and also enter a summer mixture that we could evaluate. This was deemed necessary because of the price difference between the varieties. Millet, Sudan grass, Sorghum, Sweet Sorghum and crosses between the different grasses were include to be tested for agronomic and animal production traits.

Companies and their varieties entered in the trials, are listed in Table 3.1. Companies were also asked to include a summer mixture to be tested in the different agro-ecological regions. Table 3.1 is a summary of the varieties of the different genotypes that were used in the trial and the cost of each per kilogram.

Table 3.1: Cultivars used in the screening trial

Cultivars	Pedigree	Species	Price/kg
Millet (BAR)	Pearl millet	*Pennisetum* spp.	R 9.60
Millet (AGT)	Pearl millet	*Pennisetum* spp.	R 18.00
Osakhana (Agricol)	Pearl millet	*Pennisetum* spp.	R 18.72
Pearler (BAR)	Hybrid millet	*Pennisetum* spp. X	R 148.00
Agrigreen (Agricol)	Hybrid millet	*Pennisetum* spp. X	R 48.00
Sugargraze (K2)	Sweet sorghum	Sweet sorghum X	R 60.00
Sweetfeed (AGT)	Sweet sorghum	Sweet sorghum X	R 36.00
Barsweet (BAR)	Sweet sorghum	Sweet sorghum X	R 53.50
Hunnigreen (Agricol)	Sweet sorghum	(PPS) Sweet sorghum X	R 77.50
Bargrazer (BAR)	Sorghum X Sorghum	Sorghum X	R 10.75
Supergraze (AGT)	Sorghum X Sudan	Sorghum X Sudangrass	R 10.00
AgFlash (Agricol)	Sorghum X Sudan	Sorghum X Sudangrass	R 15.20
Sentop (K2)	Sorghum X Sudan	Sorghum X Sudangrass	R 10.80
Nutritop plus (K2)	Sorghum X Sudan	(BMR) Sorghum X Sudangrass	R 58.00
K2 sudan (K2)	Sudan X Sudan	Sudangrass X	R 34.00

3.3.4.2. General information

This section contains information about the physical planting of the trial and rainfall data.

3.3.4.3. Planting of the trial

The sorghum trial and mixtures were planted with a no-till Piket planter on the 15/01/2019 in narrow 25 cm rows at a seeding rate of 10 kg/ha. The trial was planted into a very dry seedbed. The previous crop was Sunflower and the soil type is an Oakleaf soil form. Weed control included a Round-up treatment with no other pesticides.

For fertility management an N application of 42 kg/N was broadcasted before planting with a mixture that supplied: N-11, P-7,6 and K-3,5 kg/ha, applied during the planting operation. Although the trial was planted into very dry soil, the trial germinated and established well after the first significant rain fell.

3.3.4.4. Rainfall

From Figure 3.3 it is clear the rainfall was poor during the early season. The first significant rainfall of 111 mm was received in February 2019. With the 14 mm rain received in November 2018, Mr Steyn planted maize which yielded an acceptable 5.1 t/ha. After this the soil profile was unable to support germination because of the dry conditions.

The late rain in April could not be used optimally by the crops because they were already in a late stage of reproduction. Hopefully this moisture will be carried over to the next season.

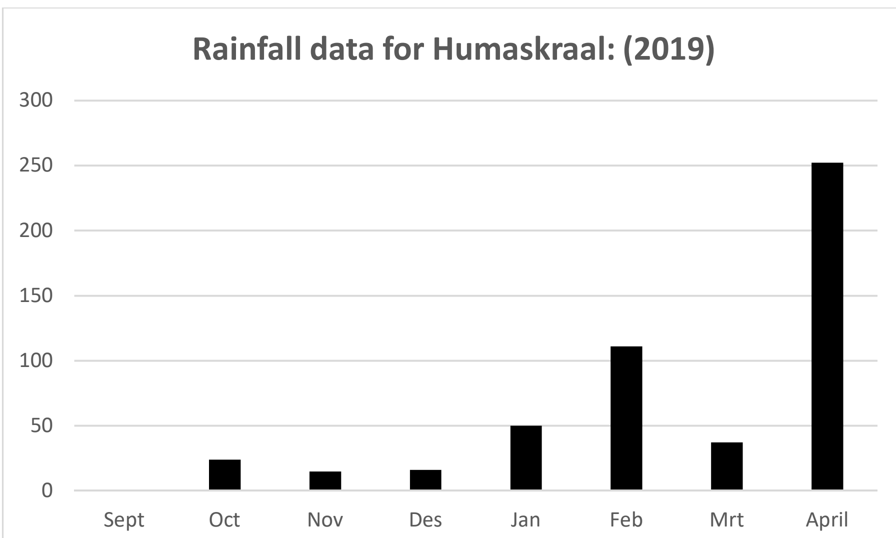

Figure 3.3: Rainfall data for Humanskraal 2019

3.3.4.5. Characteristics of the different genotypes

I. Sweet sorghum

Sweet sorghum has a vigorous growth habit. Leaves are very coarse and resemble that of maize. Plants are typically tall and generally late in maturing. They have low tillering capacity and re-growth rate after cutting or grazing. They are not recommended for grazing; they are mainly harvest for silage once they are past heading in order to maximize DM yield rather than quality. The level of cyanide in sweet sorghum are higher than other summer annual grasses.

II. Sudangrass

Sudangrass is native to Sudan in Africa; it is a tall annual forage crop with erect stems and narrow leaves. It is very fine stemmed with exceptional tillering capacity and excellent regrowth after cutting or grazing. However, sudangrass produces less forage yield compared to other summer annuals. Sudangrass is therefore recommended for either grazing or forage conservation. Plants do not tolerate frost and cold conditions and they then become dormant.

III. Sorghum x Sudangrass

Sorghum x sudangrass is a cross between sorghum (*Sorghum bicolour* (L) Moench) as the female plant and sudangrass (*Sorghum sudanense* (Piper.) Stapf) as the male parent. They are the most common hybrid, and they are considered as possible forage alternatives to maize silage in drought prone areas. These hybrids are intermediates of sweet sorghum and sudangrass in terms of character expression (medium tillering, regrowth capacities and nutrient value). The hybrids are higher yielding than sudangrass and pearl millet but they yield less than sweet sorghum. In order to ensure an excellent quality, it should be harvested or grazed to at least 45 to 60 cm.

IV. Pearl millet

This is a summer annual grass that originates in Africa and India. Of all the millets, pearl millet is the most important crop. It is robust and quick growing and can be interchanged with sorghum and maize. It is more drought resistant than sudangrass and sorghum x sudangrass. Hence, it produces excellent pasture and it has better digestibility than sorghum x sudangrass grown under the same conditions. Pearl millet is very sensitive to cold temperatures and at 2 – 3 ^{0}C will kill the crop. It is also very sensitive to overgrazing and a stubble high of less than 15 cm can be detrimental to the crop.

V. Hybrid millet (information from the product catalogue of Barenbrug)

Grazing Management - Pearler poses no risk of prussic acid poisoning, therefore it can be grazed at a much earlier stage than forage sorghum. For best results graze early - as soon as the plants are not easily pulled out of the ground. There may not appear to be a lot of feed at this stage, but due to quick regrowth and high tillering ability, feed supply is good. Early grazing will maximize protein and energy content, boosting animal productivity. High stocking rates - Pearler's quick regrowth and lack of prussic acid means it can be grazed heavily for long periods.

Soil selection - Although Pearler can produce exceptional livestock productivity, it does require suitable soil and management conditions to achieve this. Being a forage Pennisetum X, a good well-drained soil is required and a soil temperature of 18°C or more. Because Pearler has small seeds (60,000 to 80,000 seeds/kg) compared to the 32 00 seeds/kg for sorghum varieties, it can be planted at lower seeding rates.

3.3.4.6. BMR and PPS traits

Mutants and traits that influence the nutritional value and the growing season length of sorghum.

a) BMR gene

Sorghum varieties have also been improved by crossing them with mutants containing the Brown Mid Rib (BMR) gene in order to improve yield and digestibility. BMR is a marker related to decreased lignin content in sorghum, pearl millet and maize. It is most noticeable in the mid-rib of leaf as shown in Plate 3.11, but do occur in the plant as a whole.

Plate 3.11: BMR gene in sorghum (Nutritop plus)

3.3.4.7. PPS (Photoperiod sensitive) trait in sorghum

b) PPS trait

The transition from vegetative to reproductive growth in sorghum type plants hastens the decline in quality of the vegetative portion of the plant. Floral initiation is affected by several environmental factors but daylength is probable the most impontant. Regulation of flowering by daylength is referred to as photoperiodism. The delayed flowering is proposed to slow the decline in forage quality associated with floral innitiation. Floral initiation will not occur untill daylengt is less than 12 hours and 20 minutes.

All measurements are provided/shown as average ranges for the varieties of sorghum types pooled.

3.3.4.8. A short description of the different morphological properties

3.3.4.8.1. Tillering ability of different genotypes

It is well known that the fine stems, extensive tillering, and rapid regrowth of Sudangrass and Pearl millet make it better suited to pasturing than other types of sorghum. A new development on the market is the crosses of *Pennisetum* spp. (hybrid millet) with the same attributes. In Figure 3.4 the tillering ability of the different sorghum genotypes are display.

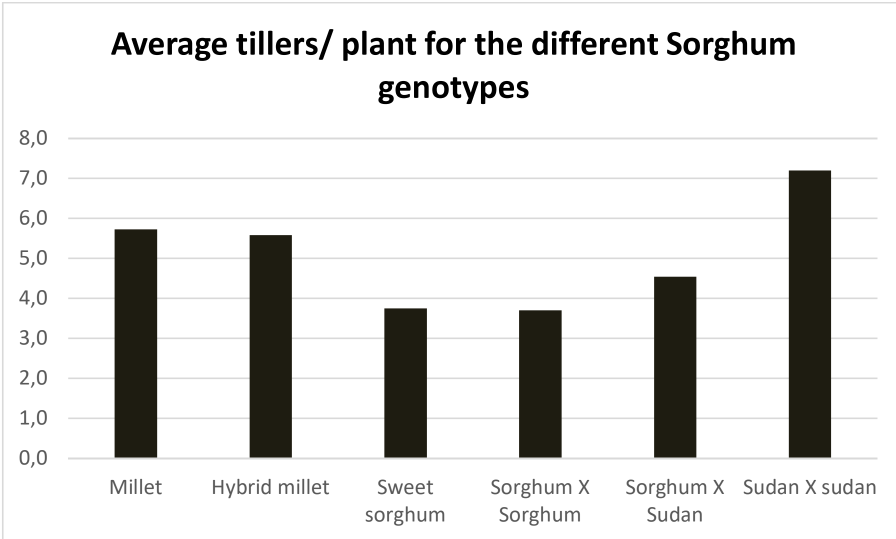

Figure 3.4: Average tillers for sorghum genotypes

3.3.4.8.2. Stem diameter

Of the sorghum types grown for forage, Sudangrass and hybrid millet have the finest stems, most profuse tillers and the most rapid regrowth following cutting of grazing. The finer stems usually are a trademark for better pasturing suitability. Millet, sudangrass and sorghum x sorghum sudangrass hybrids are widely grown commercially for direct pasture, hay, haylage, greenchop and silage. Thicker stems with higher sugar content makes sweet sorghum (Figure 3.5) better suited for standing foggage and silage.

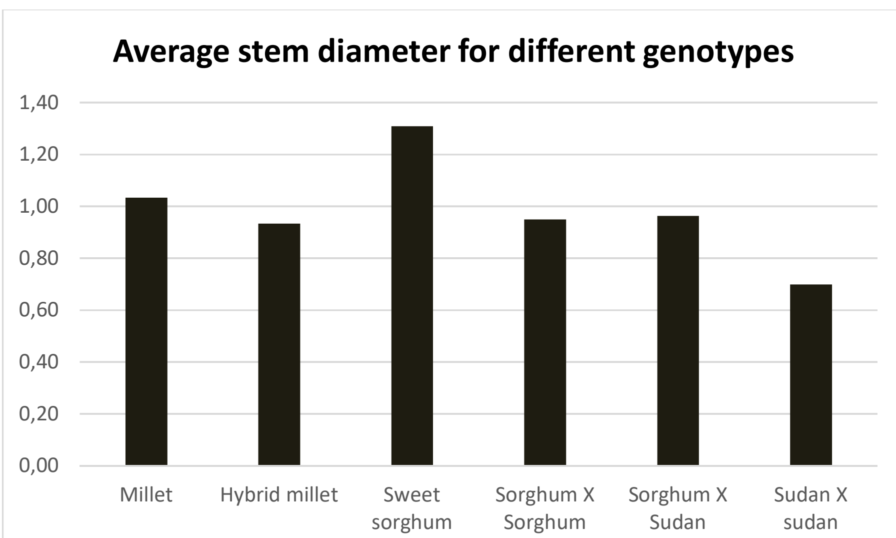

Figure 3.5: Average stem diameter for different genotypes

The thicker stems play a vital role in creating a surface mulch. This mulch, due to the high lignin content, usually protects the soil from the impact of raindrops. It also protects the soil from erosion and slower the water movement after raining events. Lignin compounds is also very complex for breakdown by micro-organisms and plays a vital role in creating long term carbon (humus) in the soil. Soil cover create soil surface temperatures that can be tolerated by plants and micro-organisms. After grazing sorghum mulch has a white coloration and reflect sunlight, which lower soil temperatures due to the albedo effect.

3.3.4.8.3 **Leave width and height** (functions of leave)

The leaves may be considered as the most important life-giving part of the plant body. The carbohydrate that is produced in the leaves in the process of photosynthesis sustains animal life, both directly and indirectly. This organic compound contains the energy which the plant obtains from the sun, the same energy that powers animal and human life. Likewise, the oxygen that plant leaves release, is essential to the continuing existence of animals and other aerobic organisms.

Plants lose a large volume of water through the leaves in the form of vapour. It is estimated that the loss of water via stomata through the process of transpiration exceeds 90 percent of the water absorbed by the roots. Transpiration as a process is also responsible for water and nutrient uptake from the soil. It also cools the plant during hot weather conditions.

The leaves serve as food storage organ of the plant both temporarily and on long-term basis. Under favourable conditions, the rate of photosynthesis may exceed that of translocation of photosynthates toward other organs. During the daytime, sugars accumulate in the leaves and starch is synthesized and stored in the chloroplasts. At night-time, the starch is hydrolysed to glucose and respired or converted to transportable forms like sucrose.

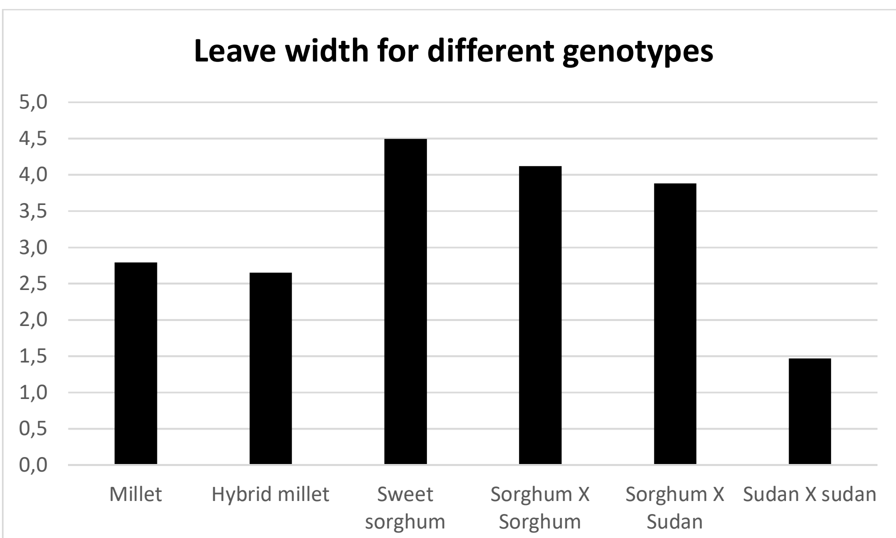

Figure 3.6: Leave width for sorghum genotypes

Studying Figure 3.6 it is evident that leave width is correlated with yield of the different genotypes. Sweet sorghum, having the widest leaves, produced the highest yield and sudan crosses, having the narrowest leaves, produced the lowest yield. Narrow leaves are also associated with multi-cut genotypes. Broad leave varieties also seemed to grow higher so a positive relationship exist between height and leave width in Figure 3.7. Sudan X seems the exception in this case and this season grown tall.

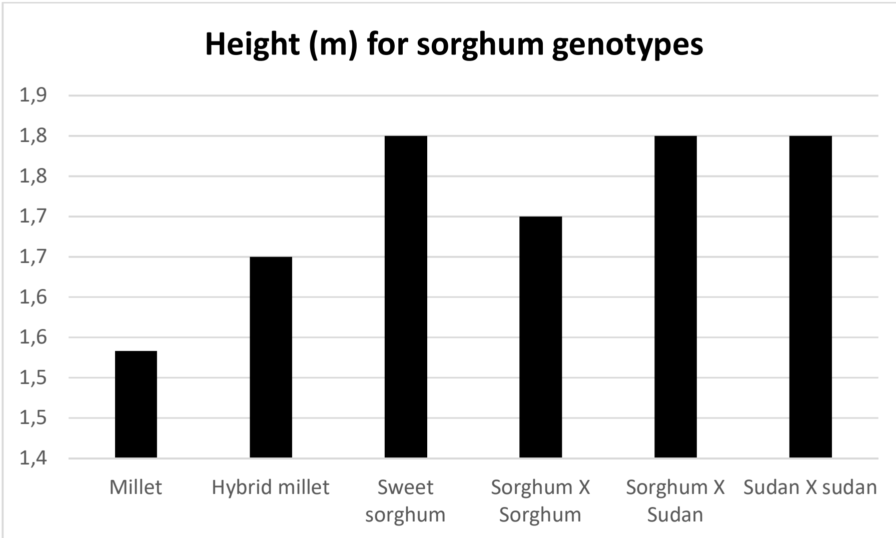

Figure 3.7: Height of sorghum types

3.3.4.8.4. Plant density for different sorghum genotypes

Under semi-arid condition of the North West province (with limited rainfall and warm temperatures) an optimal plant density of between 15 – 25 plants per m^2 were targeted. K2 Sudan grass did not germinated sufficiently to reach that target as sown in Figure 3.8. Planting into dry top soil conditions probably worsen the effect of the drought on plant density.

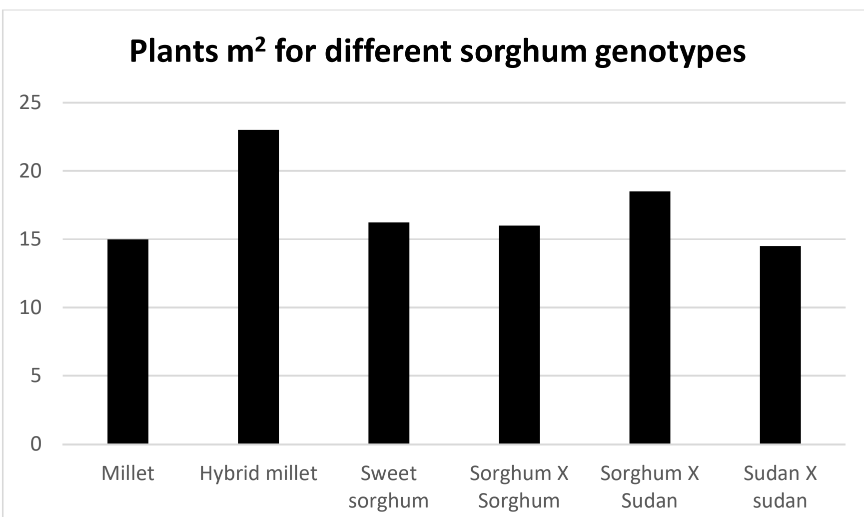

Figure 3.8: Plant per square meter for sorghum genotypes

Previous research has demonstrated that optimisation of plant density exerts a pronounced effect on productivity, therefore, planting density plays a pivotal role in most crop management practices. More specifically, appropriate plant density improves canopy micro-environment and photosynthetic capacity, delay leaf senescence, substantially increase aboveground biomass accumulation, improve light utilisation efficiency, and optimises physiological function and result in a greater potential biomass yield. As plant density reached an optimal point, plant height, tiller numbers and leaf area index (LAI) increases are observed.

3.3.4.8.5. Basal cover percentage

Basal cover can be defined as that area of the plant that extend into the soil surface. Measuring basal cover provides us with a cover percentage that can be used to determine the soil's vulnerability to experience soil erosion. For sorghum, growing very tall and is funnel shaped, erosion can still be 50% of bare soil due to the height of the plants. A basal cover of 20% for sorghum type varieties can be regarded as significant to lessen the effect of running water at the soil surface. Figure 3.9 clearly shows that millet, sweet sorghum and sudangrass did not use the space optimally. Higher plant density and amount of tillers will, as a rule, influence basal cover positively.

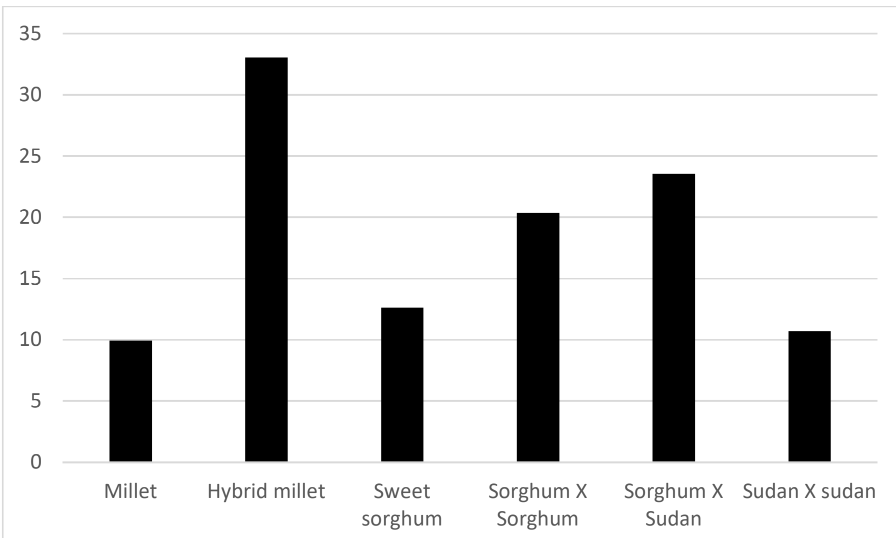

Figure 3.9: Basal cover % for different sorghum genotypes

3.3.4.8.6 Biomass production of the different genotype

The sorghum trial at Humanskraal resembled a spit plot design. Part of the plots were harvested twice while a portion of the plot was left until it reached a stage where plants were in a late soft dough stage before it was harvested. The first harvest took place on 15/03/2019, sixty days after planting. The second harvest was on 9/05/209, which allowed a regrowth period of 54 days. The full season's harvest was also performed at the last mentioned date. The full season growth was approximately 114 days after planting.

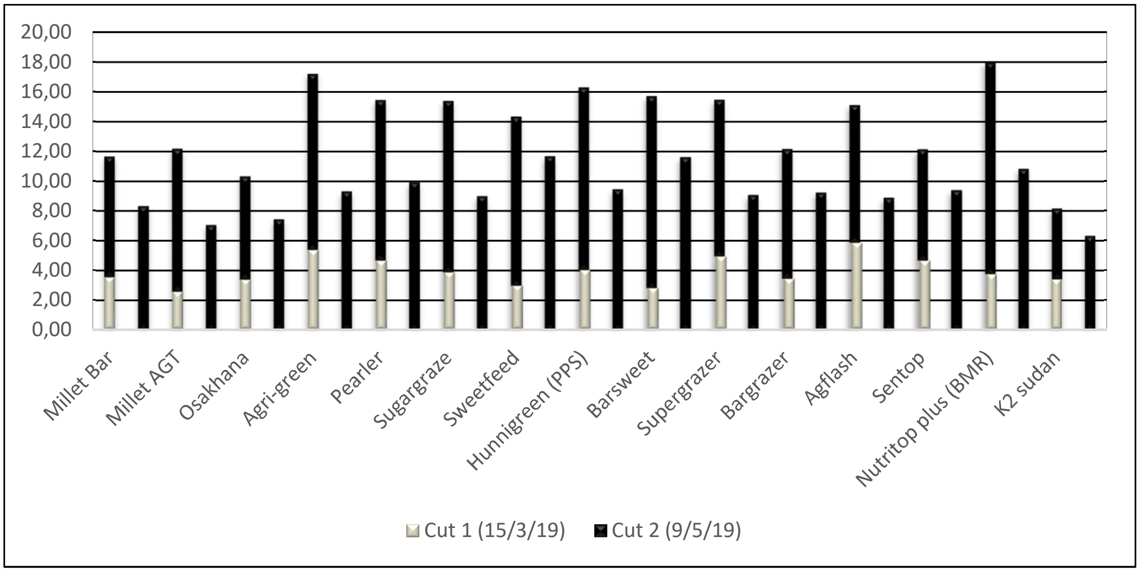

Figure 3.10: Regrowth vs full season DM

Studying Figure 3.10, it is clear that the multi-cut treatment outperformed the full season treatment. The grey area in the figure represent the yield obtained from the first cut and the black line on top, the yield obtained for the second cut, while the solid black line represents the full season yields for the different varieties. This is unexpected because under normal circumstances it is usually the full season treatment that will outperform the multi-cut treatments. This phenomenon can possible be attributed to the low rainfall early in the season. With the late rain of 250 mm in April the multi-cut treatments produced more leaves and were still in an active vegetative growth period as can be seen in Plate 3.12. The sorghum in the front of the photo was cut twice and had less panicles than the full season treatment that was cut for the first time seen at the back of the photo.

Plate 3.12: Hunnigreen still actively growing

The sorghum sudan cross, nutritop plus (BMR) treatment in terms of yield, outperformed the other treatments. As a group the sweet sorghums outperformed the sudangrass and the sorghum sudan crosses except for hybrid millet Agri-green. As discussed earlier for the different genotypes, these were the only exceptions. Agri-green, Pearler, Supergrazer and AgFlash performed well early in the season and had the highest DM yield for the treatments at the first cut. The average biomass growth per day for the treatment at the first cut was 65 kg and for the second cut increased to 182 kg, while for the full season single cut it was 78kg.

3.3.4.8.7. Seed cost relative to production

For illustrative purposes, it seems a good idea to divide the yield (DM) of each variety by the cost of seed per hectare. George Steyn planted all the different varieties at a seeding rate of 10kg/ha. From Figure 3.11 it is clear that Pearler (hybrid millet), at a cost of R148/kg, had the highest cost to produce a ton of feed on a DM basis. For farmers that wants to utilize the crop for grazing purposes or for soil surface protection, planting sorghum sudan crosses and pearl millet genotypes make a lot of sense, because of the seed cost. For instance, for Supergraze to produce a ton of DM it will cost R6. Input cost do exert pressure on economic viability.

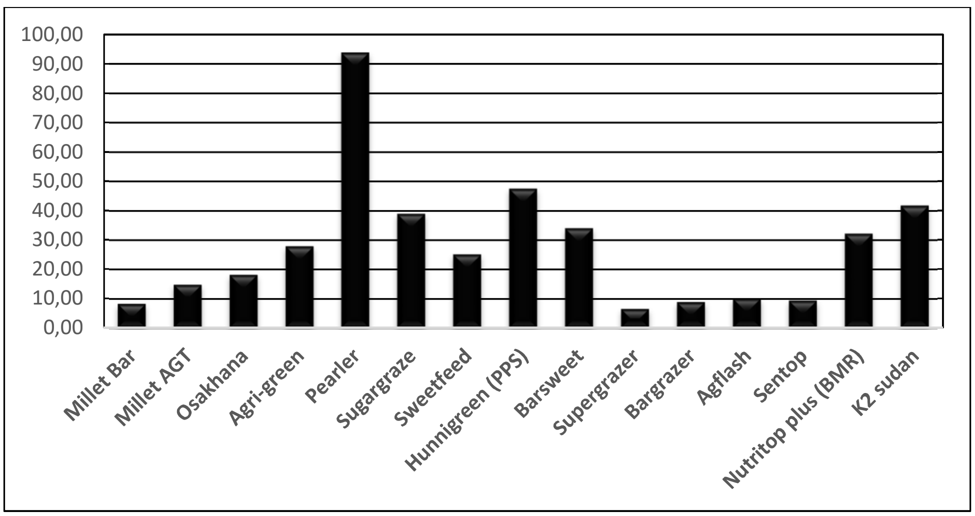

Figure 3.11: Price to produce 1 ton DM, Ottosdal 2019

3.3.4.9. Animal production

Forage quantity:

Environmental properties do have an influence on crop yield but the most important factor influencing nutritional value in relation to animal production is the stage of utilization. Older plants have less cell content and more fibres. This has a detrimental effect on intake and digestibility. The most important factors that determine animal production.

Sorghum varieties are greatly affected by the environment in which they grow. Any environmental condition such as temperature, drought, hail damage and late sowing, which are below the optimum for plant growth and development can be described as stressful for plants.

High temperatures increase dry matter production and tiller size, but reduce tiller numbers, leaf/stem ratio and organic nitrogen concentration in the DM.

The potential of forage to produce the desired animal response. It comprises of the nutrient value, anti-quality factors and potential intake, while nutritive value describes nutritive concentrations and digestibility or can be seen as a measure of a diet's ability to meet animal requirements for production and growth.

Feed quality (digestibility, metabolisable energy, neutral detergent fibre (NDF), acid detergent fibre (ADF) and crude protein) of specific forage is influence by the amount and type of compounds in the forage. Animal productivity on a forage diet is determined by the amount of intake, digestibility and the digestion rate of cell wall components.

The crude protein (CP) quality in plants is influenced by the type of species grown, management practises and maturity at harvest. When sorghum plants are young and growing rapidly, CP content may reach 20%, but as they increase in height, and near maturity, this decline to less than 7%.

This low value is less than the required rate for maintenance of livestock. For growing cattle and other ruminants a CP content of up to 19% might be required for optimal production. In Figure 3.12 leave samples from the different sorghum types were tested at the lab at Irene.

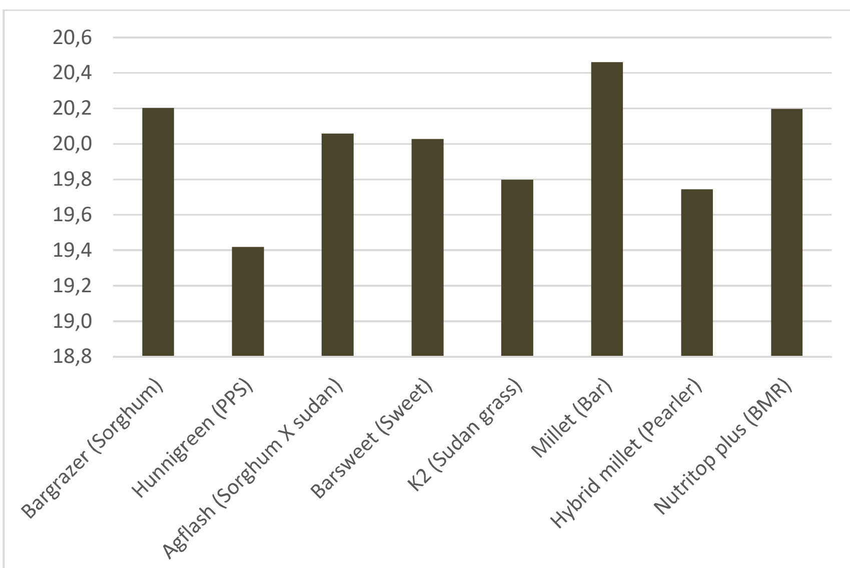

Figure 3.12: Crude protein % on DM basis for leaves, Ottosdal 2019

The leave samples were taken at a vegetative growing stage at Skulpspruit when sorghums plants were approximately 1 m in height. All treatments recorded above optimal CP content for high producing ruminants in Figure 3.12. Samples were also taken from the different treatments at Humanskraal when sorghums genotypes were at a late soft dough stage and a complete opposite picture emerges as shown in Figure 3.13 below.

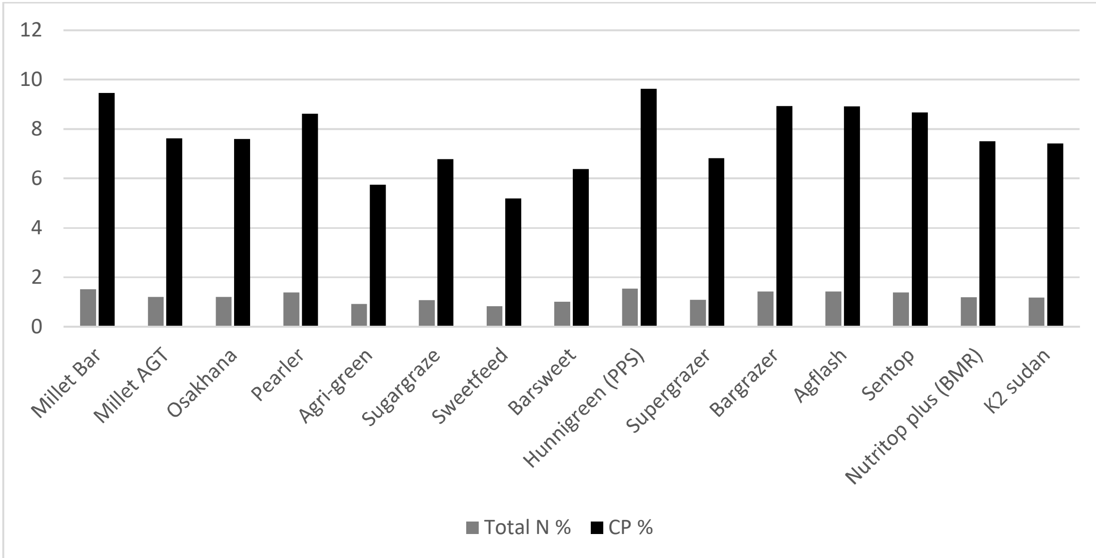

Figure 3.13: Total N% and CP% for sorghum at Humanskraal, Ottosdal 2019

The SCW lab determined the N% for the different treatments. Multiplying the N% content X 6.25 gives us a value for CP%. It is clear that Hunnigreen with the PPS trade, sorghum sudan crosses and one millet had the highest value for CP. The sweet sorghum varieties values fell below the requirements for animal maintenance at around 6% CP. Even as a mulch, this low value for nitrogen will create a situation where nitrogen will be tied up, while the residues are broken down in a CA system and create a nitrogen negative situation in the soil.

ADF and the NDF values from the young sorghum leaves sampled at Skulpspruit were also determined. ADF determine forage digestibility: the lower the lignin content, the more of the ADF fraction is digestible, and the higher the energy value of the forage. With ADF values below 30 in Figure 3.14 all genotypes will have a high energy value and will support high animal performance.

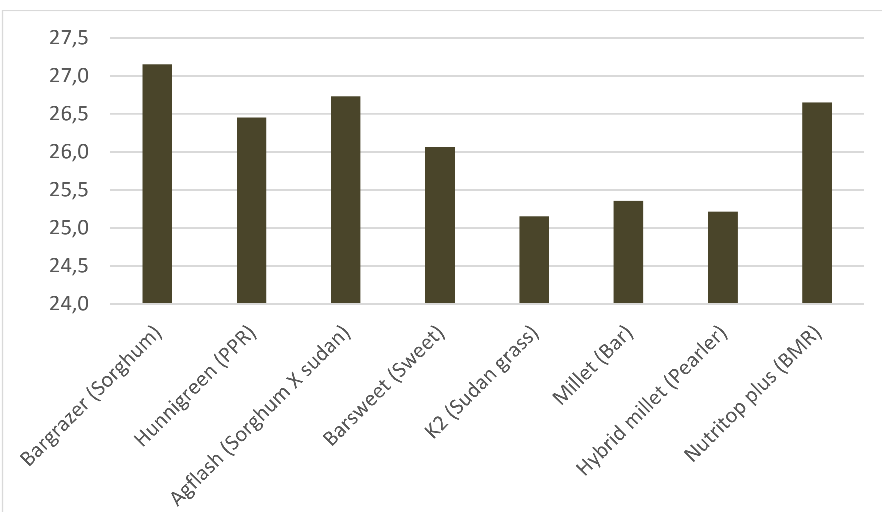

Figure 3.14: ADF values for sorghum genotypes, Ottosdal 2019

NDF indicates the cell wall content of forages and hence determines the rate of digestion. Feed that is highly digestible encourages high feed intake because of faster digestion rates, the more quickly the digestive track will be emptied and the more space is available for the next meal. The portion of DM that will be digested will increase and will increase the energy available. It is clear from Figure 3.15 that the *Pennisetum* spp. are more digestible than the other sorghum types. All the values, however, are below 60 and highly digestible and high forage intake will be possible when sorghums are in a vegetative stage.

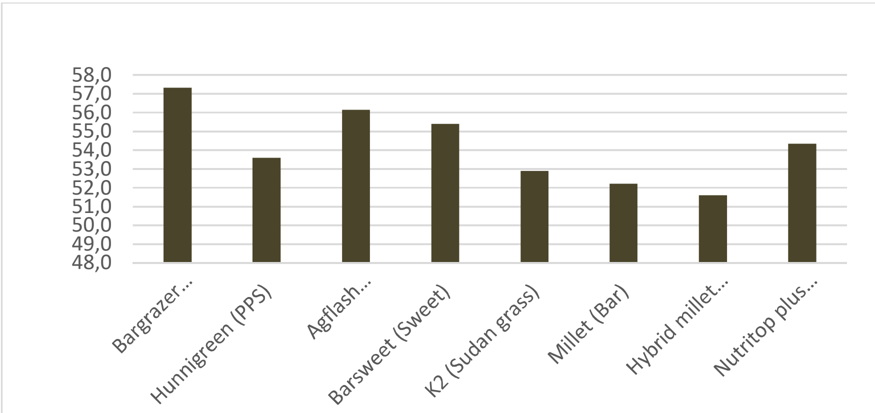

Figure 3.15: NDF values for sorghum genotypes, Ottosdal 2019

3.3.4.10. Root evaluation

To perform the root evaluation, a grid of 1 m^2 was divided into 20cm x 20cm blocks. A back actor was used to dig holes in the ground 1 m deep. The farmer evaluated the roots in each block. A score of 4 represented an excellent root distribution and 1 a lesser amount of roots in a block. Grazed as well as ungrazed treatments of two genotypes were evaluated and in both cases the ungrazed treatments perform better than the grazed plots. An example of the evaluation, done only at Skulpspruit, is given in Table 3.2.

Table 3.2: Root evaluation done at Skulpspruit

Root evaluation of sugargraze for ungrazed treatment at Skulpspruit 4/6/2019

	0-20cm	20-40cm	40-60cm	60-80cm	80-100cm	Total
0-20cm	4	4	4	4	4	20
20-40cm	4	4	4	4	4	20
40-60cm	3	3	3	3	3	15
60-80cm	2	2	2	2	2	10
80-100cm	2	2	2	2	2	10
Total						75

During severe drought, sorghum has the ability to extract water from the sub-soil (45 – 135 cm), while pearl millet absorbs water from all layers (0 – 135 cm). For this reason, it makes the latter a preferred choice in drought stricken regions.

In order to get maximum DM, the sowing date should be delayed until the ground temperatures reached at lease 15-17 °C. Table 3.2 is testimony to the prolific root system of sorghum plants. A score of 4 in the table represents excellent root distribution while 1 represent poor root distribution. Sorghum received a score of 75 which is above average. Pearl millet had a score of 80 for the same trait.

3.3.4.11. Anti-quality factors associated with fodder sorghum type plants

1. Prussic acid

Prussic acid and nitrate poisoning is a real threat when grazing sorghum. Careful management, especially under drought condition, frost and trampling since this could cause prussic acid to increase. The rupture of the cells should be avoided at all cost.

Sorghum and sudangrass plants contain a compound called dhurrin, which can break down to release prussic acid (hydrogen cyanide, HCN). Sudangrass has low levels of this compound and rarely kills animals. Sorghum has the highest levels and sorghum-sudangrasses are intermediate. There is also considerable varietal difference in prussic acid content for all types of sorghums. Dhurrin content is highest in young plants. Millet and hybrid millet contains no dhurrin and do not pose any treat of prussic acid to livestock.

Animals have the ability to break prussic acid down as long as there is enough sulphur reserve in their body tissue; however, if depleted, sulphur deficiency cause a reduction in appetite which in turn leads to a decline in average daily gain or milk production. The following practices are recommended:

a) Do not graze the crop when it is showing signs of severe stress caused by factors such as low soil moisture, trampling and initial growth after stress is also high in prussic acid.
b) Feed livestock first before introducing it to sorghum feed.
c) Do not graze the crop before it reaches 0.6 m high.
d) Introduce only a few animals rather than the whole herd and observe their reaction.
e) Provide sulphur salt lick to livestock.
f) Use low risk varieties.

2. Nitrate poisoning

Sorghum can accumulate nitrates (NO_3) during any weather conditions that interferes with normal plant growth; however, drought is the most common cause. NO_3 is converted to nitrate (NO_2) in the rumen, which it diffuses into the bloodstream and binds to haemoglobin. Most NO_3 accumulates in the stems or lower portions of the plant. Ensiling the forage can lower the NO_3 by 50%.

3.3.4.12. Conclusion

Good information was gained during the sorghum screening trial period through the 2018/2019 season. Farmers expressed their willingness to repeat the trial.

4. Agronomic field trial planning and analyses

4.1. Work package

Work Package title	**Agronomic field trial planning and analyses**
Work Package period	October 2018 to September 2019
Lead partner	Independent agronomist - Dr. A. A. Nel
Involved partners	Ottosdal No-till club members, Grain SA
Objectives	• To plan the various on-farm maize CA related field trials • To analyse and report the results of these trials
Justification	The soil and probably also the micro climate are dramatically changed when conventional cropping systems is abandoned and conservation agriculture crop systems implemented. This environmental change affect most, if not all, agronomical parameters which need to be revised for optimization. This can only be achieved through field trials. It is also important to determine if the ultimate goal of CA namely, the reversing of soil degradation, is achieved. Agronomic parameters include, row widths, plant population densities, crop rotation systems, planting technique, fertilization practices, weed control, the role of cover crops and more. Crop responses to changes in management and the environment are usually liable to interactions resulting in variation of the results, which might lead to wrong conclusions and recommendations. In order to generate scientifically sound recommendations on these agronomical parameters, proper planning and analyses of the results is needed. Field trials will also be of value to demonstrate the benefits of conservation agricultue and serve as observation and training oppertumities in other research fields such as pests and diseases.

Description of work	Planning of trials in collaboration with participating farmers. Analyses of farmer collected results and reporting of findings.

Activities	Planning of trials through the attendance of the frequent coordination meetings where aims and procedures will be discussed with farmers. Planning of trial layout and compiling of data sheets to be completed by participating farmers. Statistical analyses, interpretation, discussion and drawing of conclusions from the collected data. Presentation and reporting of the results to participants and MT as required.

Deliverables	• Annual trial plans report • Regular attendance of meetings • Reporting as required • Popular article once enough results have been acquired.

Risks	Adequate involvement and participation of farmers

4.2 Deliverables, progress and results achieved per activity

Activities *(as specified in Work Package or project proposal)*	**Deliverables or Milestones** *(as specified in Work Package or project proposal)*	**Progress and Results achieved;** and/or **Problems and Milestones <u>not</u> achieved** (in report period)
Planning of trials	Field trial plans and data sheets.	After a Club meeting (16 October 2018) where the objectives were discussed, field trial plans and data sheets were compiled and supplied.
Statistical analyses, interpretation, discussion and drawing of conclusions from the collected data.	Report on results	Al results received from the No-till club were added to previous results, all data were analysed, conclusions drawn and documented (see addendum).
Presentation and reporting of the results to participants and MT as required.	Annual and biannual reports and presentation	Results of 2017/2018 were presented to the No-Till Club at an open meeting on 14 August 2018. An article "Voorkom dié foute met bewaringslandbou" was published in September 2018 edition of SAGrain. An article

		"Bewaringslandbou skep nuwe navorsingsbehoeftes" was submitted to SAGrain in July 2019. An 18-page booklet on the trial results was compiled and printed as conference handout. A talk on crop rotation during the trial visit was given during the 2019 conference (200+ attendees. A six monthly progress report on the trial planning and analyses was compiled and submitted to the project leader. Results were presented during the September 2019 Maize Trust CA forum meeting.

4.3. Summary of agronomy work package for 2018/2019

ACTIONS TAKEN TO DATE

Field trials were described and planned according to the objectives decided on by club members during the planning meeting of 16 October 2018. The trial plans were provided to the No-till club for execution. The soil cover was measured shortly after planting of trials. Data of 2018/2019 were added to results of previous seasons, analysed and conclusions made and documented. The research objectives were to compare:

1. Crop rotation systems (since 2013/2014, continuing)
2. Argentinian and local row widths and populations (2013/2014 to 2016/2017)
3. Tines and coulter fitted on planters (2013/2014 & 2015/2016)
4. Plant population densities (2013/2014, 2015/2016 & 2016/17)
5. Maize cultivars (since 2013/2014, continuing)
6. Conventional crop systems and CA crop systems (2015/2016 to 2017/2018)
7. Grain yield and soil health as affected by a cover crop – sunflower – maize rotation system and monoculture with maize and sunflower in two plant arrangements (2018/2019 - continuing)

Results from these trials were presented at meetings and published as indicated above under "Progress and Results achieved".

PROGRESS MADE

The following number of trials were planned, conducted from 2013/2014 to 2018/2019 and the results analysed for each objective:

Objective	**Number of trials**
Crop rotation systems	8 (farm x season combinations, continuing)
Argentinian versus local row widths and populations	23 (three crops, four seasons, completed)
Tines versus coulter fitted on planter	5 (three seasons, completed)
Plant population densities	17 (four crops, completed)
Maize cultivar evaluation	12 (six seasons, continuing)
Conventional crop systems vs CA crop systems	7 (three seasons, completed)
Grain yield and soil health as affected by a cover crop – sunflower rotation under two plant arrangements	1 (one season, started in 2018/2019)

RESULTS ACHIEVED TO DATE

Since 2013/2014, a total of 73 field trials on various farms was done. Since 2015/2016, more intensive trials are done on two or three farms. The following gives a short description of the different objectives and the conclusions from the various trials. The addendum gives a more comprehensive description of the results.

Crop rotation systems: As crop rotation is one of the pillars of CA, the objective is to find the best rotation systems for this area. Results from the five seasons of crop rotation indicate that maize following sunflower and maize in monoculture in no-till systems outperform maize following other crops such as legumes. This is contrary to published results for tilled soil. The rainfall use efficiency for maize was also relatively high, in comparison with that of tilled maize of the area, indicating that the efficient use of the limited resource is improved by CA systems. Sorghum performed well when it followed maize, cowpea and soybean crops. Soybean performed well when preceded by cowpeas, maize and in monoculture. Sunflower yields were above the mean when preceded by forage sorghum, maize and sunflower in monoculture. Results from a longer period of time is needed before sound conclusions can be reached.

Argentinian versus local row widths and populations: Narrow 0.52 m spaced rows with increased plant population densities were compared to the local width of 0.76 to 0.91 m spaced rows and lower plant densities for maize. With the exception of three trials, the yield of maize was similar or higher in the Argentinian system compared to that of the local system in the remaining 16 trials. Over all trials the yield advantage of the narrow rows was 0.55 t ha^{-1}. In the case of sunflower, 0.52 m spaced rows had an average yield advantage of 0.16 t ha^{-1} over the 0.91 spaced rows at similar plant densities.

Tines versus coulter fitted on planter: Yields were similar for treatments although a tine working depth of 240 mm instead of 150 mm, resulted in a maize yield increase.

Plant population densities: The aim of this study was to get an indication of the optimum plant population density for maize, soybean sunflower and sorghum in conservation agriculture systems. Three of the maize response curves of the 0.9 m spaced rows indicate that the optimum plant population density is between 30 000 and 38 000 ha^{-1} while the third curve is inconclusive. Two of the 0.76 m row spaced trials suggest an optimum plant density of between 23 000 and 30 000 ha^{-1}. Sunflower and sorghum yields showed no significant response to a range of "normal" plant population densities while the optimum for soybean appear to be above 300 000 plants ha^{-1}.

Maize cultivar evaluation: Seed companies participate in these trials by suppling four cultivars each season for evaluation. These cultivars are no-till planted at 40 000 seeds ha-1 in strips of 12 rows at 0.52 m spacing. Every third strip is planted with a selected control cultivar. After harvesting, yields of all cultivars are adjusted or normalised according to the yield of the nearest two control strips. The adjusted yields are presented as required.

Conventional crop systems vs CA crop systems: Seven trials were done on three farms in three seasons. The performance of no-till maize grown in 0.52 m rows at 40 000 ha^{-1} and in 0.91 m rows at various densities were compared to the performance of maize grown in the tillage system which is applied on the farm and plant densities equal to or below 24 000 ha^{-1}. Tillage systems varied from mouldboard ploughing, strip till to deep ripping. There is strong evidence that the yield of the no-till maize improves due to no-till. In only one out of the seven trials was the yield of the conventionally tilled maize higher (by 0.8 t ha^{-1}) than the yield of one of the no-till systems. In six of the seven other cases, the yields of the no-till systems were equal to, or higher (from 0.04 to 2.42 t ha^{-1}) than the yields of the conventional system, most likely due to improved water infiltration capacities of the soil as found in one trial.

Grain yield and soil health as affected by a cover crop – sunflower rotation under two plant arrangements: This statistically laid-out trial started in 2018/2019 and was planted in January 2019 due to drought. Results about soil health and how yields are affected by the rotations will be available from 2019/2020. Maize plant arrangement affected yield. Maize in 0.52 m rows at 40 000 plants ha^{-1} had a significantly higher yield (0.65 t ha^{-1}) than maize in 0.91 m rows at 22 000 plants ha^{-1}, confirming previous results.

PROBLEMS ENCOUNTERED AND MILESTONES <u>NOT</u> ACHIEVED IN 2018/2019

Extremely low rainfall from November and December 2018 prevented timeous planting of the trials. Planting started early in January 2019 which is too late for most crops. All results collected in 2018/2019 should be viewed in this context.

4.4. Results 2013/2014 to 2018/2019

4.4.1. Suitable crop rotation systems for CA

Introduction

It is well known that crop rotation can reduce the risk of diseases, pests and weeds, and enhance soil quality. When grown in rotation, yields are often higher than those of monoculture crops.

Crop rotation is one of the three principles of conservation agriculture. Limited research results regarding crop rotation in conventional tillage are available, while the influence of crop rotation in no-till on the performance of any of the crops currently grown in the Ottosdal area, is unknown. Preliminary results indicate that limited monoculture (a few years) with maize may be successful in conservation agriculture, however, the long-term effect of crop rotation is unknown and need clarification.

Aim

The aim is to investigate the influence of six crops on the grain yield of each other for a number of years to find the best crop sequence.

Procedure

The six crops namely, cowpeas, forage sorghum, grain sorghum, maize, soybeans and sunflower were grown during the 2013/2014 season on three farms. The cycle length of the rotation systems is two years and a crop matrix is used for the trial layout. The matrix consists of strips of each crop next to each other (2013/2014). In 2014/2015 the strips were planted square on those of 2013/2014, resulting in five rotation plots and one monoculture plot for each crop. In 2015/2016 and 2017/2018, the layout of year 2013/2014 was used and in 2016/2017 and 2018/2019, the 2014/2015 layout was repeated.

Crops were planted in 0.52 m wide rows, fertilised according to the potential of the soil using well-adapted cultivars of the various crops. Farms where trials were planted in 2014/2015 were Humanskraal, Noodshulp and Holfontein. Since the extreme drought of 2015/2016, the trial continued only at Humanskraal. Plant population densities were 40 000 ha^{-1} for maize and sunflower, 150 000 ha^{-1} for grain sorghum, 300 000 ha^{-1} for soybean and 230 000 ha^{-1} for cowpeas respectively. The trial is usually planted in December. However, due to extreme low rainfall in November and January, the trial was planted on 6 January 2019. Forage sorghum was replaced with a cover crop mixture in 2018/2019.

Results

The first season of this trial served only to create a "rotational effect" in the soil. Yields recorded in two of the three trials planted in 2013/2014 are shown in Table 4.1. Yield results of the 2014/2015 to 2018/2019 seasons are shown in Table 4.2.

Yield of crops in 2014/2015

The yield of both maize and grain sorghum was significantly affected by the previous crop, although all yields were low. The yield of maize preceded by forage sorghum was 60% or 0.84 t ha^{-1} higher than the mean yield of maize preceded by cowpea, maize, soybean and sunflower. The grain yield of grain sorghum preceded by maize and soybean was 127% or 0.78 t ha^{-1} higher than that of grain sorghum preceded by sunflower. Compared with the other rotational crops, sunflower was the only crop that had a suppressive effect on the yield of both maize and grain sorghum. Due to a lack of replicates, no conclusion can be made about the soybean yield response.

Table 4.1. Grain yields of the crops planted in the crop rotation trial in 2013/2014

Farm	Maize ($t\ ha^{-1}$)	Sorghum ($t\ ha^{-1}$)	Soybean ($t\ ha^{-1}$)	Sunflower ($t\ ha^{-1}$)
Humanskraal	8.92	2.85	2.05	2.85
Noodshulp	6.08	3.73	2.67	2.92

Mean crop yields 2014/2015 to 2018/2019

Due to a lack of replication, no annual statistical analyses could be made since 2015/2016. Crop yields showed a very large variation from season to season. The yield of maize for example, varied from slightly more than one ton per ha to more than nine ton per ha. Due to the extremely late planting of the 2018/2019 seasonal, cowpeas, sorghum and soybean did not produce any significant yield while the maize and sunflower crops produced relatively low yields.

The overall mean maize yield for the four seasons 2014/2015 to 2018/2019 was 4.89 t ha^{-1}. The mean yield of maize following sunflower and maize (monoculture) was respectively 10 and 6% higher than the overall mean yield, while the maize yield following soybean, cowpeas, forage sorghum and grain sorghum were between 2 and 6 % lower. The yield of maize following sunflower was higher than the annual mean yield in four of the five seasons.

Excluding the crop failure of 2018/2019, the four-year mean yield of grain sorghum following cowpeas, maize and soybean was 16, 25 and 4% higher than the overall grain sorghum yield of 3.09 t ha^{-1}. Yields following sunflower, forage sorghum and grain sorghum (monoculture) were 11, 25 and 8% respectively lower than the overall mean. The yield of grain sorghum following maize was above the mean yield in three of the four seasons.

Soybean yields were strongly affected by crop rotation. The four year (excluding the 2018/2019 failure) mean yield was 19, 17 and 8% higher than the overall mean of 1.61 t ha^{-1} following cowpeas, maize and forage sorghum respectively. However, mean yields were between 3 and 22% lower than the overall mean following soybean, sunflower or grain sorghum. Soybean following cowpeas and maize had above mean yields in three of the four seasons.

The five-year mean sunflower yields after forage sorghum, maize and sunflower itself, were 5, 8 and 8% respectively higher than the overall mean yield of 1.65 t ha^{-1}. Yields were between 4 and 9% lower than the overall mean after cowpeas, grain sorghum and soybean. Above mean sunflower yields were found for all preceding crops in either two or three of the five seasons.

Table 4.2 Grain yields in t ha^{-1} from 2014/2015 to 2018/2019 as affected by the preceding crop. Yields equal to, and above the mean in a particular year, are indicated in bold print

Season	Preceding crop					
	Cowpea	Forage sorghum	Grain sorghum	Maize	Soybean	Sunflower
			Maize			
2014/2015	1.11^{B*}	**2.23^{A}**	**1.72^{AB}**	1.51^{B}	1.45^{B}	1.51^{B}
2015/2016	4.17	4.17	3.85	**5.38**	3.79	**5.94**
2016/2017	8.93	7.86	**9.24**	**9.18**	8.96	**9.29**
2017/2018	6.53	6.40	**7.20**	**8.23**	6.63	**7.74**
2018/2019	**2.74**	**2.32**	1.95	1.61	**2.59**	**2.51**
Mean	4.70	4.60	4.79	5.18	4.68	5.40
			Grain sorghum			
2014/2015	1.08^{AB}	1.08^{AB}	1.03^{AB}	**1.24^{A}**	**1.53^{A}**	0.61^{B}
2015/2016	**3.20**	2.76	2.60	**3.22**	2.62	**3.27**
2016/2017	2.81	**3.39**	**3.17**	2.39	**3.28**	**3.46**
2017/2018	**6.64**	2.20	**5.27**	**7.51**	**5.89**	3.85
2018/2019	0	0	0	0	0	0
Mean#	3.58	2.30	2.82	3.86	3.21	2.75
			Soybean			
2014/2015	0.75	**0.95**	**0.80**	0.63	**0.93**	0.56
2015/2016	**1.09**	0.85	0.61	**1.51**	**0.93**	0.49
2016/2017	**2.75**	**2.91**	1.32	**2.30**	1.89	1.86
2017/2018	**3.09**	2.22	2.22	**3.09**	2.47	2.35
2018/2019	0	0	0	0	0	0
Mean#	1.96	1.34	1.48	1.77	1.77	1.32
			Sunflower			
2014/2015	1.61	**2.23**	**3.35**	2.00	1.28	2.00
2015/2016	**1.57**	0.99	1.00	1.10	**1.98**	**1.96**
2016/2017	**2.20**	**2.14**	1.84	1.92	**2.27**	2.05
2017/2018	1.74	1.69	**1.75**	**2.02**	1.64	1.63
2018/2019	0.76	**0.79**	0.65	**0.88**	0.69	**0.86**
Mean	1.57	1.73	1.49	1.78	1.54	1.79

*Means followed by different letters in a row are significantly different at P = 0.05.

#Mean for 2014/2015 to 2017/2018

Soil cover

The soil cover left by the preceding crop after planting of the current crop at Humanskraal from 2016/2017 to 2018/2019, is shown in Table 4.3. The cover left by all crops varied markedly from season to season. As expected, the cover left by cowpeas, sunflower and soybeans (mean 43%) was lower and more variable than the cover left by forage sorghum, grain sorghum and maize (mean 85%).

Table 4.3 The soil cover left by the preceding crop after planting of the current crop from 2016/2017 to 2018/2019 at Humanskraal

Season	Preceding crop					
	Cowpea	Forage sorghum	Grain sorghum	Maize	Soybean	Sunflower
			Maize			
2016/2017	27	98	82	96	42	26
2017/2018	90	88	90	90	55	53
2018/2019	50	98	89	96	36	66
Mean	56	95	87	94	44	48
			Grain sorghum			
2016/2017	27	90	82	70	18	24
2017/2018	93	93	95	88	65	50
2018/2019	61	70	82	77	20	30
Mean	60	84	86	78	34	35
			Soybean			
2016/2017	28	90	64	90	16	28
2017/2018	73	88	83	73	60	35
2018/2019	41	80	91	82	11	43
Mean	47	86	79	82	29	35
			Sunflower			
2016/2017	40	82	64	76	22	26
2017/2018	75	88	78	90	60	49
2018/2019	39	86	80	73	25	39
Mean	51	85	74	80	36	38
Over all mean	54	88	82	84	36	39

Water infiltration rate

The water infiltration rate of soil is one of the important changes observed when conventionally tilled soil is converted to CA. The time it took for 25 mm of water to infiltrate the soil was measured on all maize plots in February 2018 (Table 4.4). It took less than 6 minutes and relatively similar and high for all preceding crops compared to the typical 8 – 20 minutes for tilled soil.

Table 4.4 The time it took for 25 mm of water to infiltrate the soil on maize plots during February 2018 in minutes at Humanskraal

Season	Preceding crop					
	Cowpea	Forage sorghum	Grain sorghum	Maize	Soybean	Sunflower
2017/2018	4.16	4.52	3.75	4.20	5.30	3.16

Rainfall use efficiency

The rainfall use efficiency is calculated by dividing the grain yield by the accumulated rainfall from 1st October to 30th May for each season. The results are shown in Table 4.5.

Table 4.5 Rainfall use efficiency in kg ha^{-1} mm^{-1} accumulated rainfall from 1st October to 30th April for the different grain crops as affected by the preceding crop at Humanskraal from 2015/2016 to 2017/2018

Season	Preceding crop					
	Cowpea	Forage sorghum	Grain sorghum	Maize	Soybean	Sunflower
			Maize			
2015/2016	9.0	9.0	8.3	11.6	8.2	12.8
2016/2017	13.1	11.6	13.6	13.5	13.2	13.7
2017/2018	15.7	15.4	17.3	19.8	15.9	18.6
2018/2019	5.51	4.67	3.92	3.24	5.21	5.05
Mean	10.8	10.2	10.8	12.0	10.6	12.5
			Grain sorghum			
2015/2016	6.9	6.0	5.6	7.0	5.7	7.1
2016/2017	5.0	4.7	3.5	5.1	4.1	4.8
2017/2018	16.0	5.3	12.7	18.1	14.2	9.3
2018/2019	-	-	-	-	-	-
Mean#	9.3	5.3	7.3	10.1	8.0	7.1
			Soybean			
2015/2016	2.3	1.9	1.3	3.3	2.0	1.1
2016/2017	4.3	1.9	3.4	2.7	4.0	2.8
2017/2018	7.4	5.3	5.3	7.4	5.9	5.7
2018/2019	-	-	-	-	-	-
Mean#	4.7	3.0	3.3	4.5	4.0	3.2
			Sunflower			
2015/2016	2.1	2.2	2.4	4.2	3.4	4.3
2016/2017	3.2	2.7	2.8	3.0	3.2	3.3
2017/2018	4.2	4.1	4.2	4.9	3.9	3.9
2018/2019	1.5	1.6	1.3	1.8	1.4	1.7
Mean	2.8	2.6	2.7	3.5	3.0	3.3

#Mean for 2014/2015 to 2017/2018

Rainfall use efficiencies show large variation from season to season for all crops due to the amount and distribution of the seasonal rainfall. High values were recorded in 2017/2018 and low values in 2018/2019, the latter due to the extremely late planting date and the fact that about half of the rainfall was recorded in April at the end of the growing season.

Maize rainfall use efficiencies showed a large variation with the highest value 6.1 times higher than the lowest value among season and preceding crops. The overall mean efficiency for maize was 11.2 kg ha^{-1} mm^{-1}. The ranking order of preceding crops for maize rainfall use efficiency was sunflower > maize > cowpea > grain sorghum > soybean > forage sorghum.

The rainfall use efficiency of grain sorghum (mean = 7.9 kg ha^{-1} mm^{-1}) also showed large variation with the highest value more than 5 times the lowest value. The ranking order of grain sorghum preceding crops for rainfall use efficiency was maize > cowpeas > soybean > grain sorghum > sunflower and forage sorghum.

Soybean rainfall use efficiencies (mean = 3.8 kg ha^{-1} mm^{-1}) also showed a high variation with the highest value more than 6 times the lowest value among seasons and preceding crops. The ranking order of grain soybean preceding crops for rainfall use efficiency was cowpeas > maize > soybean > grain sorghum > sunflower > forage sorghum.

Sunflower had the lowest variation of all crops with the highest rain fall use efficiency value at 3.8 times that of the lowest value. The overall mean rainfall use efficiency of sunflower was 3.0 kg ha^{-1} mm^{-1}. The ranking order of sunflower preceding crops for rainfall use efficiency was maize > sunflower > soybean > cowpeas > grain sorghum > forage sorghum.

Discussion and conclusions

The 2013/2014 and 2016/17 seasons will be remembered for abundant well distributed rain resulting in exceptionally high yields. In contrast, 2014/2015, 2015/2016 and especially 2018/2019 will be remembered for drought and late plantings. The 2017/2018 season had a relatively low rainfall with zero recorded in November and more than 100 mm in March which benefitted the yields of maize, sorghum and soybean crops. In 2018/2019 planting of crops were possible only in January due to a very poor distribution of rainfall with about half recorded in April. Only two (maize and sunflower) of the six crops produced harvestable yields.

The yields of maize, sorghum and soybean are most likely affected by a rotation x season interaction as the effects of the preceding crops are not straightforward. A preceding crop that enhances the yield of a particular crop in one season, may suppress it in a second season. What is surprising over the five seasons, is how well maize performed in monoculture and after sunflower. In three of the five seasons, maize had above mean yields in monoculture and in four of the five seasons above mean yields were recorded for maize following sunflower. Maize yield following the two legumes had above mean yields in only one of the five seasons. The opposite is expected as the yield enhancing effect of legumes on maize is well known. The possibility exists that this well-known rotational effect found on tilled soil is absent in no-till soils.

Sorghum performed well when it followed maize, cowpea and soybean crops while sorghum in monoculture and following sunflower performed poorly. Soybean performed well when preceded by cowpeas, maize and in monoculture and it performed poorly when preceded by forage sorghum and sunflower.

Sunflower yields were higher after forage sorghum, maize and sunflower (monoculture) and lower after grain sorghum, cowpeas and soybeans. The good performance of both maize and sunflower when grown in rotation is encouraging as they are the main crops grown in the area.

Crop yields were often relatively lower when preceded by grain and forage sorghum. This may be, in part, due to lowered plant population densities. Grain and forage sorghum usually left a high amount of residue and stubble which also intercepts wind-blown residue from other crops like maize which hampers the planting and crop establishment. Forage sorghum, planted in the previous season, often regrow in the newly planted following crop, negatively affecting its growth and yield.

The soil cover left by the grass type crops is about double that left by the broad leave crops. As expected, the extend of soil cover is affected by the amount of seasonal rain. After as season of low rainfall, soil cover values are relatively low, especially for the legume and sunflower crops. Due to the relative high biomass of forage sorghum, maize and grain sorghum, the soil cover after these crops are high despite the effect of rainfall. What is clear from these results is that the soil cover easily exceeds 30% which is contrary to the popular believe that no significant and effective soil cover can be created in the area.

No guidelines are available to score the water infiltration rates. However, the time it took for 25 mm to infiltrate on all maize plots was less than 6 minutes which is far less than the 8 to 20 minutes generally found on tilled soil in the area. With this high infiltration rate, and protection of the soil by the cover, the likelihood of runoff and soil erosion is minimal.

The capturing of most rainfall is reflected by the high rainfall use efficiencies found for maize. In 58% of the 24 season and rotation instances, was the rainfall use efficiency above 10 kg ha^{-1} mm^{-1}. In a recently published article, maize rainfall use efficiencies of the Lichtenburg and Delareyville areas were higher than 10 kg ha^{-1} mm^{-1} in only two out of 11 seasons for both areas (Van der Walt, Smith & Fourie, 2018. Reëngebruiksdoeltreffendheid in die Noordwes-streek. SA Graan, Augustus 2018). The latter values represent the rainfall use efficiency of conventionally tilled soil as it is the predominant systems for the areas. This contrast in the rainfall use efficiency values is a clear indication that conservation agriculture systems are superior in the utilisation of the most limiting resource, rainfall.

Due to the variability of the weather and the soil recovering process that is most likely still in progress, results from more seasons are needed to strengthen or alter the conclusions.

4.4.2. Comparison between local and Argentinian row widths and plant population densities

Introduction

Row widths currently used for all crops in the local conservation agriculture system are 0.76 and 0.91 m. However, the most frequently used width is 0.91 m. Norms for maize plant population densities are lower than 24 000 ha^{-1}. Row widths of 0.52 m or less are used in Argentinian systems, with plant population densities at 40 000 ha^{-1} for maize, almost double the local used density. Similar densities are used for other crops except for soybean, where the Argentinian recommend 250 000 ha^{-1} compared to the local 300 000 ha^{-1}.

Aim

The aim was to compare the yields of maize, soybean, sorghum and sunflower grown in Argentinian crop row widths of 0.52 m (Photo 5.1), and plant population densities with locally used row widths and population densities.

Procedures

From 2014/2015 to 2016/2017, 19 trials were done on several farms using an Argentinian Pierobon planter (provided by Valtrac under the Grain SA x Argentina cooperation agreement) with row widths of 0.52 m representing the Argentinian system, while the planter of the farmer was used to plant according to his usual densities and row width of 0.76 or 0.91 m. The target plant populations are shown in Table 4.6.

Photo 5.1: A Jumil planter in action on the trials at Humanskraal 2017/2018 demonstrating it's ability to plant successfully through crop residue.

Table 4.6. Plant population densities for crops in the Argentinian and local systems

Crop	System	
	Argentinian (plants ha^{-1})	Local (plants ha^{-1})
Maize	40 000	24 000 or less
Soybean	300 000	300 000
Sorghum	120 000	120 000
Sunflower	40 000	40 000

The Argentinian system consisted of a strip, or strips with six rows, or multiples of six rows, with the local practice next to it. All inputs, such as fertiliser and cultivars were similar for both treatments. At harvesting, the yield of the treatments, and the final plant population densities were determined. An appropriate harvester table to harvest the Argentina maize trial was not available at harvest and the trials were harvested by hand. Nineteen maize, two soybean, one sorghum and four sunflower trials were done from 2013/14 to 2016/17.

Results

Maize

Results of the combined data from 19 trials, done on various farms, from 2013/2014 to 2016/2017, are shown in Fig. 4.1. An analysis of variance showed that the yield of maize is significantly affected by the row width plant population systems ($P = 0.02$). The mean yield of the Argentinian system was 0.55 t ha^{-1} higher than the yield of the local row width and plant populations. However, in three instances, the opposite was true where the yield of the local system was between 0.38 and 1 t ha^{-1} higher than the yield of the Argentinian system. The mean increase for trials in favour of the Argentinian system was 0.8 t ha^{-1} with a range from 0.03 to 2.86 t ha^{-1}.

Soybean

Two field trials with soybean were done from 2013/2014 to 2016/2017 where the row widths of 0.52 and 0.76 m were compared at Humanskraal. In both cases the yield of the 0.76 m width was higher (mean of 0.2 t ha^{-1}) than the yield of the 0.5 m rows.

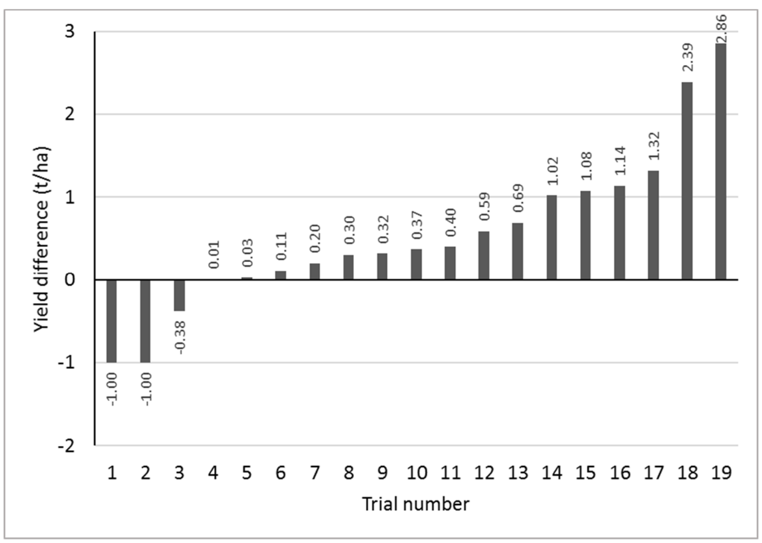

Fig. 4.1 The yield difference of maize in Argentinian (0.52 m) and local (0.91 m) row widths and plant population densities of 19 field trials done from 2013/2014 to 2016/17. Positive values represent cases where the yield of the Argentinian system was higher than that of the local system and the other way around.

Sorghum

Row widths of 0.52 m and 0.76 m was also compared in 2013/2014 on sorghum at Humanskraal. The yield for the 0.52 and 0.91 m rows was 6.57 and 6.45 t ha^{-1} respectively.

Photo 5.2: Sunflower row widths of 0.91 and 0.52 m in 2015/2016.

Sunflower

Sunflower had equal plant population densities for the 0.52 and 0.91 cm rows. One field trial was done in 2013/2014 and three in 2015/2016. Higher yields were constantly found for the narrower 0.52 m row width than for the 0.91 m width (Fig. 4.2). Analysed over all trials, the yield advantage for the 0.52 m Argentinian row width over that of the local width, was a significant 0.16 t ha^{-1}.

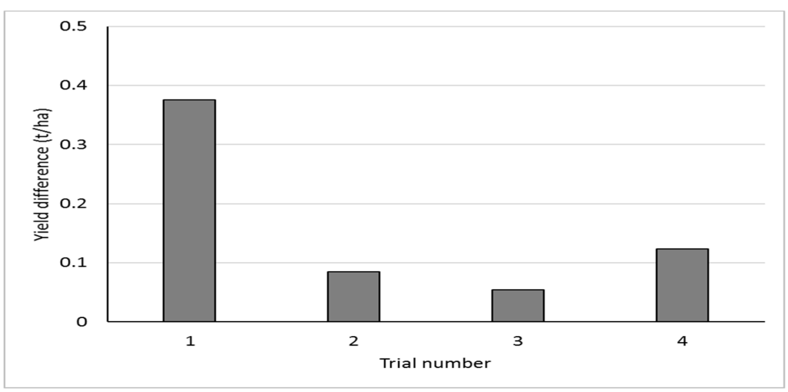

Fig. 4.2 The sunflower yield difference between Argentinian (0.52 m) and local (0.91 m) row widths in four field trials done with sunflower at 40 000 plants ha^{-1} done in 2013/2014 and 2015/2016. All four cases indicate that the yield of the Argentinian system was higher than that of the local system.

Discussion and conclusions

Taking an overall look at maize, it is clear that most of the time a similar or higher yield can be expected from the narrow 0.52 m row with a high plant population Argentinian system, than with the local 0.76 to 0.91 m rows with lower plant population densities, even during seasons with drought. It should be kept in mind that three cases exist where the local system had higher yields than the Argentinian system. The cause should be investigated to determine under which conditions higher yields with the local system can be expected.

4.4.3. The use of tines versus coulters on planters on the performance of crops

Introduction

Different planter options are available, with either a coulter or a tine fitted to the fertiliser unit. Coulters usually disturb the soil less than tines, which is an advantage. Deeper placement of fertiliser, and a deeper seedbed can be created with tines to benefit seed emergence and seedling growth. It is unclear whether coulters or tines are best suited for crop growth and yield in local conditions.

Aim

To determine the influence of tines and coulters on the yield of maize.

Procedures

Trials were done in 2013/2014, 2014/2015 and 2015/2016 on the farm Humanskraal. Strips of maize were planted with coulters and adjacent to it, with tines fitted to a Jumil JM2670-SH-EX planter as treatments in 0.52 m rows. In 2013/2014 the treatments were replicated but not in 2014/2015 and 2015/2016. Accordingly, statistical analyses were not possible on the latter two trials.

Three tine configurations were also compared in two replicated field trials in 2014/2015.

- Long tine, working depth 240 mm
- Short tine, working depth 150 mm
- Diamond point depth 150 mm

Results

Maize planted with tines and coulters in 2013/2014, 2014/2015 and 2015.2016 had about similar yields, as the difference was 5% or less. Mean measured yields were respectively 8.69, 0.57 and 4.72 t ha^{-1} for the three consecutive seasons.

The effect of tine type and working depth on the yield of maize is shown in Fig. 4.3. The yield of maize, planted with a tine with a working depth of 240 mm, was 18% higher than the mean yield obtained with the short and diamond type tines.

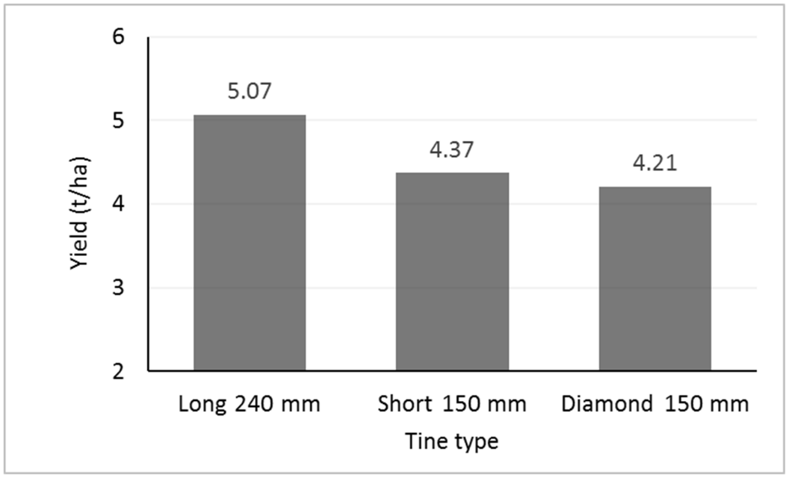

Fig. 4.3. The effect of tine type and working depth on the yield of maize in 2014/2015.

Discussion and conclusions

After three years of investigation no evidence could be found that either tines or coulters cause higher grain yields. However, soil texture was not considered in these trials. Farmers are of the opinion that tines are best suited for sandy soils or soils that has recently been converted to no-till, while coulters are better suited for loamy and clay soil. Deeper working depths (240 vs 150 mm) of tines caused a higher yield. Experience has shown that tine depth can be reduced as the quality of the soil improves with time. The optimum depth of disturbance of the soil will depend on several soil parameters such as texture, structure extend of compaction etc. which usually have a large variation. Further investigation into this matter is needed to link optimum depth of disturbance to these soil parameters.

4.4.4. Maize cultivar evaluation in conservation agriculture

Introduction

Cultivar selection is an important aspect in the optimisation of maize production, which the farmer can control. Currently, national cultivar trials are not done in no-till or in any conservation agricultural system. It is thus unknown how cultivars will perform in no-till, under high (40 000 seeds ha^{-1}) population densities and row widths of 0.52 m.

Aim

The aim is to compare the yields of available maize cultivars at 40 000 plants ha^{-1} in 0.51 m spaced rows, annually.

Procedures

A cultivar trial was planted on the 7th January 2019 on the farm Humanskraal. Twenty-six cultivars, supplied by seven seed companies were included. The trial layout consisted of 12 rows of a particular cultivar planted in 0.52 m spaced rows of 90 m length at density of 40 000 seeds ha^{-1}. A 12-row control cultivar strip was included between every two adjacent tested cultivars.

Three plots of 30 m^2 in each cultivar strip were hand harvested, threshed and the yield calculated. Cultivar yields were normalised through the following steps: The mean yield of all control strips was calculated as Yc. A factor was calculated for each control strip as Yc divided by the yield of the control strip. Individual measured cultivar yields were then adjusted by multiplying it with 0.66 times the control strip factor next to it plus 0.33 times the control strip factor, which are one cultivar strip away from it.

Seed prices of all cultivars for the 2018/2019 season were collected from the suppliers. The net return, taking the seed prices of the various cultivars into account were calculated at a seeding rate of 40 000 ha^{-1} and a grain price of R2 500 t^{-1}.

Results

The adjusted cultivar yields are shown in Fig. 4.4. Seed cost and net returns are shown in Fig. 4.5. and Fig. 4.6.

Discussion and conclusions

Well performing (0.4 t above the average yield) cultivars in the 2018/2019 season were DKC 72-76BR, DKC 74-26R, DKC 75-65BR, KKS 8301, PAN 5A-182 and US 9612. In terms of net return, were DKC 72-76BR, DKC 74-26R, KKS 8301, PAN 5A-182, US 7923, US 9612 and US 9777 exceeded the mean with more than R1 500 ha^{-1}.

New cultivars are introduced every season, replacing older ones. The weather also varies from season to season which impact on the relative performance of cultivars. Cultivar evaluation is thus a continuous process.

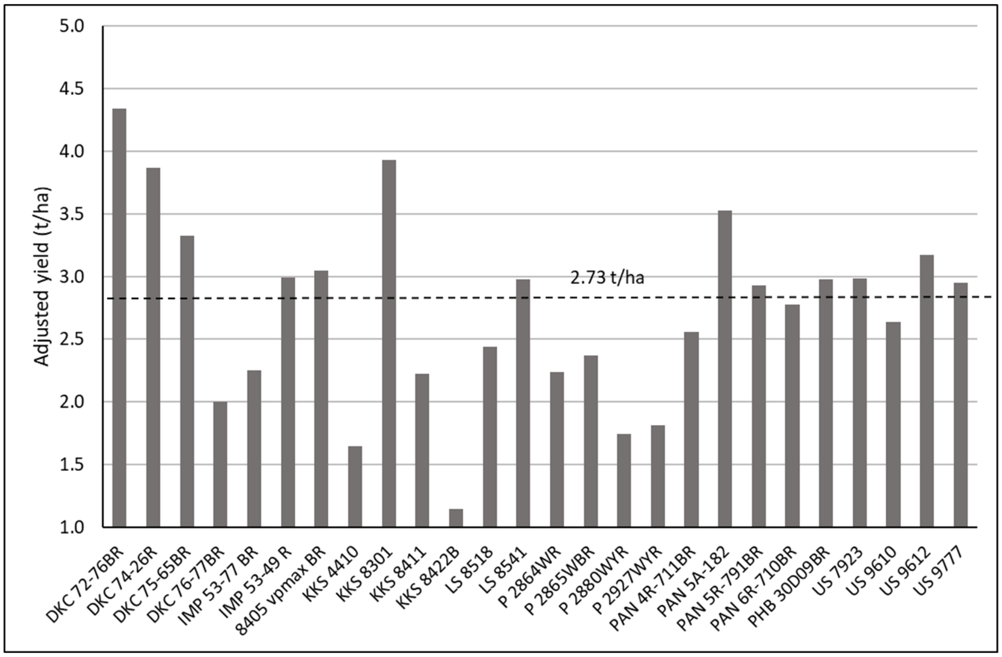

Fig. 4.4. Adjusted grain yields of cultivars at Humanskraal 2018/2019. The mean adjusted yield of all cultivars is indicated by the horizontal line.

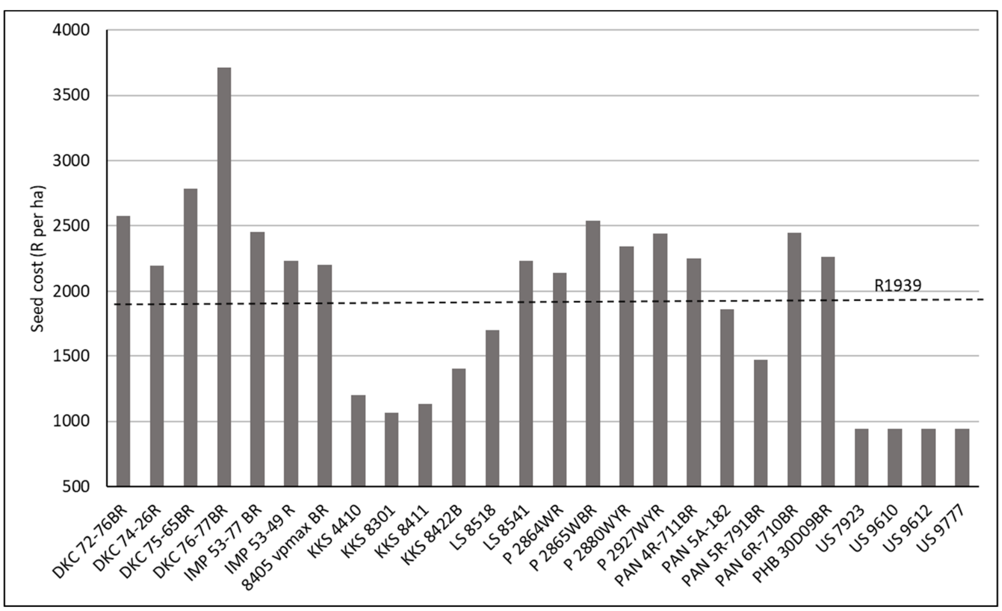

Fig. 4.5. The 2018/2019 seed cost ha^{-1} for each cultivar at a seeding rate of 40 000 ha^{-1}. The mean is indicated by the horizontal line.

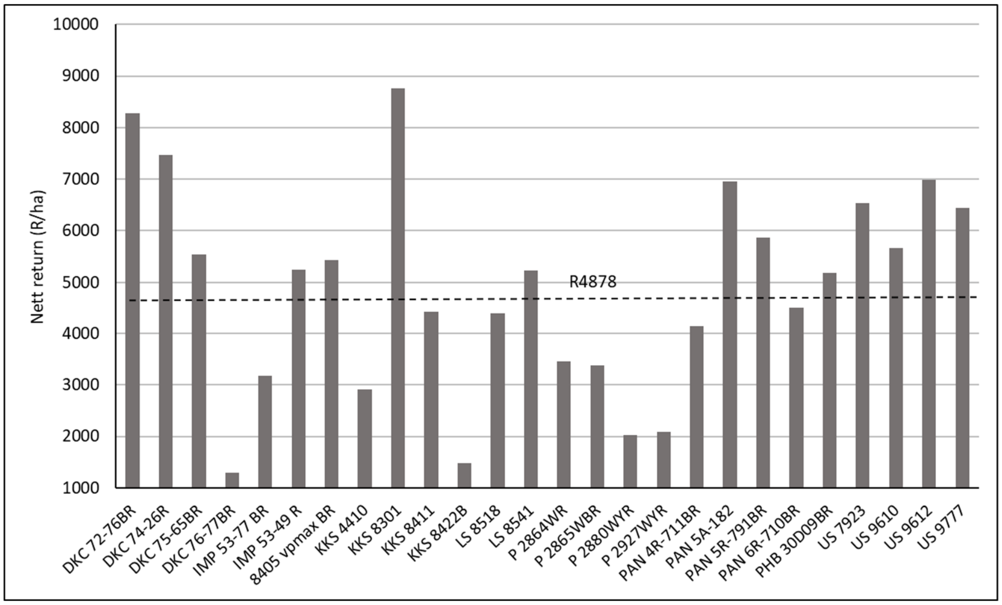

Fig. 4.6. The net return for cultivars calculated from the adjusted grain yields and seed price at a grain price of R2 500 t^{-1} at Humanskraal 2018/2019. The mean net return of all cultivars, is indicated by the horizontal line.

4.4.5. A comparison of conventional and conservation agriculture (CA) cropping systems

Introduction

It is now well known that crop production under conventional soil tillage accelerates soil erosion and cause a decline in soil quality and crop productivity. Conventional crop systems are consequently not sustainable in the long-term and the only alternative is to change to conservation agriculture cropping systems with its principles of no-tillage, a surface mulch of crop residue and crop rotation.

Due to a local lack of scientifically based results the need exists to collect results on the success of CA crop systems in comparison with conventionally produced crops in field trials. The results of such a comparison will confirm if the sustainability of maize production has improved due to a change to CA. A field trial where conventional and CA crop systems are compared can also serve as a demonstration of the benefits of CA crop systems.

Aim

To compare the yield of maize in conventional and CA production systems with both 0.52 and 0.91 m spaced rows in the CA systems.

Procedures

Annual field trials were done on farms in which commercially available equipment are used. The current conventional system used on the farm was the control which was compared with one or two row widths in no-till monocultured maize.

Treatments were assigned to strips on a selected land. The participating farmers from 2015/2016 to 2017/2018, the conventional and the CA systems which were applied are shown in Table 4.6. In all instances, no-till consisted of no primary tillage such as ripping or ploughing but, shallow tillage with disk was done to eradicate weeds between harvesting of 2014/2015 crop and planting of the 2015/2016 maize. Mechanical weeding, which caused soil disturbance was applied in all the conventional systems while chemical weed control was applied in all the CA systems.

Results

On the farm of Jaco Bamberger, the no-till system of 0.52 m spaced rows with a planting population of 40 000 plants ha^{-1} outperformed all the other systems with 0.98 t ha^{-1} in 2015/2016 (Table 4.7). The rest of the systems had similar yields. In 2016/2017, the two no-till systems had higher yields than the tilled systems with the 0.52 m spaced rows and 40 000 plants ha^{-1} again in the top position.

On the farm of Niël Rossouw in 2015/2016, the yield of the no-till systems was 2.2 t ha^{-1} higher than the yield of the strip till system (Table 4.8). In 2016/2017 however, the yield of the strip till systems was higher than the yield of the 0.91 m spaced rows no-till system and slightly lower than the yield of the 0.52 m spaced rows no-till system.

Table 4.6. Participating farmer, description of the tillage system applied and number of seasons of no-till 2015/2016 and 2016/2017

Participating farmer/farm	Tillage system and row width (m)	Population density (x1000 ha^{-2})
	2015/2016	
Jaco Bamberger	**1.** Mouldboard plough, 2.3 m	22.6
	2. Rip-on-row 45 cm deep, 2.3 m	22.6
	3. No-till, 0.52 m	40.0
	4. No-till, 0.91 m	24.2
Niël Rossouw	**1**. Strip till 20 cm deep 1.5 m	17.8
	2. No-till 0.91 m	22.0
	3. No-till 0.52 m	42.0
Pieter van Vuuren	**1.** Rip-on-row 40 cm deep, 2.3 m	13.1
	2. Rip-on every second row 1.15 m	26.1
	3. No-till, 0.91 m	17.6
	4. No-till 0.52 m	30.0

2016/2017		
Jaco Bamberger	**1.** Moulboard plough, 1.5 m	24.2
	2. Rip-on-row 45 cm deep, 1.5 m	33.4
	3. No-till, 0.52 m	40.0
	4. No-till, 0.91 m	27.5
Niël Rossouw	**1**. Strip till 20 cm deep 1.5 m	21.8
	2. No-till 0.91 m	21.0
	3. No-till 0.52 m	40.0
Pieter van Vuuren (Doornspruit)	**1.** Rip-on-row 40 cm deep, 2.03* m	20.0
	2. No-till, 0.91 m	24.2
	3. No-till 0.52 m	40.0
2017/2018		
Pieter van Vuuren (Doornspruit)	**1.** Rip-on-row 40 cm deep, 2.03* m	20.0
	2. No-till, 0.91 m	24.2
	3. No-till 0.52 m	40.0

* 2 x 2.3 m + 1.5 m spacing

At Doornspruit, the yield of maize in the rip-on-row with a 2.3 m row spacing system, was between 0.80 and 2.18 t ha^{-1} lower than the mean yield of the two no-till systems from 2015/2016 to 2017/2018 (Table 4.9). Clear differences in the water infiltration capacity of soil among the cropping systems were found in March 2018 (Table 4.10) at Doornspruit. It took almost three times longer for 25 mm of water to infiltrate into the soil of the conventionally tilled system than into the soil of the two no-till systems.

Table 4.7. The yield of maize (t ha^{-1}) as affected by cropping system on the farm of Jaco Bamberger in 2015/2016 and 2016/2017. Cropping systems consisted of CA1 (No-till, 0.52 m spaced rows, 40 000 plants ha^{-1}), CA2 (No-till, 0.91 m spaced rows, 27 000 plants ha^{-1}), CT1 (Mouldboard ploughing 0.25 m deep, 0.91 m spaced rows, 24 000 plants ha^{-1}) and CT2 (Rip-on-row 0.45 m deep, 1.5 m spaced rows, 33 000 plants ha^{-1})

Season	Cropping systems			
	CA1	CA2	CT1	CT2
2015/2016	3.99	3.10	2.93	3.06
2016/2017	5.76	4.35	3.98	3.34
Mean	4.88	3.73	3.45	3.20

Table 4.8. The yield of maize (t ha^{-1}) as affected by cropping system on the farm of Niël Rossouw in 2015/2016 and 2016/2017. Cropping systems consisted of CA1 (No-till, 0.52 m spaced rows, 40 000 plants ha^{-1}), CA2 (No-till, 0.91 m spaced rows, 21 000 plants ha^{-1}) and CT (Strip tilling 0.3 m wide and 0.25 m deep, 1.5 m spaced rows, 22 000 plants ha^{-1})

Season	Cropping systems		
	CA1	CA2	CT
2015/2016	4.58	5.07	2.61
2016/2017	7.30	6.26	7.05
Mean	5.94	5.67	4.83

Table 4.9. The yield of maize (t ha^{-1}) as affected by cropping system on the farm of Pieter van Vuuren from 2015/2016 to 2017/2018. Cropping systems consisted of CA1 (No-till, 0.52 m spaced rows, 40 000 plants ha^{-1}), CA2 (No-till, 0.91 m spaced rows, 24 000 plants ha^{-1}) and CT (Rip-on-row 0.45 m deep, 2 x 2.3 m + 1 x 1.5 m spaced rows, 18 000 to 22 000 plants ha^{-1})

Season	Cropping systems		
	CA1	CA2	CT
2015/2016	4.68	3.39	2.47
2016/2017	6.22	6.35	4.11
2017/2018	3.77	3.83	3.04
Mean	4.89	4.52	3.21

Table 4.10. The time it took for 25 mm of water to infiltrate in three cropping systems in minutes, at Doornspruit during February 2018. Abbreviations of cropping systems as indicated in the heading of Table 5.4

Season	Cropping systems		
	CA1	CA2	CT
2017/2018	2.9	3.5	9.1

Discussion and conclusions

The cropping systems were not replicated in these trials and clear statistically based conclusions cannot be made. There is however a strong indication that the yield of maize is higher than the yield of maize in the conventional systems. In only one out of the seven farm and season trials was the yield of the CT higher (by 0.8 t ha^{-1}) than the yield of one of the CA systems. In six of the seven other cases, the yields of the CA systems were equal to, or higher, (from 0.04 to 2.42 t ha^{-1}) than the yields of the CT system.

The improved yields of the CA systems at Doornspruit are most likely due to the higher water infiltration capacities of the soil and thus higher availability of water to the CA crops. Evidence of the difference in runoff and erosion between the no- and conventionally tilled systems is evident on a photo taken during April 2018 in the Doornspruit trial (Photo 5.3).

Considering that these trials were done as the first or second year of no-till on these farms when relatively lower no-till yields can be expected, the results of the no-till systems are encouraging.

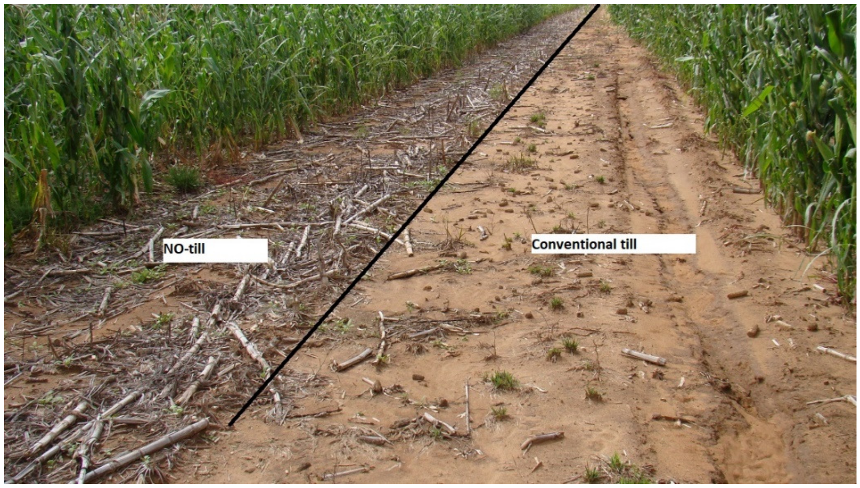

Photo 5.3. Evidence of runoff and erosion on a conventionally tilled plot with a lower water infiltration capacity compared to a no-till plot with a higher water infiltration capacity and little if any evidence of runoff and erosion.

4.4.6. Optimum plant population of crops in conservation agriculture

Introduction

The plant population of crops remains an important aspect of the optimization of grain production. Theoretically, plant population determines the rate of soil moisture usage. If the plant population is relatively high and rainfall below normal, the risk of drought damage increases. If the plant population is too low, the available rainfall is under-utilised. Accordingly, plant population should match the yield potential created by the rainfall. Rainfall varies from season to season and each season requires its own optimal plant population. Due to the unpredictability of rainfall, a suitable plant population for the long-term yield potential should be used.

Depending on the yield potential, populations of 14 000 to 24 000 plants ha^{-1} are currently used for maize, around 40 000 plants ha^{-1} for sunflower and 300 000 plants ha^{-1} for soybeans. These populations have been determined through research and experience with conventional plough-based crop systems. It is unknown if these populations should be adjusted for conservation agriculture systems.

Aim

The aim of this study is to get an indication if the plant populations currently used, should be increased or decreased for conservation agriculture systems for maize, soybean sunflower and sorghum.

Procedures

From 2013/2014 to 2016/2017 eight no-till field trials were done with maize and two each with sunflower and sorghum, and one trial with soybean. Plant population densities varied from 15 000 to 40 000 ha^{-1} in the various field trials for maize, from 155 000 to 300 000 ha^{-1} for soybean, 60 000 to 120 000 ha^{-1} for sorghum, and 35 000 to 50 000 ha^{-1} for sunflower with row widths of either 0.76 or 0.91 m. Yields were measured on plots of at least 60 m^2. Quadratic curves ($Y = a + bX – cX^2$ where, Y = grain yield and X = plant density and a, b and c are coefficients) were fitted to yield data from each trial to determine if yield were related to plant population density.

Results and Discussion

Maize

Maize responded well to plant population density in all eight trials (Figs 4.7). Three of the response curves of the 0.9 m spaced rows indicate that the optimum plant population density is between 30 000 and 38 000 ha^{-1} while the third curve is inconclusive. Two of the 0.76 m row spaced trials suggest an optimum plant density of between 23 000 and 30 000 ha^{-1}. The two remaining curves of the 0.76 m row spaced trials is inconclusive.

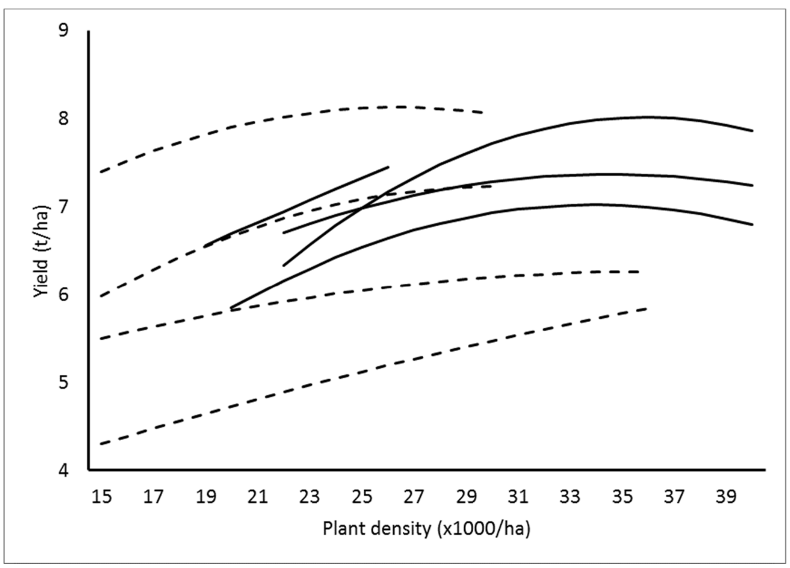

Fig. 4.7. No-till maize yield as related to plant population density in eight field trials from 2013/2014 to 2016/2017. Row widths of 0.76 and 0.91 m are represented with dotted and solid lines respectively.

Sunflower

Sunflower showed no response to plant population density in any of the two trials done (Fig. 4.8). Although curves were fitted for these two trials, the regression analysis for each indicated a non-significant relationship.

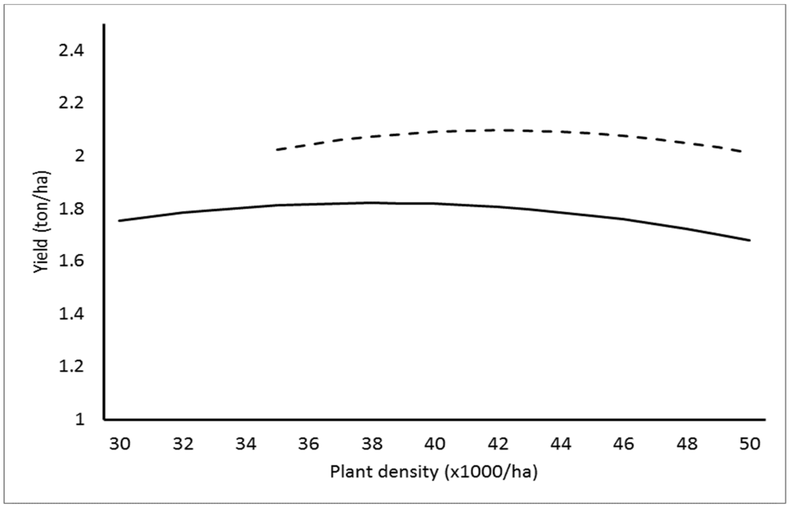

Fig. 4.8. Sunflower yield as related to plant population density in 2013/2014 and 2014/2015 with 0.76 and 0.91 m row widths indicated by dotted and solid lines respectively.

Sorghum

Sorghum yield also showed no significant relationship with plant population density as indicated by the regression analyses (Fig. 4.9).

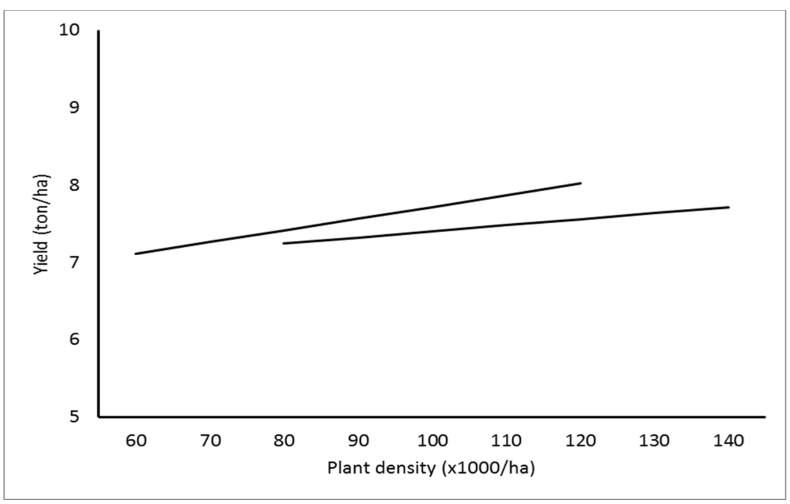

Fig. 4.9. Sorghum yield as related to plant population density.

Soybean

The yield of soybean on the other hand, responded to plant population density with an optimum higher than 300 000 plants per ha^{-1} (Fig. 4.10). The yield response rate was approximately 3 kg ha^{-1} per 1000 plants ha^{-1}.

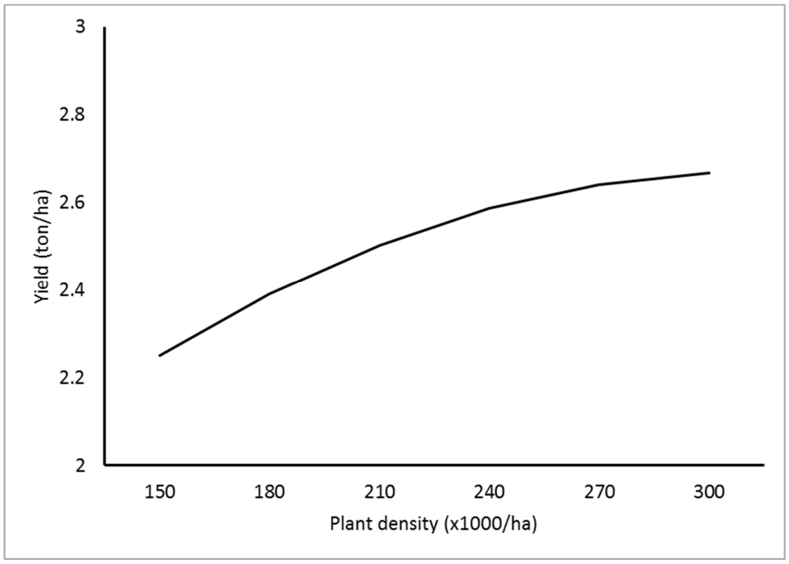

Fig. 4.10. Soybean yield as related to plant population density in 0.76 m rows.

4.4.7. Grain yield and soil health as affected by a cover crop – sunflower – maize rotation system and monoculture with maize and sunflower in two plant arrangements

Introduction

The benefit of a cover crop mixture on soil health is well known. Under local condition only limited preliminary research has been done with cover crop mixture with the aim of evaluating different species. How it may affect soil health and cash crop yields when included in a three-year rotation system is still unknown. CA cash crops are grown in row widths from 0.5 to 0.8 m. Previous trials have shown that plant configuration (row widths and populations) can affect crop yield. How this affects soil health is also unknown.

Aim

The aim of this trial is to determine how soil health and crop yield is affected by a cover crop mixture – maize -sunflower rotation and maize in monoculture with maize in 90 cm rows at 24 000 plants ha-1 and 50 cm spaced rows at 40 000 plants ha^{-1} and sunflower in 90 and 50 cm spaced rows at 40 000 plants ha^{-1}.

Procedure

A no-till field trial was planted on 10 January 2019 on the farm Korannafontein. The preceding crop was sunflower. Treatments consisted of two crop rotation systems and two plant arrangements.

Crop rotation systems: 1. Monoculture maize
2. Sunflower – cover crop mixture – maize

Plant arrangement: Maize: 1. 90 cm rows at 22 000 plants ha^{-1} (R90-22K)
2. 50 cm spaced rows at 40 000 plants ha^{-1} (R50-40K)
Sunflower: 1. 90 cm rows at 40 000 plants ha^{-1} (R90-40K)
2. 50 cm spaced rows at 40 000 plants ha^{-1} (R50-40K)

The cover crop row width was 30 cm. The trial layout was a randomised complete-block with three replicates or blocks with split plots. Plots consisted of strips of 700 x 30 m across a field. Crop rotation systems were assigned to main plots and plant arrangements to subplots (Photo 5.4).

Maize (DKC 78-79BR) and sunflower (Agsun 8251) received 30 kg N and 18 kg P ha^{-1} at planting plus a further 50 kg N ha^{-1} as a topdressing. The cover crop was *Agri-Life 12* (supplier: Agricol) consisting of 44% cowpeas, 20% sunhemp, 12 pearl millet, 8% forage sorghum, 8% Japanese millet, 4% "Nigger" and 4% Dolichos. The monthly amount of rain recorded is shown in Table 4.11.

Table 4.11. Monthly rainfall in mm at Korannafontein

Season	Oct	Nov	Dec	Jan	Feb	Mrch	Apr	Total
2018/19	18	16	25	30	94	32	261	476

Soil samples were taken and analysed and the results are reported in Section 2. The cover crop was flattened with a "rolmoer" and the maize and sunflower yields harvested with a combine and the yields recorded. Maize yield was subjected to an analysis of variance. Sunflower yields were not separately recorded for plant arrangement.

Soil samples were collected at the onset of the trial and again after harvest and send for analyses by a service provider. Results on the soil are presented under Work package 2, 2. "Assessment of soil quality".

Results

Yield

Sunflower yielded 1.3 t ha^{-1}. The overall maize yield was a remarkable 5.38 t ha^{-1} taking into account that the planting date was about three weeks later than the last recommended date. Results of the analysis of variance is shown in Table 4.11.

Table 4.11. The yield of maize as affected by crop rotation system (monoculture maize and sunflower – cover crop maize rotation) and plant arrangement, 90 cm rows at 22 000 plants ha^{-1} (R90-22K) and 50 cm rows at 40 000 plants ha^{-1} (R50-40K) at Korannafontein

Season	Arrangement	--- System yield (t ha^{-1}) ---		Mean yield	ANOVA
		Monoculture	Rotated	(t ha^{-1})	F-ratio
2018/2019	(R90-22K)	5.10	5.01	5.05	41.8*
	(R50-40K)	5.69	5.71	5.70	
	Mean (t ha^{-1})	5.40	5.36		
	ANOVA F-ratio	0.45			

*Significant at $P \leq 0.05$

The yield of maize was significantly affected by plant arrangement. The yield of the 50 cm row width planted at 40 000 plants ha^{-1} was 0.65 t ha^{-1} (13%) higher than the yield of the 90 cm rows at 22 000 plant ha^{-1}. This result confirms results of previous trials conducted on several farms. As this is the first year of this trial, a “rotational effect” was not present and no such effect was expected which is confirmed by the analysis of variance. It also shows that the yield advantage is still present despite the extremely late planting date.

Photo 5. 4 The rotation plant arrangement trial one month after planting showing the cover crop on the left with a maize plot on the right-hand side.

5. Coordination and facilitation of project activities

Work Package title	**Coordination and facilitation of project activities among farmer participants**
Work Package period	October 2018 to September 2019

Lead partner	Local facilitator Mr L Zietsman (Ottosdal No-till Club)
Involved partners	Dr A Nel, Mr G Trystman, Grain SA

Objectives	• Coordinate on-farm experimentation activities among all participating farmers • Ensure timely and correct implementation of relevant activities and treatments • Assist with the use of specialised implements for trial purposes • Promote synergy among farmer participants • Monitor and report on project activities and progress related to farmer involvement.

Justification	On-farm experimentation involving farmers as 'researchers' are seen as central to research projects under the banner of the CA-Farmer Innovation Programme at Grain SA. This implies that trial treatments or replications are implemented on the farm by the respective farmer participants. A range of support measures are needed to ensure the success and quality of these farmer-led actions, including the engagement of relevant research and technical team members around these farmers. A particular role and function identified by the project team is that of a local farmer facilitator, primarily assisting, guiding, calibrating and coordinating the participating farmers to implement the experimental designs (treatments) correctly. This person also has to manage and move specific specialised implements (e.g. a no-till planter) between the farmers, allowing timely and correct use of it. The person selected is locally based and have an intimate knowledge of the local natural resources and stakeholders, especially the farmers. Expected result of this function is the elimination of undesirable variables and the increased quality of the trials and data.

Description of work	Prepare farmers and implement on-farm trials. Manage, maintain and move specialised implements to be used by the various farmers involved in the trials. Making sure that farmers understand the treatments and what is expected from them. Calibrate or train farmers on specific implements / practices where necessary. Conduct regular field/farm visits, monitor and coordinate relevant activities such as weed and pest control, assist with sampling of soil and other observations where necessary. Document inputs

	and activities, harvest trials and record yields. Attend regular project meetings and assist with report writing.

Activities	1. Land preparation 2. Planting 3. Seasonal trial management 4. Monitoring, sampling and harvesting 5. Monthly meetings (project team) 6. Annual report and admin 7. Participate in Awareness events

Risks	• Being a dryland experiment, low and erratic rainfall may compromise crop yields; • Wild animals and birds may jeopardise crop performance and yields; • Instrumental and logistical failure can result in incomplete activities and results

DELIVERABLES, PROGRESS AND RESULTS ACHIEVED PER ACTIVITY (March 2016)

Activities	**Deliverables**	**Progress and Results achieved**
1. Land preparation (10 visits)	Assist farmers to lay out their trial plots Prepare (calibrate and train) farmers on the trial treatments Make sure land preparation (e.g. weed control) is done according to specifications Make sure the correct type and quantity of production inputs are ready	Assisted to prepare land on 3 trials on 2 farms
2. Planting (10 visits)	Prepare planter for planting Move planter between trials for timely planting Make sure trials are planted to standard treatment specifications and according to the trial layout	Assisted to establish 5 trials on 2 farms See list of trials in **Table 5.1** below.
3. Seasonal management (30 visits)	Assist farmers in weeding and pest/disease management	Completed seasonal activities for 2018-2019
4. Monitoring, sampling and	Assist farmers to complete field forms	Completed seasonal activities for 2018-2019

harvesting (Done with activity 3 above)	Monitor the farmer-led actions Harvest or assist in harvesting of trials	
5. Monthly meetings (project team) & Training	Participate in monthly forum meetings, discussing problems and possible solutions to that and organisation of activities.	Participated in several informal meetings
6. Annual report and admin (2 days)	Written report covering trial implementation, results and progress.	NA
7. Participate in Awareness events	Assist in organising and managing of annual conference and trial visits	CA conference in Ottosdal was held on 13-14 March 2019.

Table 5.1: List of location and type of trials established in Ottosdal area, 2018/19 season

Trial Number:	**1**	**2**	**3**	**4**	**5**
Farmer co-worker or farm:	**Cover crops**	**Crop Rotation**	**Maize cultivar evaluation**	**Cover crop rotation trial (new)**	**Row width X plant density (MSc Study**
George Steyn Humanskraal	√	√	√		√
H Otto Korannafontein				√	

7. Summary of expenses on August 2019

Description of Ottosdal CA project work packages	**Total Actual YTD by Aug 2019**	**Total Budget YTD 2018/19**	**Available to use In Sep 2019**
Soil	61 328	98 664	37 336
Cover crops	96 595	175 264	78 669
Agronomy	65 514	122 872	57 358
Grain SA	67 726	155 500	87 774
Farmer facilitator	111 300	113 346	2 046
Total	**480 768**	**665 646**	**184 878**

*** Expenses and invoices still expected which will affect the final amount until 30 September 2019.**