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 2017 TO SEPTEMBER 2018

Compiled by:
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September 2018

Ottosdal No-till Club

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1. Coordination and management

Work Package title	**Coordination and management**
Work Package period	October 2017 to September 2018

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 monthly or bi-monthly 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:** Frequent 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 meeting took place on ***14 August 2018***. **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 2018. Around 200 people attended the event. **Activity 5: Reporting.** All partners participates 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 2018.

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 2017 to September 2018

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 • To compare the effect of different CA treatments on soil quality / health • To establish relationships between different soil parameters, yield and atmospheric elements

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 as well as crop growth and yield, will involve regular field visits, sampling of soil on selected transects / sites and time intervals, laboratory analyses of the samples, 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 admin (technical data) 6. 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 failure can result in incomplete data results

2.2 Deliverables, progress and results achieved per activity

Activities	Deliverables	Progress and Results achieved
1. Monitoring and Sampling	Soil classification (types and depths) Detailed sampling at selected sites; Selected samples as required	Soil classification and analysis were done for every trial and on selected farms pre-2017/2018 Root evaluations was done on selected trials by Mr A Dreyer (SGS). A total of sixty-eight soil samples was taken on the crop rotation and cultivar trials at Humanskraal, on the CA versus conventional trial at Doornbult and on three CA farms.
2. Lab Analyses	Organic C (%) Standard soil analysis: 4 basic cations, P, pH, ratios, micro-elements Texture (once-off, top- and subsoil)	All samples were delivered to Nvirotek for inorganic chemical analyses as well as three compounded samples to Agrisol and nine to Soil Health Solutions for Haney soil health analyses.
3. Monthly meetings (project team) & Training	Participate in monthly forum meetings, discussing problems and possible solutions to that.	Participated in two meetings that were held on 19 July and 14 August 2018.
4. Annual reference group meeting (advisory committee)	Report progress and findings to advisory committee; Discussion and evaluation of data. Learning from each other.	Scheduled for 18 September 2018
5. Annual reports and admin (technical data)	Written technical report covering trial procedures, results and progress.	Submitted as required -
6. Participate in Awareness events	Trial visits with stakeholders; participate in awareness events, such as information day and/or cross-visits	Mr Dreyer took part in a television recording on 16 April 2018, explaining root development under CA and conven tionaltilage. A six monthly progress report on the trial planning and analyses was compiled and submitted to the project leader. Results were discussed during a trial visit with club members (April 2018). Results were presented during the September 2018 CA working group meeting.

2.3. Summary of soil quality work package for 2017/18

Actions taken to date

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 methods 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 Haney soil health assessment. Sixty samples were sent to Envirotek for conventional soil analyses. Results already received were interpreted and form part of this report. At the time of writing of this report, none of the results have been reported at any event or in any article yet as some of the laboratory analyses were still in progress.

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
Comparing a conventional crop system with two CA 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	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

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: Yield results from the four seasons of crop rotation suggest 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 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 improved by forage sorghum and maize. Results from a longer period of time is needed before sound conclusions can be reached.

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.

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 no-till. Maize and sunflower were each grown in monoculture and in rotation with grain sorghum, forage sorghum, cowpea, soybean and maize in the case of sunflower, and with sunflower where maize is the main crop. The trial is not replicated and consists of only one plot 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. The monoculture forage sorghum system was also 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 – 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.

Results and discussion

Differences among the rotation systems are small and most likely due to natural variation. Mean values for the pH, organic material content and some nutrients are shown in Table 2.1. The pH, which is also reflected by the hydrogen ion percentage, of the 5 cm layer is higher than the pH of the 5 – 15 cm layer for all crops. This is also reflected by the hydrogen ion concentration This is most likely due to regular liming of the area by the farm owner. The organic matter content of the upper and lower layers is similar in the case of sunflower while the content of the upper layer is lower than that of the deeper 5 – 15 cm layer in the maize and sunflower crops. This is inconsistent to what is expected as the general trend in no-till is for the upper layer to get enriched with organic material.

Potassium, calcium and magnesium contents of the upper layer is higher than the contents of the lower layer for all three crops. This is in line with results from elsewhere that, under no-till, stratification of some nutrients develops.

Table 2.1 The mean pH, organic material, potassium, sodium, calcium, magnesium and phosphorus contents, and percentage hydrogen saturation for the maize, and sunflower rotation systems and monoculture forage sorghum at two soil depths on the crop rotation trial at Humanskraal 2018

Depth (cm)	pH (H2O 1:1)	Org Mat (%)	K (mg kg^{-1})	Na (mg kg^{-1})	Ca (mg kg^{-1})	Mg (mg kg^{-1})	P (mg kg^{-1})	H (%)
				Maize				
0 - 5	6.6	0.55	380	23	1027	201	78	7
5 - 15	5.9	0.83	251	23	585	137	62	18
				Sunflower				
0 - 5	7.0	0.43	450	19	933	169	67	8
5 - 15	6.4	0.43	260	23	563	110	61	21
				Forage sorghum				
0 - 5	6.0	0.52	349	17	710	183	61	15
5 - 15	5.3	0.85	220	17	389	94	59	35

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

Introduction

The aim of this trial on the farm Doornbult 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 exists to collect results on the success of CA crop systems in comparison with conventionally produced crops in a field trial which can also serve as demonstration to farmers and visitors.

The cropping systems which are replicated three times, consist 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 a convention nutrient analyses and for a soil health analysis. These results, when analysed over seasons, will show how the soil changes due to the cropping system.

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 an indication of under fertilisation in the past.

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 (H2O 1:1)	Org Mat (%)	K ($mg\ kg^{-1}$)	Na ($mg\ kg^{-1}$)	Ca ($mg\ kg^{-1}$)	Mg ($mg\ kg^{-1}$)	P ($mg\ kg^{-1}$)	H (%)
			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 $P \leq 0.05$.

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 1.2.2. 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.

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

2.1.3 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}. Next to this trial is a commercial no-till field where maize and sunflower are grown in rotation with residues left on the soil. A row width of 0.76 m at a maize population density of about 24 000 ha^{-1}. The maize crop residue is utilised by cattle to a limited extend. It is expected that a difference between the trial and the field will develop in time. Soil samples were taken in August as described above.

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.

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 (H2O 1:1)	Org Mat (%)	K (mg kg^{-1})	Na (mg kg^{-1})	Ca (mg kg^{-1})	Mg (mg kg^{-1})	P (mg kg^{-1})	H (%)
			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

2.1.4 Adjacent CA and conventional tilled soils

Introduction

The organic material content of soil is an indication of the 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. Soil samples were taken on four farms where the CA and conventional lands are adjacent. 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.

Results and discussion

The results are shown in Table 2.5. The organic material content of the conventional tilled soils is between 23 and 71% higher than that of the CA soils. This is the opposite of what was expected.

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

System	Farm			
	Droëkraal 1	Droëkraal 2	Doornpoort	Humanskraal
CA	0.40	0.34	0.62	0.56
Conventional	0.63	0.58	0.76	0.80

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	Sept 2017 to March 2018
Lead partner	ARC-API (Mr. Gerrie Trytsman)
Involved partners	Grain SA, Ottosdal no-till club, ARC-GCI

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 • Establish intercropping trial on sunflowers

Description of work	**On-farm, farmer-led screening trials; crop livestock integration; double cropping with Sunflower; cooperation with seed company and the priming of tried soils. 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. 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 should clarify the roll of every party involved.	A plot of 42 ha mixed summer annuals were planted at George Steyn. The seed was sourced from Barenbrug seed company. This will be used to implement an integration trial Summer annual 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) again was planted and on the previous year's cover crops maize, soybean and sunflowers were established (10ha), which will be grazed. Summer annual cover crops were planted on the cash crops of 2017 again. Treatments, then are rotated between cash crops and cover crops (green fallow; 10ha). These cover crops were grazed as a demonstration at the time of the conference mid-March. Regrowth again was grazed from start of May Hannes Otto produced cowpea seed which was planted on his farm the previous year. Mixture of (sorghum, babala and cowpea) looks great. The cover crop will be grazed later in August-October (standing hay). He is happy with the progress. He bought a new fine seed planter from Piket and he intend to plant more cover crops this coming season
2. Purchase Materials & Equipment	Acquisition of seed, inoculum, stickers, implements, chemical inputs.	Warm season cover crops seed was delivered to farmers after purchasing it from Barenbrug. Winter annual seed was delivered 22 February for

		screening trial. A new planter for planting small seed was delivered to Humanskraal. Lourens Rhudolf (Landini) organized it.
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.	The screening trial was planted mid-December, summer annuals. Winter annuals end of February. December planting of cash crops in regenerative trial also took place. The livestock integration and regenerative trial was planted on the16/1/18.
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.	Discussed trials with farmers and deliver seed. 26/9/ meeting Ottosdal decision was taken to carry on with screening trial. Took soil samples from the regenerative and integration trial. 22-23/01/2018 samples for nematodes and crown rot were taken. Photos was taken with every visit of the trials. Leave samples were taken to determine the nutrient content for P, K and Ca.
5. Monitoring and Sampling	Completed data sheets for 1. Input cost 2. Germination 3. Cover % 4. Height of cover of each addition 5. Biological productivity t/ha 6. Root evaluation:	The information of the previous 3 years is the ARC's statistical division. The data will be presented to farmers at the March farmers day. Summer and winter annuals were harvested on 4/5/2018. Results will be discussed.
6. Lab Analyses	C:N content of plant material.	Will be forthcoming.

7. Monthly meetings (project team) & Training	Partake in monthly forum meetings, discussing problems and possible solutions to that.	26/09/2018 Meeting at Ottosdal steering com. 9/11/2018 ordered summer annuals from Barenbrug. 22/01/2018 nematodes and crown rot sampling. 13/2/ 2018 No-till conference, present talk. Man a demonstration point on Cover crops.
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. 6-month technical report completed by March 2018. Final report in September
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 "Winter cover crops and potential benefits in a mixed farming system." Grain SA A presentation to farmers on 14/08/2018

3.3 Results achieved

Al the trials were harvested and dry Matter (DM) for the different treatments were calculated.
1. Screening trial
2. Infiltration trial
3. Regenerative trial
4. Integration trial
5. Tracking SOM

A short summary of the results of the screening trial is presented for the 2017-18 season. Data sampling for varies other inputs are also discussed.

3.3.1 Maize planting (on various cover crops)

Plate 3.1: Maize

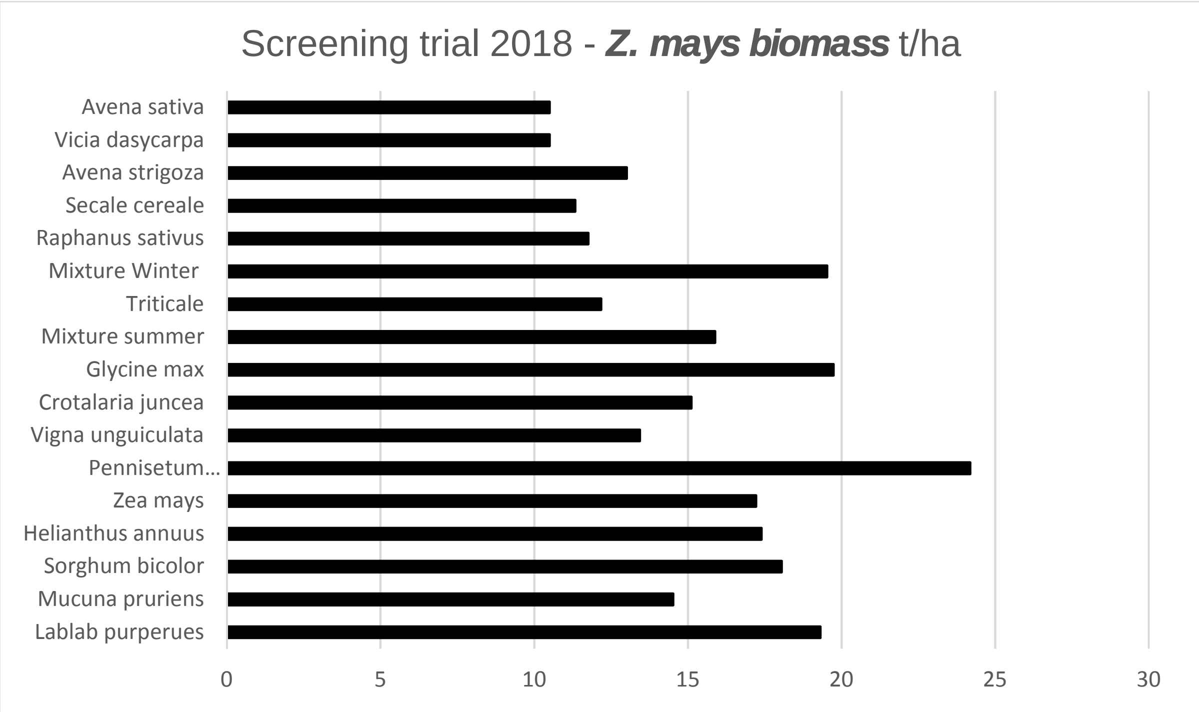

Figure 3.1: Maize biomass performance on different treatments

Discussion: Except for the winter mixture, maize on cool season crops this year did not do well. Early season rain could not recharge the ground water. Maize on Babala did well and produce an unexpected crop of 14 t/ha grain.

3.3.2 Sunflower planting (on various cover crops)

Plate 3.2: Sunflower in bloom

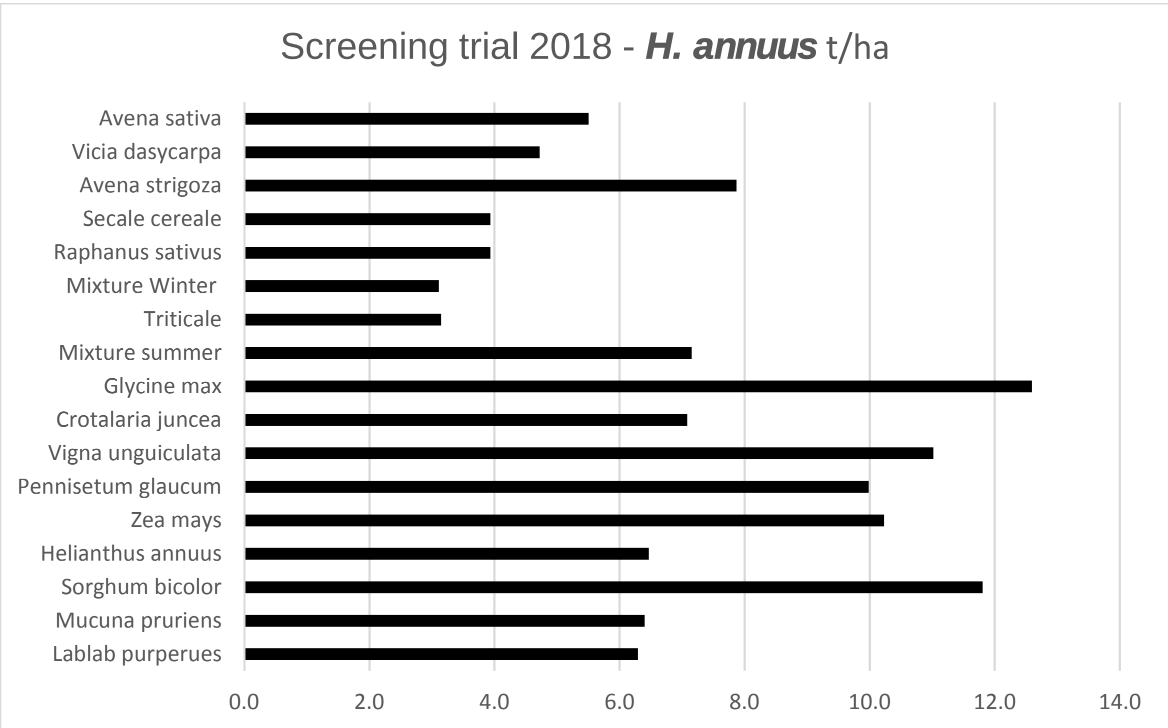

Figure 3.2: **Sunflower biomass performance on different treatments**

Discussion: Sunflower did not perform well this year. Plant density seemed to be very high. Also bird damage occurred because it was the only sunflower in the vicinity.

3.3.3 Soybean planting (on various cover crops)

Plate 3.3: **Soybean**

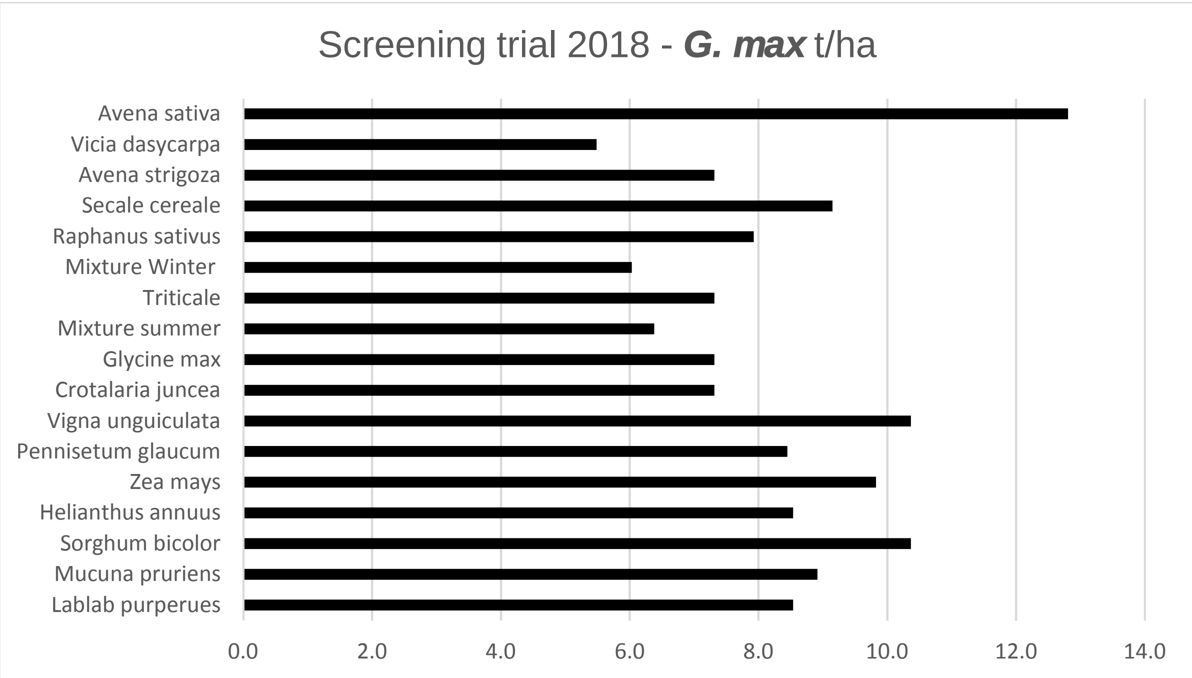

Figure 3.3: Soybean biomass performance on different treatments

Discussion: Soybean did well on oats and most summer crops. New genetic material will influence crop positively.

3.3.4 Sorghum planting (on various cover crops)

Plate 3.4 Sorghum

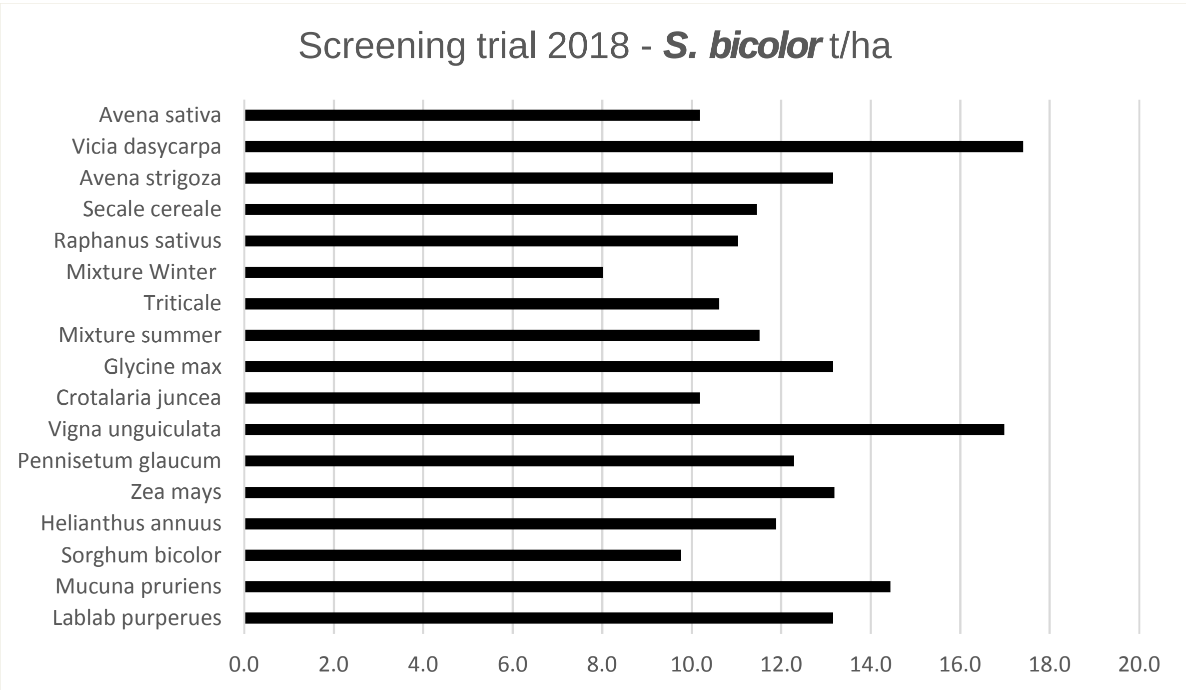

Figure 3.4: Sorghum biomass performance on different treatments

Discussion: The three best biomass production figures are on legumes (winter and summer). A crop that produce ample soil cover. If a good market exists, a good alternative crop to maize and sunflower.

3.3.4.1 Grain production summary from maize

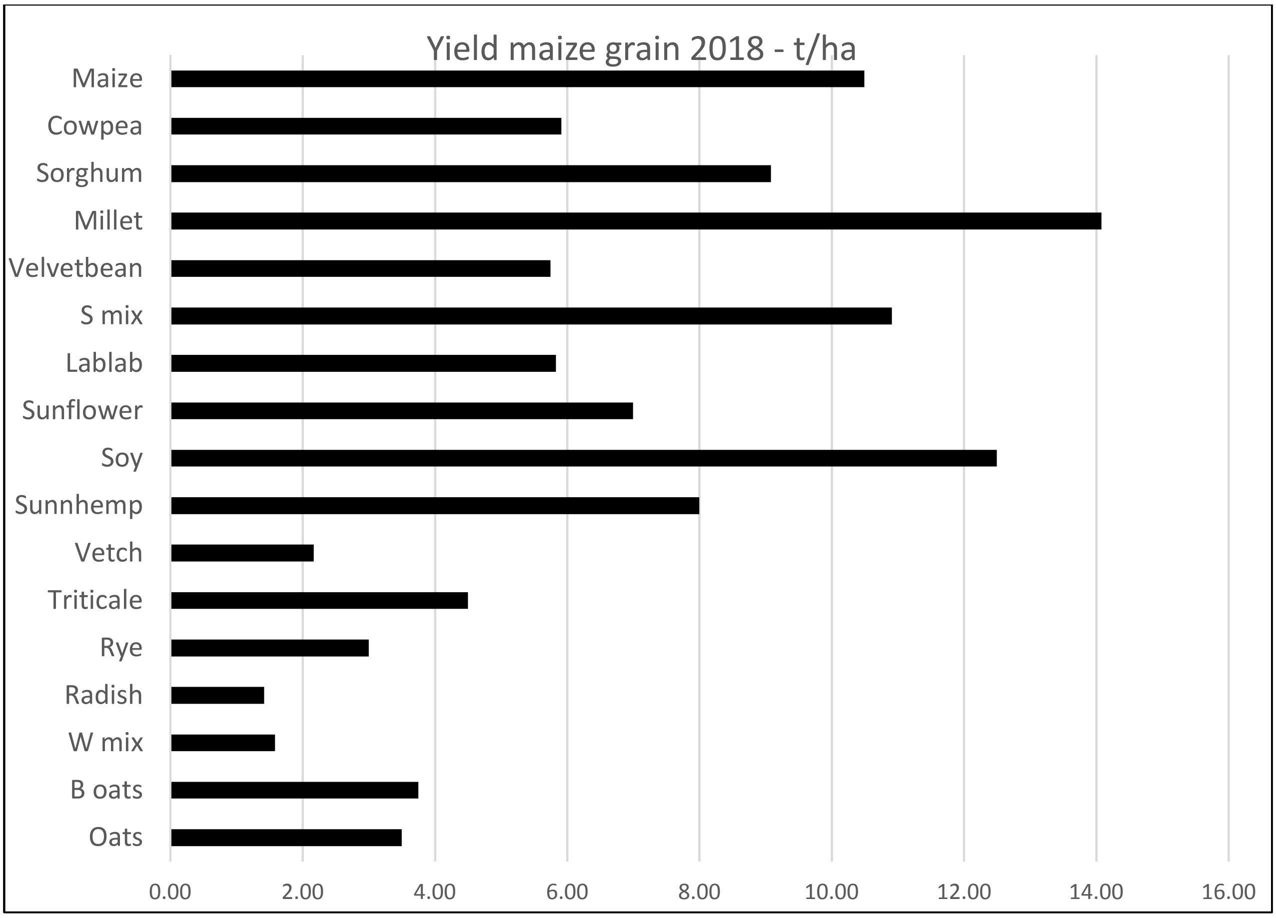

Figure 3.4.1: Grain production summary from maize

Discussion: Lollie Zietsman, technical assistant and farmer facilitator of Ottosdal CA FIP project, harvested the different treatments containing cash crops. Maize yields on cool season crops are low. Rain early in the season did not refill the soil moisture. These crops utilize moisture during winter months and no carry over moisture is left after terminating the crop. The other cash crop results still need to be captured. The average yield over all treatments is above 6,7 t/ha^{-1}. This yields a water use efficiency figure of 16.8 kg/mm.

3.3.5 Cowpea planting (on various cover crops)

Plate 3.5: Cowpea looking good

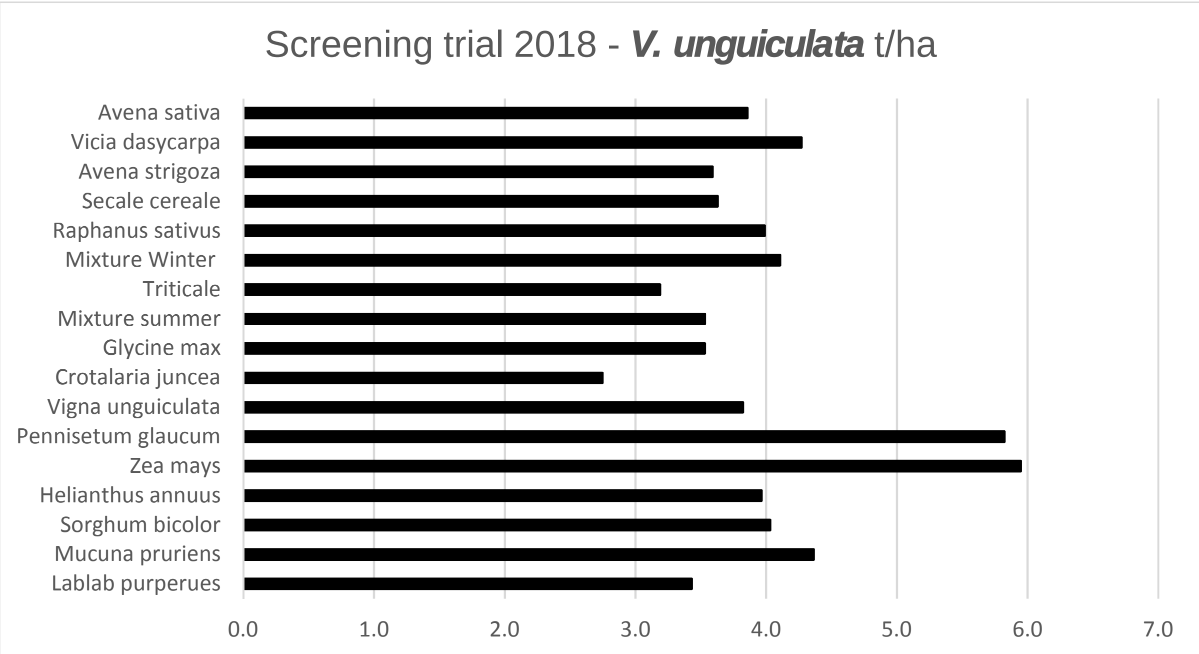

Figure 3.5: Cowpea biomass performance on different treatments

Discussion: Cowpeas produce well on all treatments. Grasses such as babala and maize that produces a lot of residues seems to be favoured by cowpeas this past season.

3.3.6 Lablab planting (on various cover crops)

Plate 3.6: Lablab performing as always

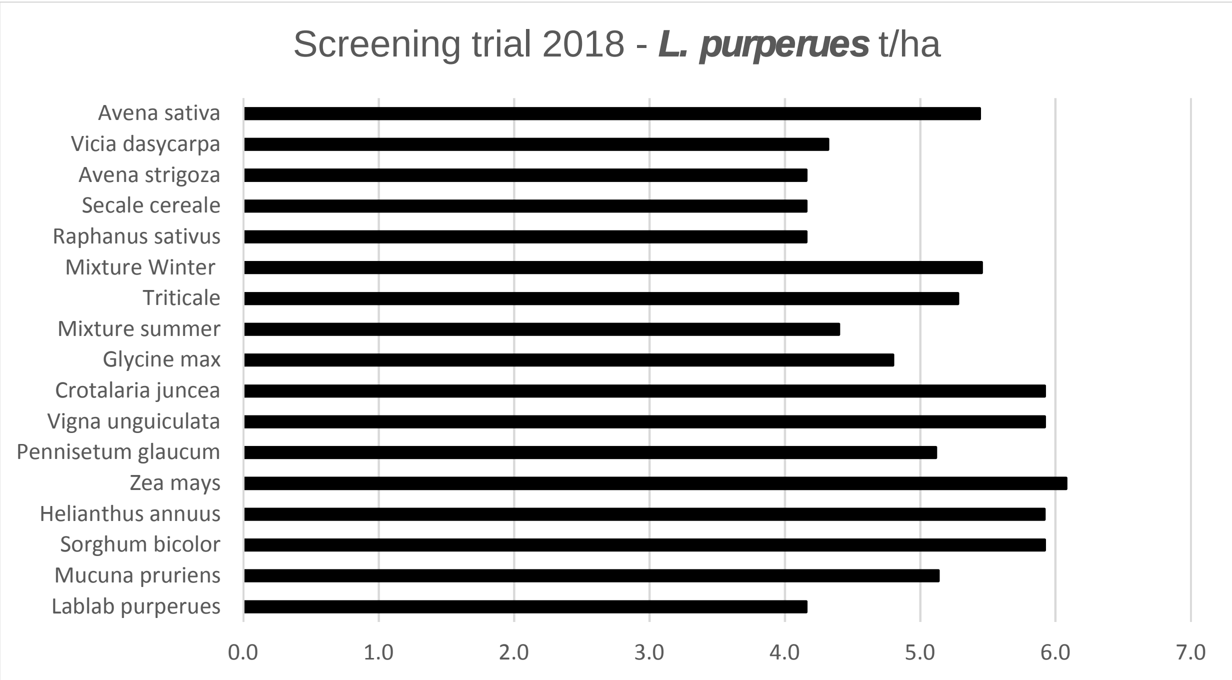

Figure 3.6: Lablab biomass performance on different treatments

Discussion: This tropical legumes' ability to survive in the most brutal climatic conditions is unrivalled. Performing well and negatively impacting weed is a strong attribute of this biannual legume.

3.3.7 Velvetbean planting (on various cover crops)

Plate 3.7: Bunch type Velvetbean

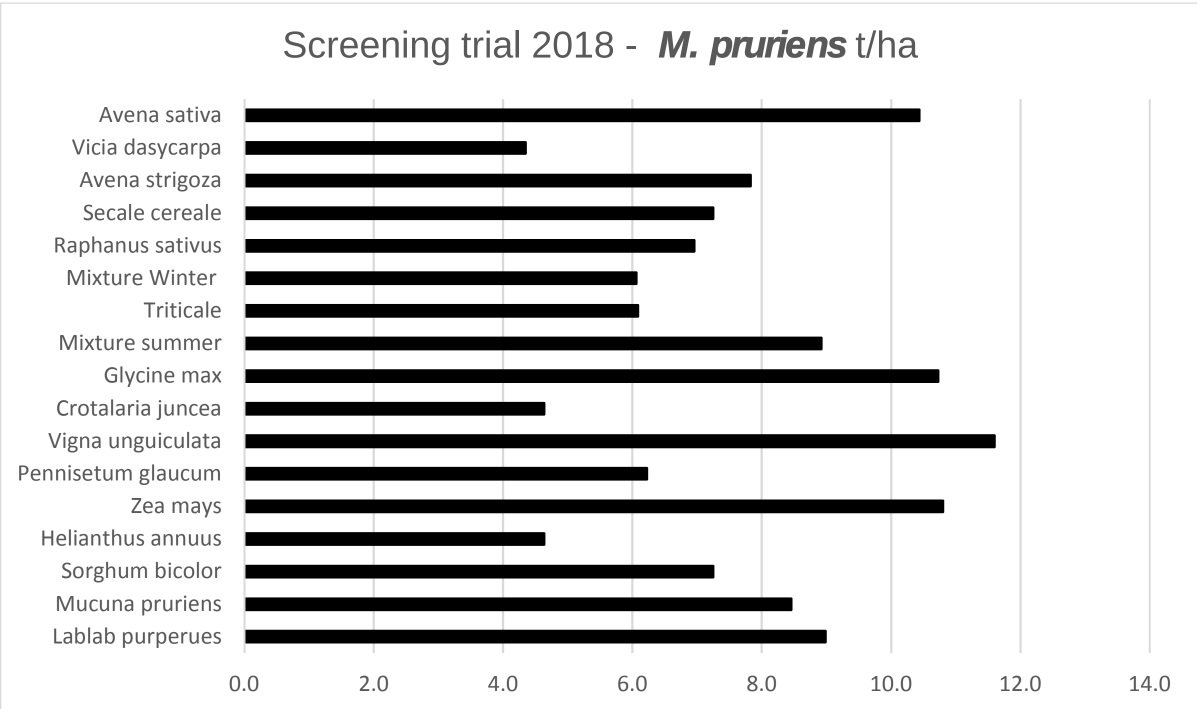

Figure: 3.7: Velvetbean biomass production on treatments

Discussion: This past season we tried a Velvetbean variety that has a more bunch (bush type) growing habit. It also has the ability to produce viable seed in a sub-tropical climatic condition. It did fairly well but making seed means the ability to grow till killed by frost is lost. As Cowpeas it was overgrown with weeds late autumn.

3.3.8 Sunnhemp plantings (on various cover crops)

Plate 3.8: Sunnhemp

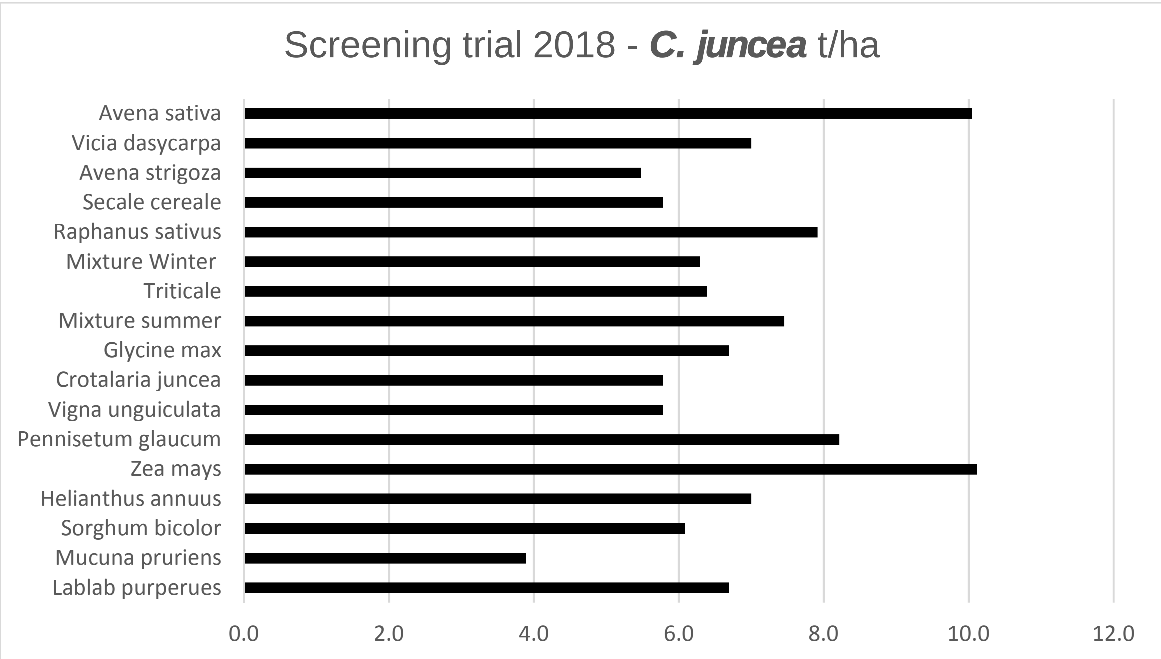

Figure 3.8: Sunnhemp biomass production on different treatments

Discussion: This legume has a woody stem growing upright as it has to support itself. Having more lignin than other trailing legumes the mulch takes longer to degrade in harsh environments. Maize yield on Sunnhemp was the highest of all the legumes. A crop from Africa suitable for our subtropical condition.

3.3.9 Babala plantings (on various cover crops)

Plate 3.9: Actively growing babala crop

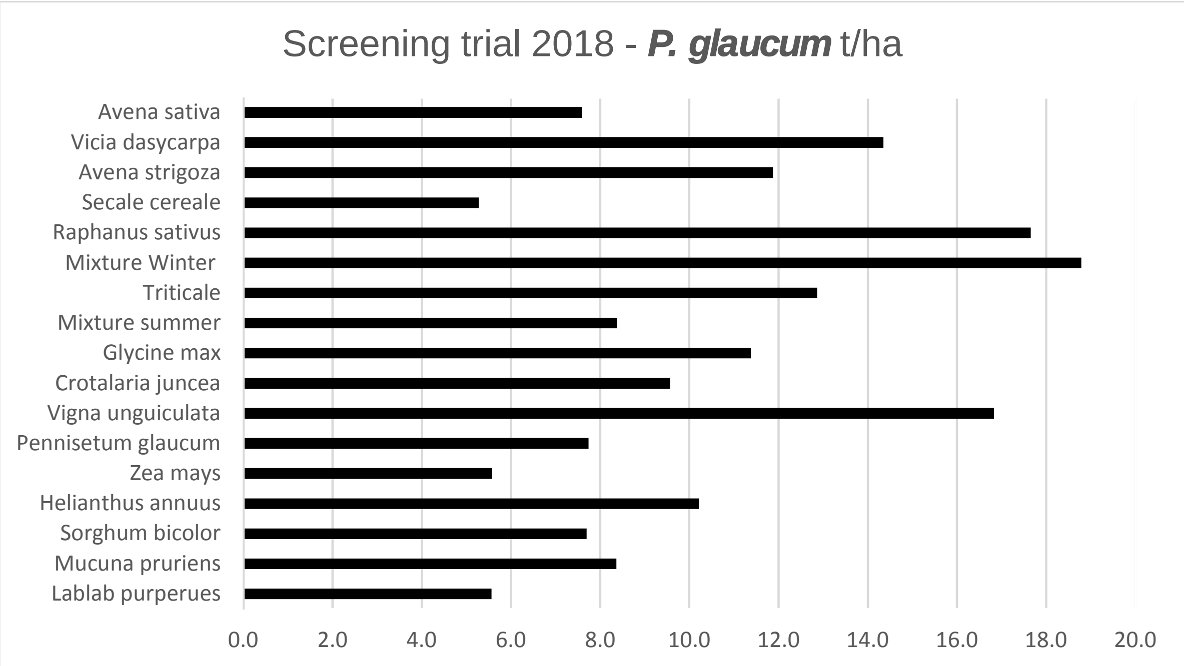

Figure 3.9: Babala biomass production on different treatments

Discussion: The only crop that performs well after rotation with Radish. Notorious for producing an excellent mulch. Lead to highest performance of maize grain the second year running. An ancient Africa crop with a tremendous well developed root system.

3.3.10 Summer mix on various cover crops

Plate 3.10: Summer mix showing diversity

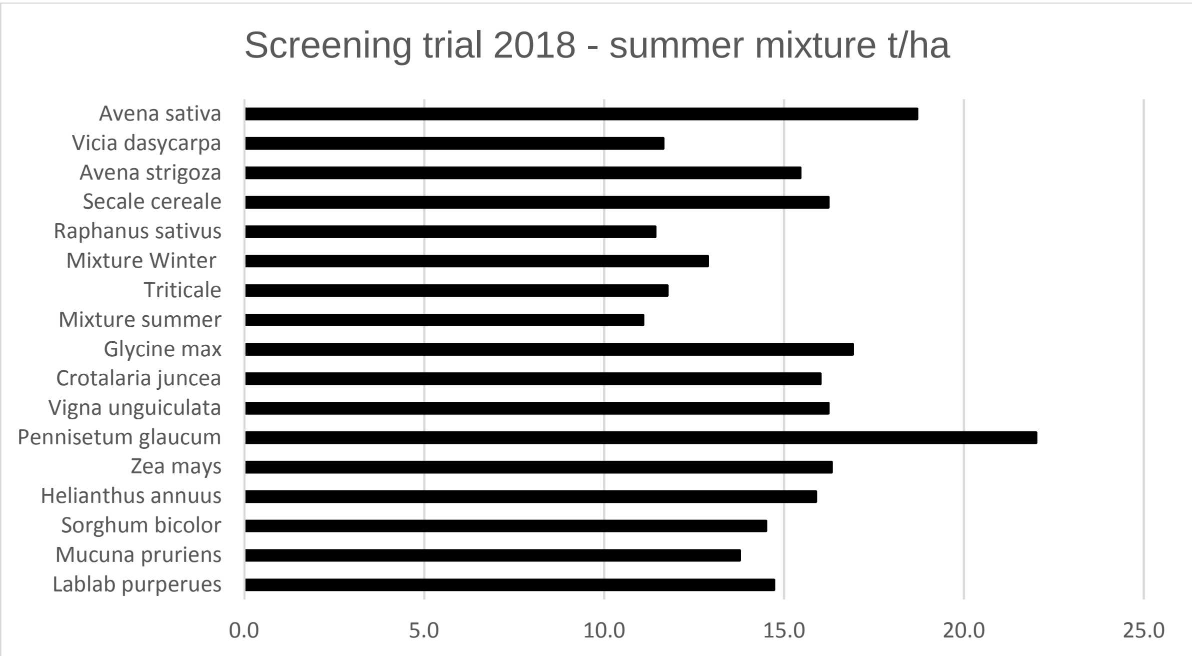

Figure 3.10: Excellent performance of summer mix on all treatments

Discussion: Novices starting with CA will benefit using a mixture. Getting divers, well balanced mulch holds the key to a good start. With two legumes lablab and sunnhemp, fixing nitrogen and sorghum producing bulk this mix can also be grazed by livestock.

3.3.11 Triticale

Plate 3.11: Triticale looking well after good rains end of March

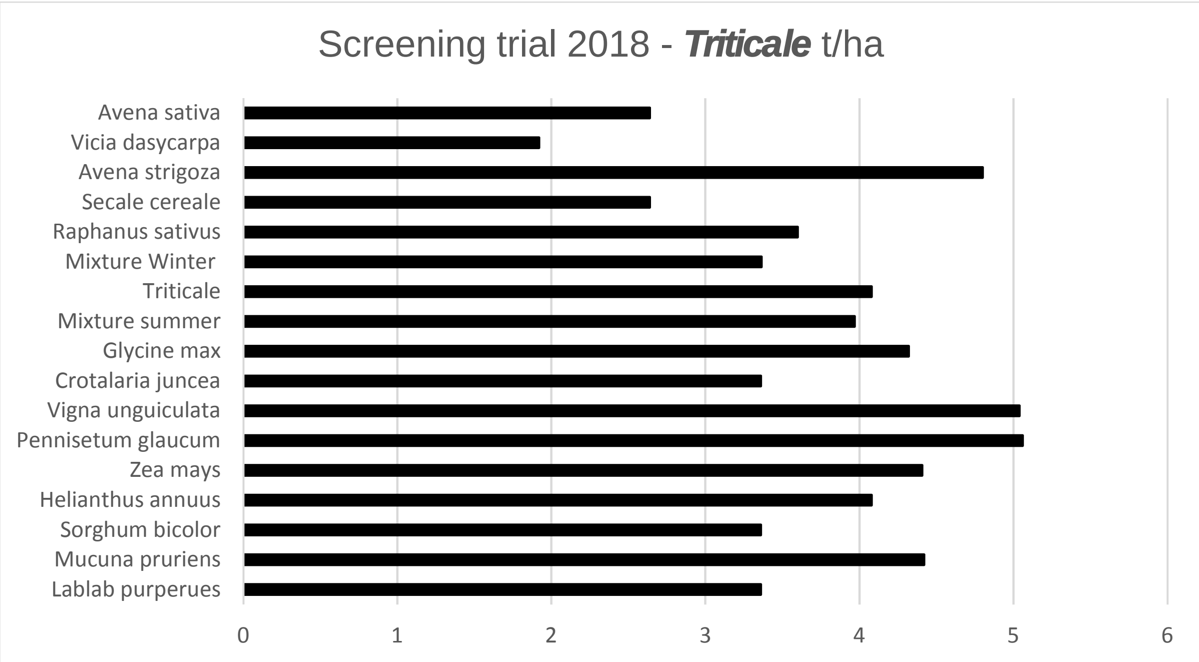

Figure 3.11: Triticale biomass production on different cover crop treatments

Discussion: A cross between a wheat and rye, triticale has a well developed root system and excellent cold tolerance. Not a lot of leaves means that it produces a mulch that will performs well in terms of erosion control.

3.3.12 Winter mixture

Plate 3.12: Winter mixture

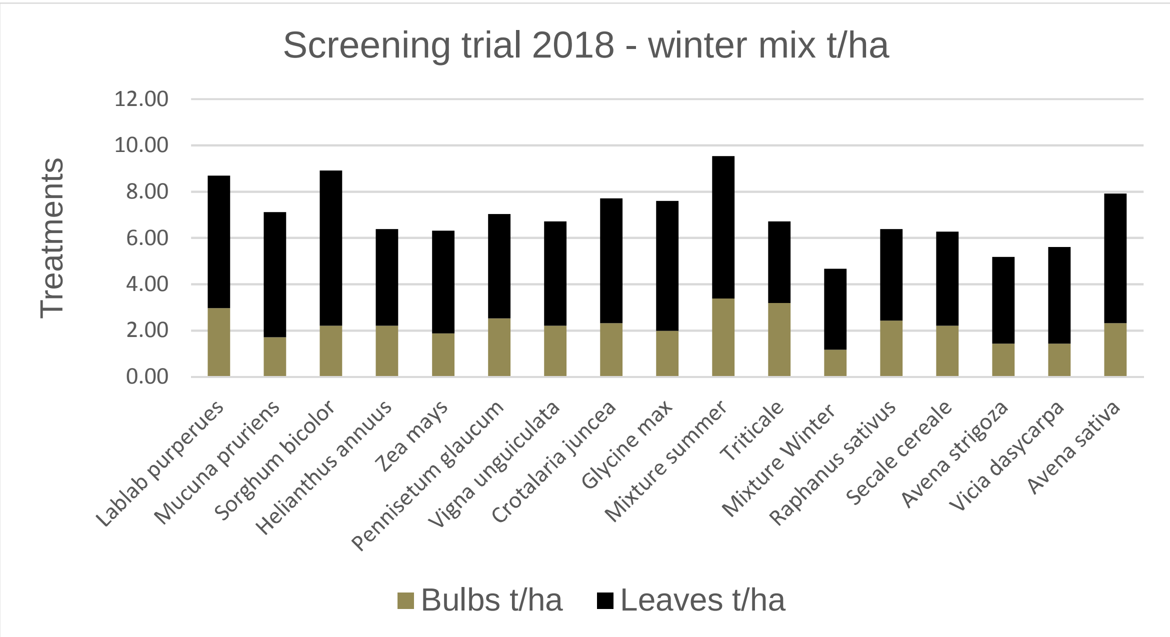

Figure 3.12: Biomass production of winter mix at Humanskraal

Discussion: Due to the biological cultivation effect of Radish that influence infiltration and can possible lead to the reduction of soil compaction, a radish cultivar was used that produce a longer and thinner bulb. As previously reported an excellent N scavenger. In mixture no more than 1kg/ha is recommended. Seed also expensive.

3.3.13 Radish

Plate 3.13: Slender radish bulbs with good leave production capabilities

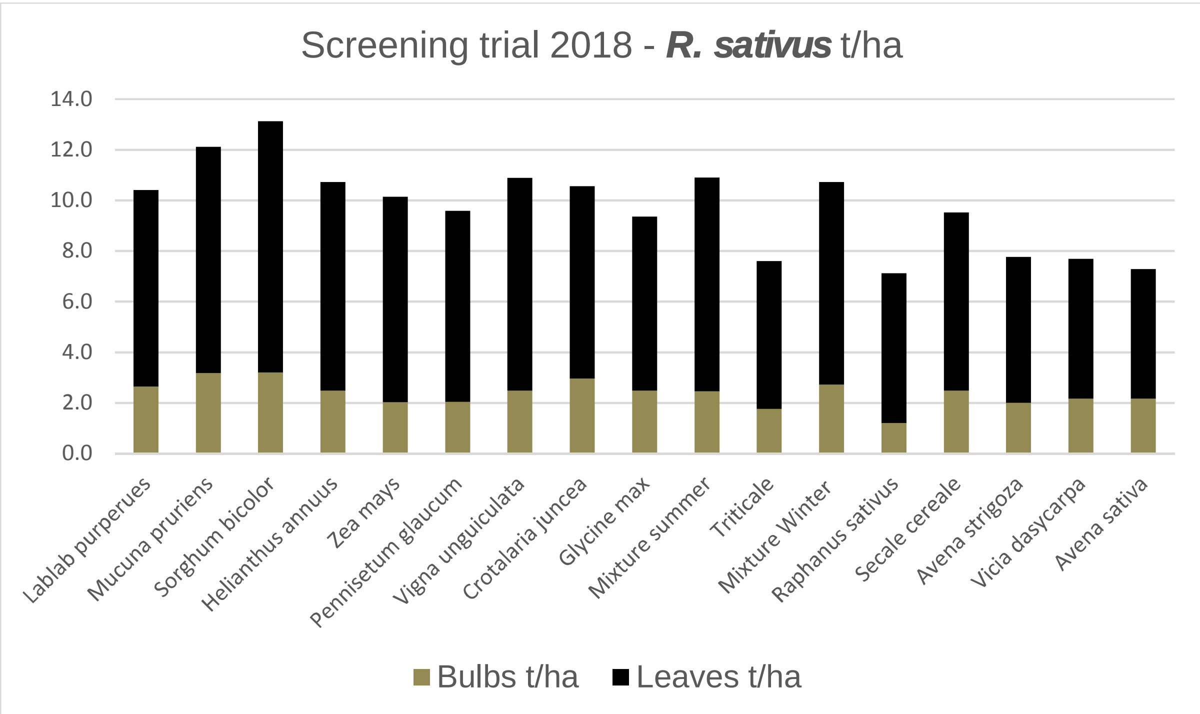

Figure 3.13: Biomass production of radish on different cover crop treatments

Discussion: A specie with high genetic diversity. Can impact soil condition by producing bulbs. On sandy loam soil it is best to use cultivars such as daikon and ground hog, which has excellent leave producing traits. Long slender bulbs with a taproot can then uplift compaction layers deep in the profile.

3.3.14 Rye

Plate 3.14: Rye in a flag leave stage

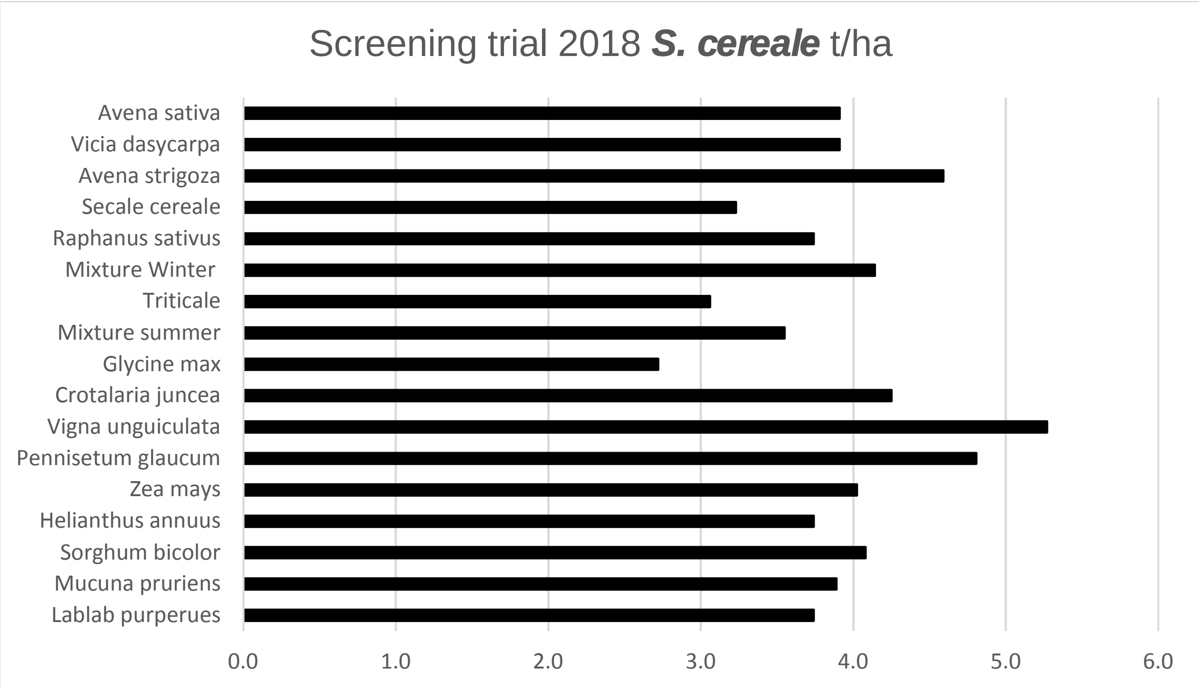

Figure 3.14: Biomass production of rye on different treatments

Discussion: Very hardy cold tolerant crop. Produces a good mulch with a high C:N ratio. A good companion crop in a cool season mixture. With an average of 4-6 t/ha DM a very consistent producer.

3.3.15 Oats

Plate 3.15: Oats on different treatments

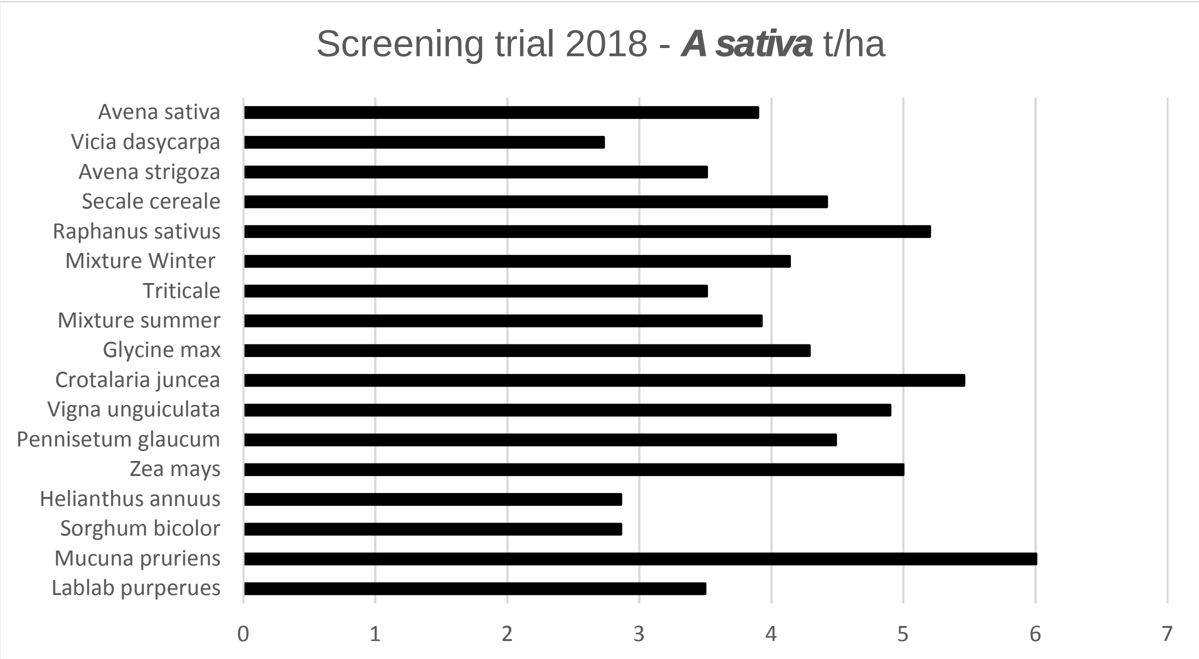

Figure 3.15: Biomass production of oats on different treatments

Discussion: The most palatable cool season annual. Sensitive to cold temperatures. Produces good quality fodder. Has a long growing season especially the spring type. Respond well to residual N from legume treatments. Can become invaded with weeds.

3.3.16 Hairy vetch

Plate 3.16: Hairy vetch on different treatments

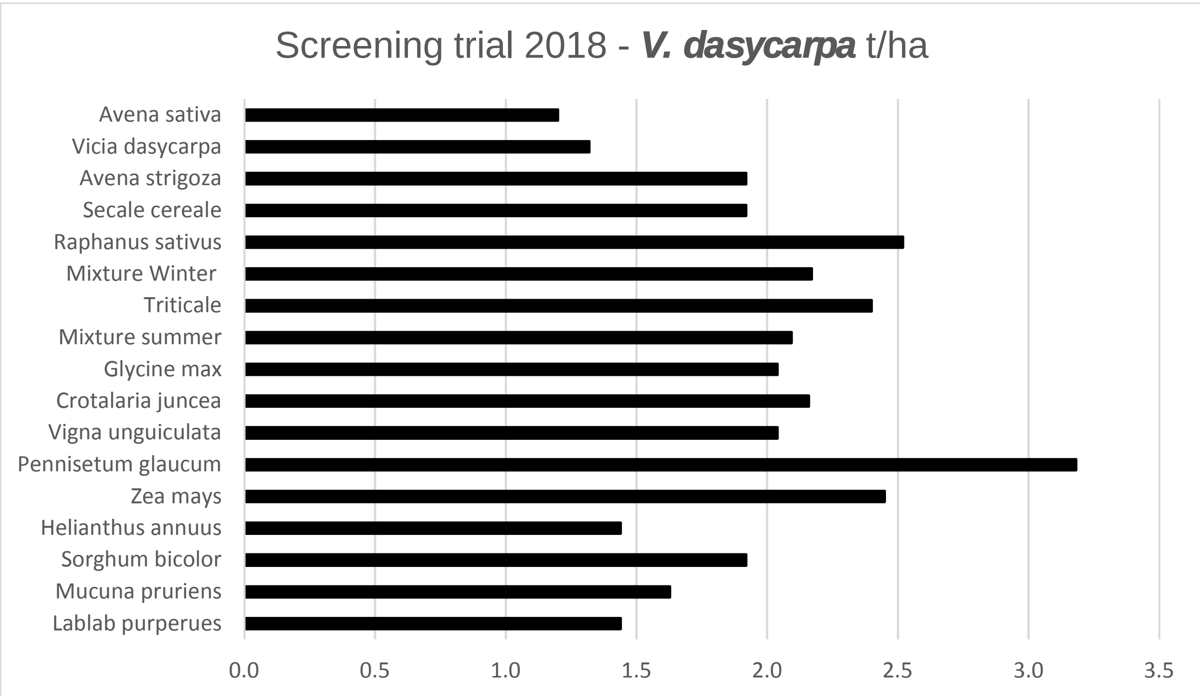

Figure 3.16 Biomass production on different treatments

Discussion: Can cover the soil for an extended period of time. Respond to spring rain and can regrow after producing viable seed. Flimsy residue covers for subsequent crop. Fix nitrogen which are correlated with the biomass.

3.3.17 Black oats

Plate 3.17: Black oats on different treatments

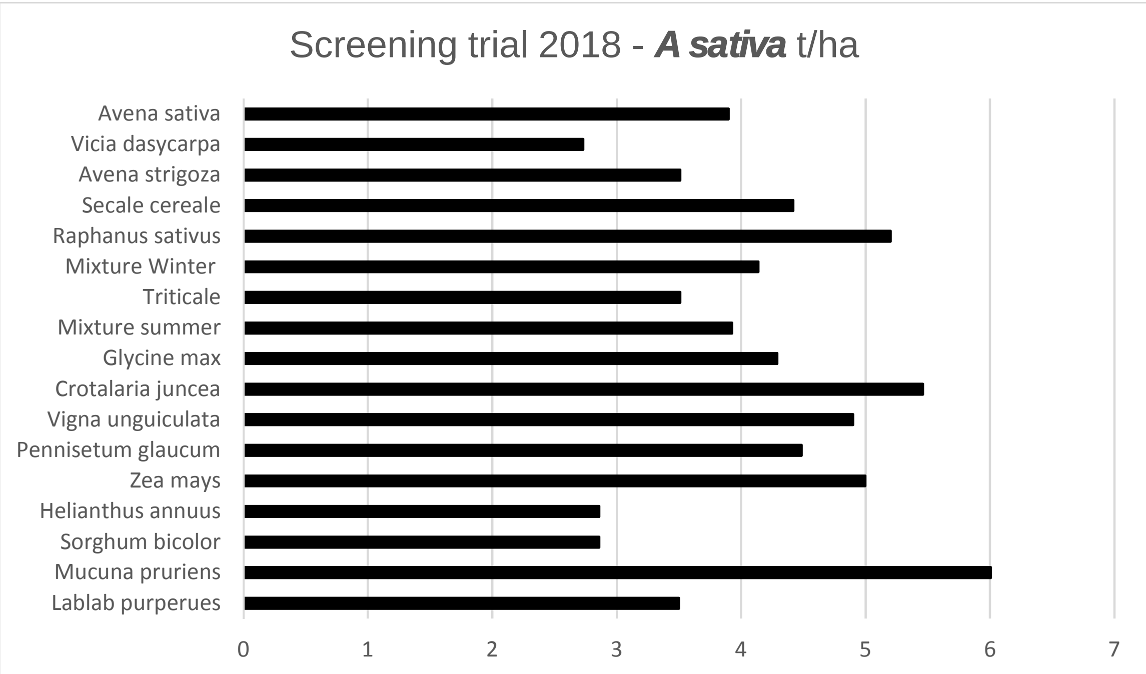

Figure 3.17: Biomass production on different treatments

Discussion: At this stage one of the cool season crops that produces under a range of climatic conditions. Under extreme cold condition signs of stress is observed. A performer in terms of biomass production. Do well with a bit of N from legumes.

3.4 Infiltration test

The previous year the performance, value and interpretation of doing an infiltration test was discussed in detail. These tests were repeated this year and revealed valuable information. Figure 3.4.1 shows infiltration rates measured on different crops planted repeatedly (monoculture, grey bar) and the same crops planted after sunflower (black bar) under no-till.

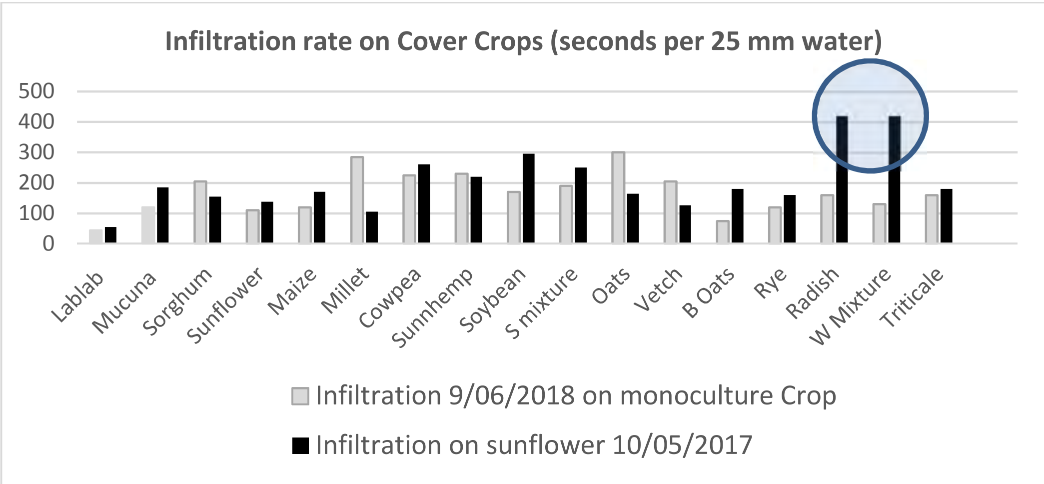

Figure 3.4.1: Infiltration on sunflower of different treatments and infiltration rates on monoculture

Discussion: Most treatments had very good infiltration rates (below 180 seconds), while only radish and winter mixture on sunflower had poor infiltration rates. The use of a radish cultivar in 2016/17 that produces big bulbs created some level or form of soil compaction that impeded infiltration. A different cultivar was used during 2017/18 and the infiltration rate drastically improved for the two treatments where radish was included (radish and winter mixture). This effect was also observed in cash crop trial plots (see plate 3.4.1 below), where soya bean growth was negatively affected after a winter mix with radish included.

Plate 3.4.1: Stunted growth due to compacted soil on the right (soybean, maize and sunflower)

The pressure exerted by bulbs and the lack of residues on the surface created a less than favourable situation. Fine silt and clay particles clock the macro pores within the soil due to the kinetic energy of rain ponding the soil surface. This created a compacted layer at a depth of about 15 cm that stunted the root growth. When inspecting the phenomenon, the top soil was dry and full of roots, the deeper layers were moist with no roots. All other treatments' values for the infiltration tests were satisfactory. These genetic variations between cultivars for various reasons should be researched if we want to fine-tune using diversity for regenerative purposes.

3.5 Regenerative (green fallow) trial

A summer annual mixture was left to develop fully and were then left standing (vertical mulch) for the winter (plate 3.5.1). This crop system, being summer annuals, are killed by frost. A small amount of radish (cool season annual) was mixed with the seed. This ensured the presence of living roots in the soil during winter. A core principle of conservation agriculture is adhered to by applying this strategy. The root exudes glycoproteins that can attract micro-organisms, which use this sugary substance as food. In return they provide mineral nutrients to the plant (roots) The winter annual part of the trial was not established.

Plate 3.5.1: Summer annual cover crop 2016-2017

The reason for this will be made clear by the photo below. The soybean (right) in the foreground was planted on cool season mixture whiles the soybean (left) was planted on the summer mixture. Clear from the picture is the fact that the C3 plant (cool season crops) do not produce the mulch that the C4 (summer annuals) display. The mixture did contain a fair amount of radish, though.

Plate 3.5.2: Cash crop on summer and winter annuals (right)

3.5.1 Yield for cash crops

Figure 3.5.1 shows that soybean had a higher yield on winter annual cover crops. A cold snap during the second week of May terminated the growth of the crops. Being under stress due to soil water shortage the soybeans on the winter annual cover crops completed its growth cycle faster and had higher yields compared to the soybeans on the summer annuals. Maize and sunflower produced higher yield on the summer annuals.

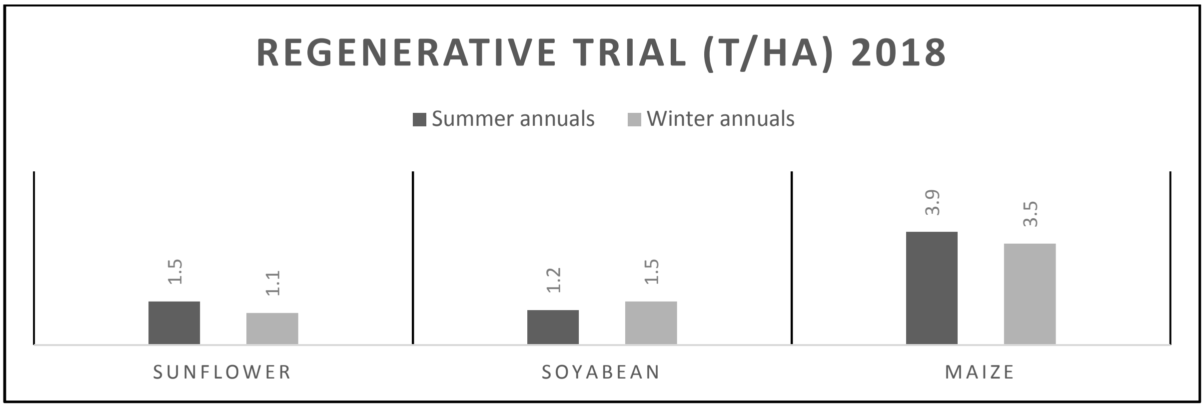

Figure 3.5.1: Regenerative trial

3.6 Livestock integration trial

After employing CA principles for six years, soil analyses revealed that cash crop soils still had a low SOM (1-1,2%) content and that total microbial biomass was poor. Also no natural microbial predators such as protozoa and nematodes are present in the soil. What could be the cause of this undesirable situation?

According to Kristine Nichols from the Rodale Institute, grain crops takes time to grow enough and produce photosynthetic carbon to produce exudates. When it becomes reproductive, root exudates shut off as the plant shunts resources into seed production. So there is only a four to five-week period when plants push exudates into the soil. This allow too little time and thus, grain production don't contribute a lot to build up soil carbon.

Past practices of agrochemical use and high rates of inorganic fertilizer have most probably also negatively impacted soil micro-organisms diversity. Could we rectify these problems by planting a diverse summer crop mixture and utilizing it with livestock?

3.6.1 The theory

Using high-density low frequency grazing to utilize the summer mixture we are trying to restore our soil carbon stock in the soil. The above-ground chewing, tearing and trampling by livestock grazing creates wounds that the plants must heal. But the plants don't do this alone. They need micronutrients and microbial metabolites and this cooperation they achieve by pumping a steady supply of carbon rich exudates from their roots to recruit microbial assistants.

By letting livestock graze half of what is available, the diverse sward will regrow. The manure of livestock also contains more humic substances than plant residues. Dung beetles and saprophytic fungi can feed on this nutrient rich matter and help recycle elements back into the soil. This carbon will eventually become part of the more resistant carbon pool, humus "the very dead". By planting fodder crops, nutrients deep in the soil is returned to the surface and placed back into biological circulation. The mulch left on the surface will upon decaying release plant accessible nutrients back to the soil to be used by subsequent crops. By not using excessive amounts of agrochemicals soil can recuperate with microorganisms breaking down unwanted chemical substances.

3.6.2 The Practice

A total area of 53 ha of a diverse summer mixture of crops was planted which include grasses, legumes, cash crops and radish. Two planters were used to plant the big seed and fine seed, separately. The planting density for both big and small seed were 110 000 seed/ha. A Total of 220 000 plants/ha was the aim. The small seed were planted at a 30^{0} angle over the big seed rows. Direct drilling the seed brought a 50% seed cost saving. Plate 2 is testimony of the successful establishment of the cover crop. Planting took place on 16/01/2018, the photo was taking on 1/02/2018

Plate 3.6.1: Cover crops establishing successfully

3.6.3 Grazing

Livestock was bought (plate 3) at an auction at Vryburg and transported by truck to the farm Humanskraal of Mr. George Steyn. Due to the high prices of weaners at the time, cow/calf pairs were bought, 200 in total that equates to 150 LSU, with an estimated DM need of 2034 kg/day.

Plate 3.6.2: Livestock grazing cover crops

Electric fencing equipment was used to divide the grazing area in 3 ha camps. Each camp was used for a period of 3 days before moving livestock to a new camp. An additional area was also identified where animals could be parked in case of extended rainy events. A perennial warm season grass of smutsfinger, close to the cover crop was identify as suitable for this purpose. Water was supplied at a central point with a corridor on the side of the cover crop that gave livestock excess to the water.

3.6.4 Discussion

The most nutritional leaves and seed heads was consumed by animals. Most of the more fibrous stems were trampled. This created a mulching effect that covered the soil surface completely as shown in plate 3. Meat production was in the order of 215 kg/ha with a feed conversion ratio of 10.7:1. A total of 11,4 tons of meat was produced on 53 ha in 60 days. Figure 3.6.1 gives a break-down of the biomass that was produced by the cover crop.

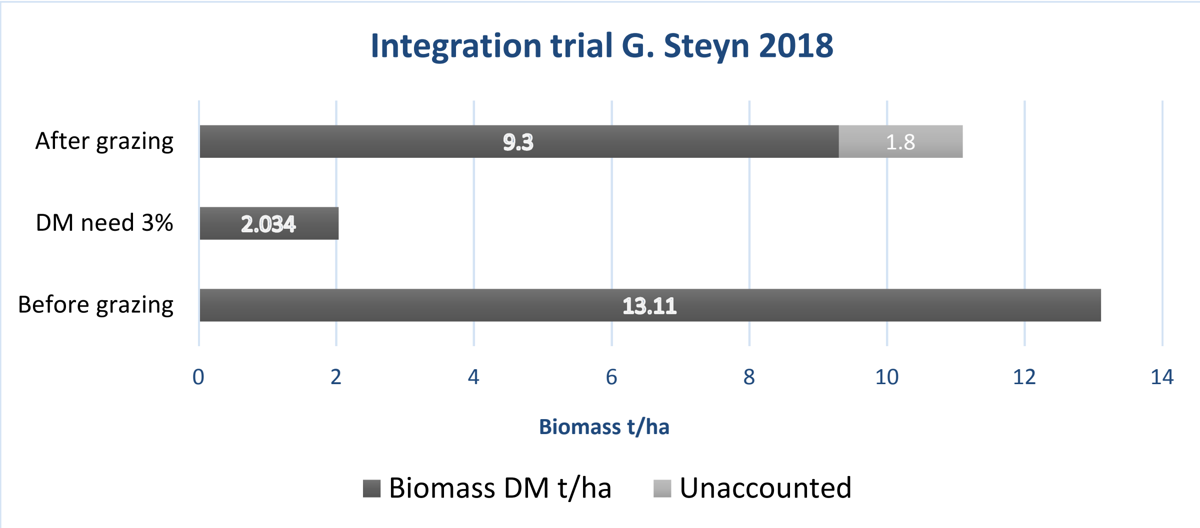

Figure 3.6.1: Biomass utilization profile

Selling at auction meant that a 7% commission fee has to be paid to the auctioneer at cost of R120 000. Transporting the livestock also had high cost implications. According to the farmers buying livestock at auction is risky and you might just end up buying other farmers' problem animals. Using your own animals will be less risky and adding value to your own livestock, make more sense to him.

3.7 Tracking soil health (SOM)

Through the process of photosynthesis plants obtain their carbon from the air and not from the soil. Soil carbon is not a plant nutrient, it does not feed plants directly and is not essential. Yet there is a close relationship between soil organic carbon (SOC) and crop yields. Farmers and researchers around the world regards SOC or soil organic matter (SOM) as the universal metric to measure soil health. What makes it valuable is that it is easy to measure, cheap and can be done using low tech methods.

SOM can be defined as all organic materials found in soils irrespective of their origin or state of decomposition. Not included is surface litter and livestock dung. SOM consist of between 50 to 58% carbon such that SOM is simply the multiplication of measured soil organic carbon (SOC) with a factor 1.724 to 2.

The biological functions of SOM are primarily to provide metabolic energy that drives biological processes, to act as a supply of macro-and micro-nutrients and to ensure that both energy and nutrients are stored and released in a cycle that connects above- and belowground energy transformations. As part of SOM the organisms in the microbiome played an integral part in the soil ecosystem as explained by table 3.7.1.

Table 3.7.1: Soil ecosystems function of SOM

Functional group	Function	Representative members
Chemical engineers	Regulate 90% of energy flow and stimulate plant growth; make antibodies	Bacteria and fungi
Biological regulators	Regulate populations of soil organisms, through grazing, predation or parasitism	Protozoa and small invertebrates, such as nematodes, pot worms springtail and mites
Ecosystem engineers	From pore network and bio-structures, aid in aggregation and particle/microbial transport	Plant roots, earthworms, invertebrates including millipedes, centipedes, beetles, caterpillars, etc.

The effect of SOM on soil water retention tends to be greater in coarse textured compared to fine textured soils. An increase in SOM from 1-3% can double the plant available water in the sandy loam soils of North West.

One of the objectives of the trial at Ottosdal was to investigate which crops and crop sequences will positively influence the sequestration of soil carbon, since SOM building in the soils of the sub-tropical, semi-arid environment of North West is a major challenge. Soil samples for selected treatments were annually analysed using the Haney soil health test, which include SOM and a range of other parameters (see Figure 3.7.1). These treatments represent all the different functional groups in the trial, which are grasses, legumes cash crops and brassicas.

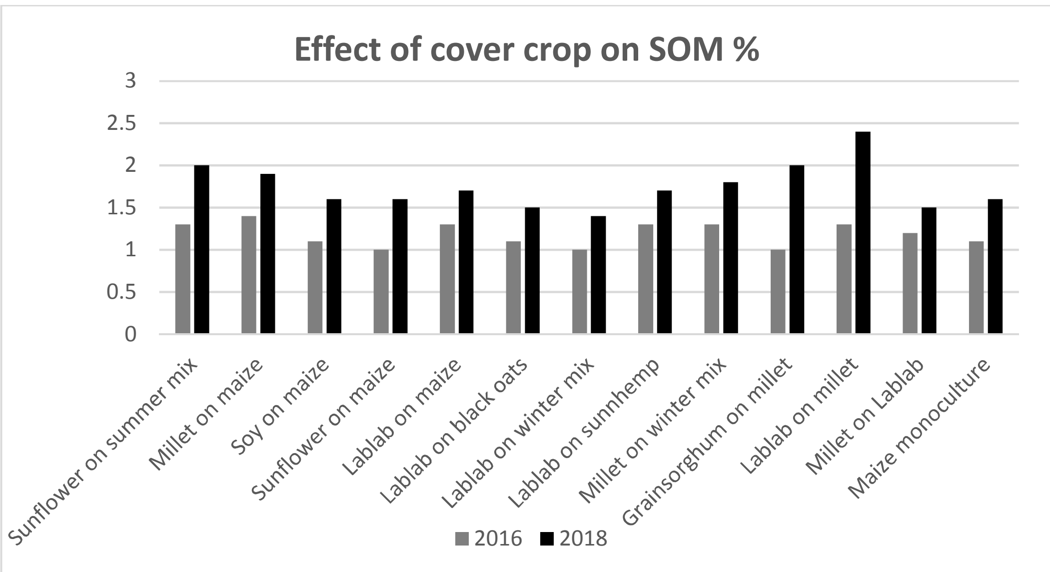

Figure 3.7.1: SOM% on screening trial treatments

3.6.2. Discussion

At Humanskraal the highest value measured for SOM (2.4%) was under a lablab (dolichos) and millet (babala) rotation. The SOM level almost doubled (an increase from 1,3% to 2.4%) over the last two years, which is remarkable in this environment, almost reaching the critical level. Plant material with a C:N ratio of 24 or higher, such as babala, will often immobilize soil N, i.e. bacteria will use available N to break the fibrous material down. Legumes fix atmospheric N in symbioses with rhizobia bacteria, which eliminates immobilization. Treatments that include high yielding annual grass crops such as babala and sorghum also speed-up SOM build up. It is clear that the summer mixture that includes both legumes and grasses can support SOM sequestration by supplying N as well as C. For the cash crops the value of the sunflower on summer mixtures (2%) holds promise, as sunflower leaves low levels of residues (<30% cover) before planting the next crop. All treatments showed higher values for SOM over the two-year period.

3.8 Conclusion

All farmers want to manage soil in a way it was design to function. Soil health, which includes the building of SOM/SOC in the transitional phase remain important. Cover crops play a role in getting positive results so much faster. Bringing livestock back to the lands is also encouraging and spread the risk of crop failure. Even if conditions are not 100% some component with in a mixture will thrive and produce.

3.9 Any problems that have been encountered with the project.

Good cooperation from all the different role players. As far as the cover crops it is envisaged that integration with livestock will now be prioritised.

4. Agronomic field trial planning and analyses

4.1 Work package

Work Package title	**Agronomic field trial planning and analyses**

Work Package period	October 2017 to September 2018
Lead partner	Independent agronomist - Dr. A. A. Nel
Involved partners	Ottosdal No-till club members, Grain SA, SGS

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 will probably affect most, if not all, agronomical parameters which need to be revised for optimization. This can only be achieved through field trials. These 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 were compiled.	After meeting with the No-till Club where the objectives were discussed, field trial plans and data sheets were compiled and handed to the Club.
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 submitted to SAGrain in August 2018. A 20-page booklet on the trial results was compiled and printed as conference handout. Results of all trials were presented at the 2018 conference as well as a talk on crop rotation during the trial visit. Some results were presented for a television recording on 16 April 2018. A six monthly progress report on the trial planning and analyses was compiled and submitted to the project leader. Results were discussed during a trial visit with club members (April 2018). Results were presented during the September 2018 CA working group meeting

4.3 Actions taken to date

Field trials were described and planned according to the objectives decided on by club members during the planning meeting of 13 October 2016. The trial plans were provided to the No-till club for execution. Some observations, namely the soil cover and water infiltration rates were made during the season. Results from the 2017/18 were added to results of previous seasons, analysed and conclusions made and documented. The research objectives were to compare:

1. Crop rotation systems (all seasons)
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 (all seasons)
6. Conventional crop systems and CA crop systems (2015/2016 & 2017/2018)

Results from these trials were presented at several meetings and in published popular articles.

4.4 Progress made

The following number of trials were planned, conducted from 2013/2014 to 2017/2018 and the results analysed for each objective:

Objective	Number of trials
Crop rotation systems	6 (farm x season combinations)
Argentinian versus local row widths and populations	24 (three crops, four seasons)
Tines versus coulter fitted on planter	5 (three seasons)
Plant population densities	13 (four crops)
Maize cultivar evaluation	11 (five seasons)
Conventional crop systems vs CA crop systems	7 (three seasons)

4.5 Summary of results achieved to date

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: The objective is to find the best rotation systems for CA. Results from the four 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 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 improved by forage sorghum and maize. 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.

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 moldboard 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.

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}.

PROBLEMS ENCOUNTERED AND MILESTONES NOT ACHIEVED

No serious problems were encountered and all milestones were reached.

4.6 Detailed trial results for 2013/2014 TO 2017/2018

4.6.1 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 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.

Results

The first season in crop rotation 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 2017/2018 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 2017/2018

Due to a lack of replication, no annual statistical analyses could be made since 2015/2016. The overall mean maize yield for the four seasons 2014/2015 to 2017/2018 was 5.55 t ha^{-1}. The mean yield of maize following sunflower and maize (monoculture) was respectively 10.3% and 9.6% higher than the overall mean yield, while the maize yield following soybean, cowpeas, forage sorghum and grain sorghum were between 1 and 7 % lower. The yield of maize following grain sorghum, maize and sunflower was higher than the annual mean yield in three of the four seasons.

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 three year mean yield was 10, 22 and 10% higher than the overall mean of 1.61 t ha^{-1} following soybean (monoculture), cowpeas and maize respectively. However, mean yields were 8, 17 and 18% lower than the overall mean following grain sorghum, forage sorghum and sunflower respectively. Soybean grown in monoculture and following maize had above mean yields in three of the four seasons.

Three-year mean sunflower yields were 7 and 10% higher than the overall mean yield of 1.83 t ha^{-1} after forage sorghum and maize respectively. Yields were 7, 4, 3 and 2% lower after grain sorghum, soybean, cowpeas and sunflower (monoculture) respectively. Above mean sunflower yields were found for all preceding crops in either one or two of the various seasons.

Soil cover

The soil cover left by the preceding crop after planting of the current crop at Humanskraal for 2016/2017 and 2017/2018, is shown in Table 4.3. The difference in cover left by cowpea, soybean and sunflower between the two seasons were relatively large between the two seasons. Forage sorghum, grain sorghum and maize on the other hand, left a high amount of residue with a relatively small difference between the two seasons.

Table 4.2 Grain yields in t ha^{-1} from 2014/2015 to 2017/2018 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**
Mean	5.19	5.17	5.50	6.08	5.21	6.12
			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
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
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
Mean	1.77	1.97	1.70	2.01	1.76	1.79

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

Table 4.3 The soil cover left by the preceding crop after planting of the 2016/2017 and 2017/2018 crops 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
Mean	59	93	86	93	49	40
			Grain sorghum			
2016/2017	27	90	82	70	18	24
2017/2018	93	93	95	88	65	50
Mean	60	92	89	79	42	37
			Soybean			
2016/2017	28	90	64	90	16	28
2017/2018	73	88	83	73	60	35
Mean	51	89	74	82	38	63
			Sunflower			
2016/2017	40	82	64	76	22	26
2017/2018	75	88	78	90	60	49
Mean	58	85	71	83	41	38
Two-year mean	57	90	80	84	43	45

Water infiltration rate

As a measure infiltration rate of the soil, the time it took for 25 mm of water to infiltrate the soil was measured on all maize plots during February 2018 and is shown in Table 4.4. It took less than 6 minutes for all preceding crops which is high 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
2016/2018	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 for 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
Mean	12.6	12.0	13.1	15.0	12.4	15.0
			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
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
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
Mean	3.2	3.0	3.1	4.0	3.5	3.8

Maize rainfall use efficiencies showed a large variation with the highest value 2.4 times higher than the lowest value among season and preceding crops. The overall mean efficiency for maize was 13.4 kg ha^{-1} mm^{-1}. The rainfall use efficiency of grain sorghum (mean = 7.9 kg ha^{-1} mm^{-1}) varied even more, with the highest value more than 5 times the lowest value. Soybean (mean = 3.8 kg ha^{-1} mm^{-1}) also showed a high variation with the highest value more than 6 times the lowest value. Sunflower had the lowest variation of all crops with the highest value only 2 times that of the lowest value. The overall mean rainfall use efficiency of sunflower was 3.4 kg ha^{-1} mm^{-1}.

Discussion and conclusions

The 2013/2014 and 2016/17 seasons will be remembered for ample well distributed rain resulting in exceptionally high yields. In contrast, 2014/2015 and especially 2015/2016 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.

The yields of maize, sorghum and soybean are most likely affected by a rotation x season interaction. 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 four seasons, is how well maize performed in monoculture and after sunflower. In three of the four seasons, maize had above mean yields in these two crop systems. Maize yield following the two legumes were in all seasons below the seasonal mean. 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 undisturbed soil conditions.

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 improved by forage sorghum and maize and suppressed by grain sorghum and soybean crops.

It is possible that the relatively lower yields of crops following grain and forage sorghum 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.

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 can reach high values of more than 50% 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 the only four (all in the early stage of the trial) out of a possible 18 cases, were the rainfall use efficiency below 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 twice in 11 years for both areas (Van der Walt, Smith & Fourie, 2018. Reëngebruiksdoeltreffendheid in die Noordwes-streek. SA Graan, Augustus 2018).

Apart from crop rotation, these results are also proof of the advantages of conservation agriculture over conventional tillage-based crop systems. Results from more seasons is needed to strengthen or alter the conclusions as more seasonal weather variability is considered.

4.6.2 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. Maize plant population densities are normally 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}. It is unknown how the Argentinian row widths and plant population densities will perform in comparison with local systems.

Aim

The aim was to compare the yields of maize, soybean, sorghum and sunflower grown in Argentinian crop row widths of 0.52 m, 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: The Argentinian Pierobon planter in action on the trials at Humanskraal 2014/2015.

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 Figure 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.

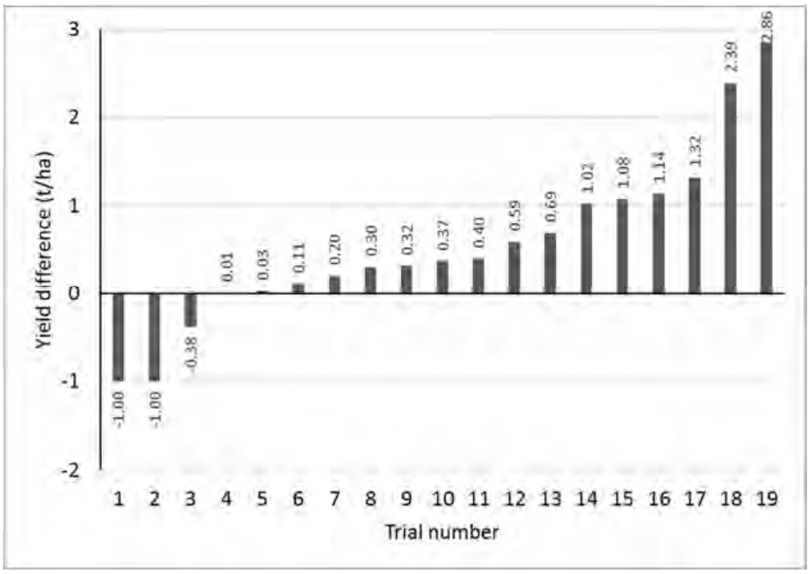

Fig. 4.1 The yield difference of maize in Argentinian (0.52 m) and local (0.91 m) row widths and plant population densities of 19 field trials done from 2013/2014 to 2016/17. Positive values represent cases where the yield of the Argentinian system was higher than that of the local system and the other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

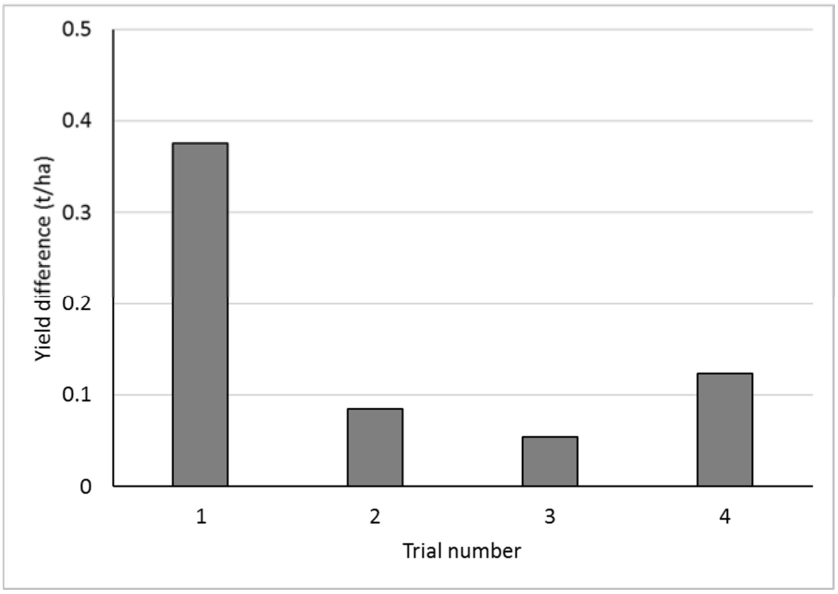

Fig. 4.2 The yield difference between Argentinian (0.52 m) and local (0.91 m) row widths in four field trials done with sunflower at 40 000 plants ha^{-1} done in 2013/2014 and 2015/2016.

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.

4.6.3 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.

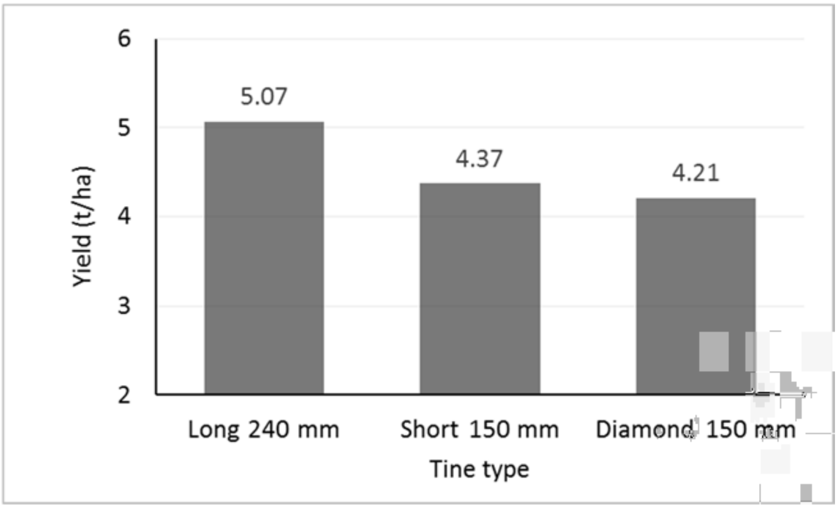

Fig. 4.3 The effect of tine type and working depth on the yield of maize in 2014/2015.

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 special variation. Further investigation into this matter is needed to link optimum depth of disturbance to these soil parameters.

4.6.4 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 plants 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 11th December 2017 on the farm Humanskraal. Twenty-seven 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 control cultivar was included between every two adjacent tested cultivars.

Two plots of 40 m^2 in each cultivar strip were hand harvested the grain 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. The net return taking the seed prices of the various cultivars into account were also calculated at a seeding rate of 40 000 ha^{-1} and a grain price of R1 800 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 2017/2018 season were DKC 77-77BR, P3058WY, PAN 5R-791BR, US 9610 and US 9777. In terms of net return, US 9610, US 9721 and US 9777 exceeded the mean with more than R1000 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.

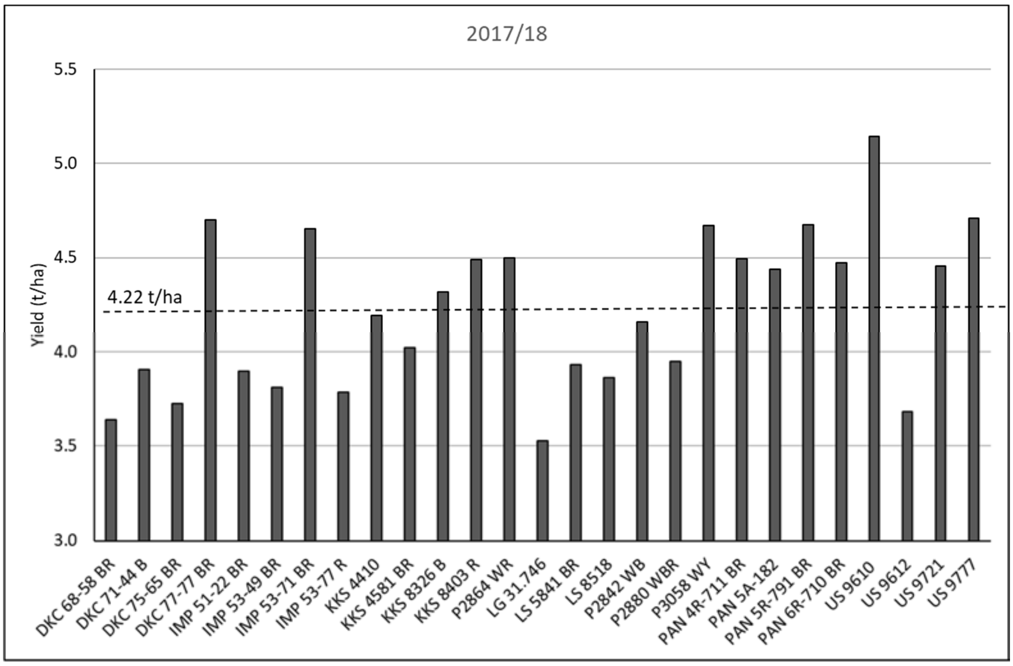

Fig. 4.4 Adjusted grain yields of cultivars at Humanskraal 2017/2018. The mean adjusted yield of all cultivars is indicated by the horizontal line.

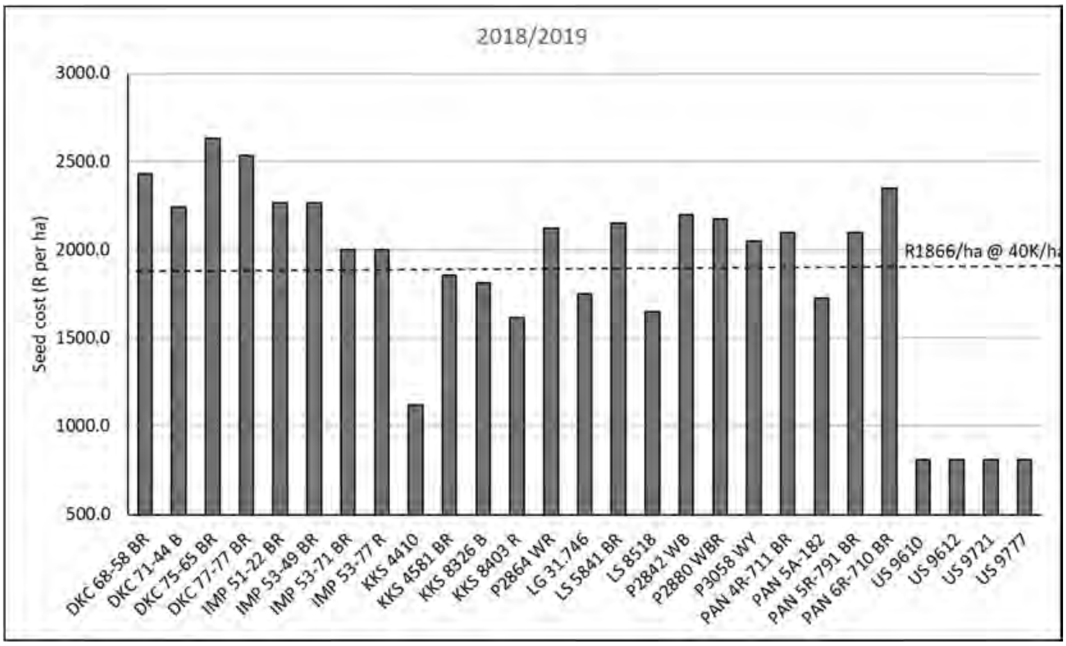

Fig. 4.5 The 2018/2019 seed cost ha^{-1} for each cultivar at a seeding rate of 40 000 ha^{-1}. The mean is indicated by the horizontal line.

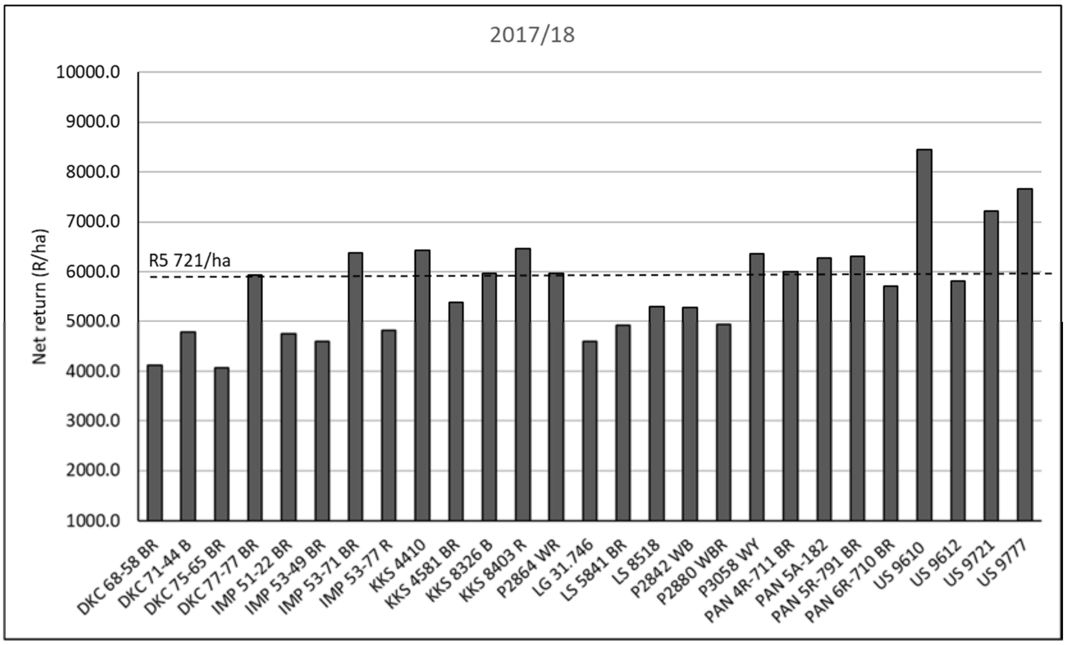

Fig. 4.6 The net return for cultivars calculated from the adjusted grain yields and seed price at a grain price of R1 800 t^{-1} at Humanskraal 2017/2017. The mean net return of all cultivars, is indicated by the horizontal line.

4.6.5 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 4.7. 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 4.8). 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 4.9). In 2015/2017 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 4.7 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	**1.** Rip-on-row 40 cm deep, 2.3 m	13.1
Vuuren	**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	**1.** Rip-on-row 40 cm deep, 2.03* m	20.0
Vuuren (Doornspruit)	**2.** No-till, 0.91 m	24.2
	3. No-till 0.52 m	40.0
	2017/2018	
Pieter van	**1.** Rip-on-row 40 cm deep, 2.03* m	20.0
Vuuren	**2.** No-till, 0.91 m	24.2
(Doornspruit)	**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 4.10). Clear differences in the water infiltration capacity of soil among the cropping systems were found in March 2018 (Table 4.11) 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 4.8 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 4.9 The yield of maize 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 4.10 The yield of maize as affected by cropping system on the farm of Pieter van Vuuren (Doornspruit) 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 + 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 4.11 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 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 (Fig. 4.7).

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. However, results from more seasons are needed for confirmation of the findings.

Figure 4.7 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.

4.6.6 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 (Fig 4.8). 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.

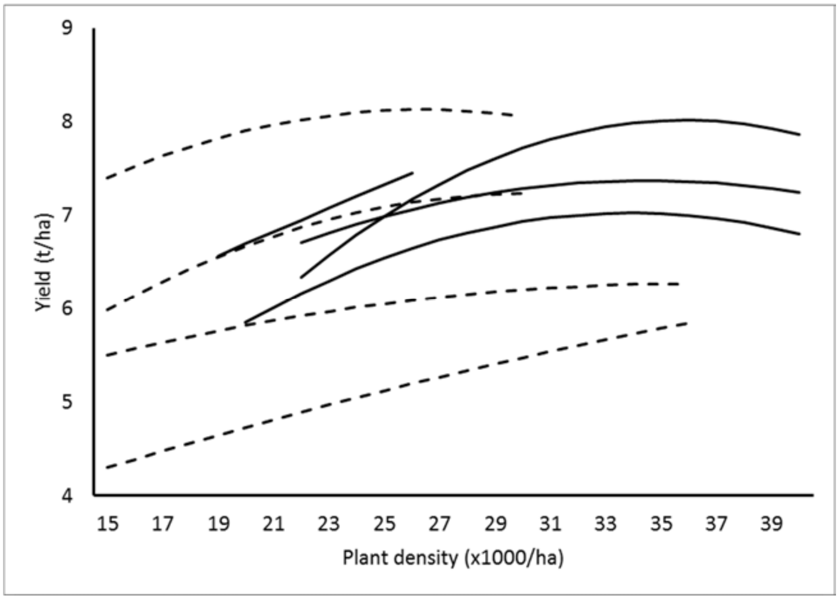

Fig. 4.8 No-till maize yield as related to plant population density in eight field trials from 2013/2014 to 2016/2017. Row widths of 0.76 and 0.91 m are represented with dotted and solid lines respectively.

Sunflower

Sunflower showed no response to plant population density in any of the two trials done (Fig 4.9). Although curves were fitted for these two trials, the regression analysis for each indicated a non-significant relationship.

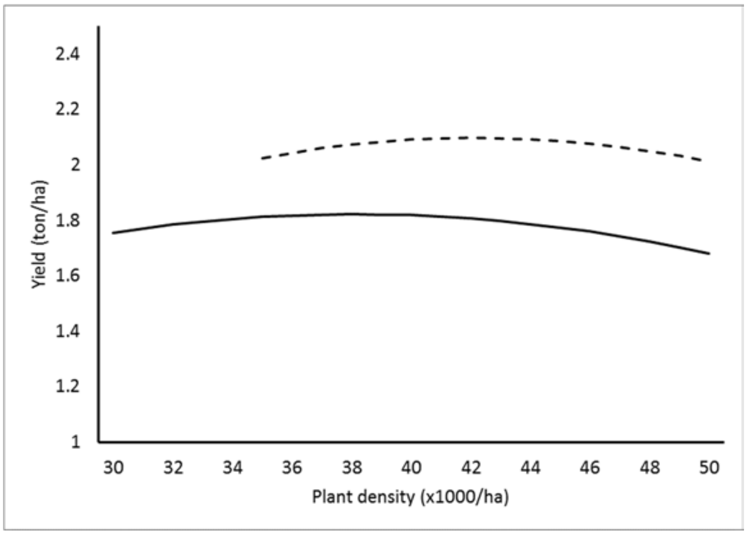

Fig. 4.9 Sunflower yield as related to plant population density in 2013/2014 and 2014/2015 with 0.76 and 0.91 m row widths indicated by dotted and solid lines respectively.

Sorghum

Sorghum yield also showed no significant relationship with plant population density as indicated by the regression analyses (Fig. 4.10).

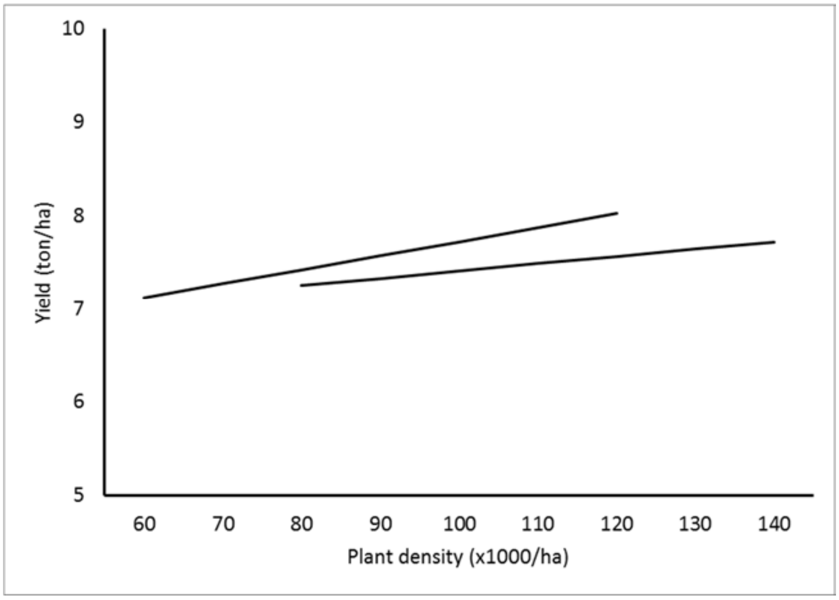

Fig. 4.10 Sorghum yield as related to plant population density.

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. 4.11). The yield response rate was approximately 3 kg ha^{-1} per 1000 plants ha^{-1}.

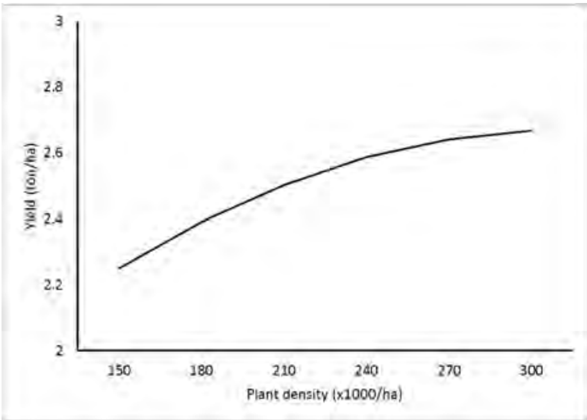

Fig. 4.11 Soybean yield as related to plant population density in 0.76 m rows.

5. Coordination and facilitation of project activities

Work Package title	**Coordination and facilitation of project activities among farmer participants**
Work Package period	October 2017 to September 2018

Lead partner	Local facilitator (Ottosdal No-till Club)
Involved partners	ARC-GCI, ARC-API, 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 5 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 on 2 farms See list of trials in **Table 6.1** below.
3. Seasonal management (30 visits)	Assist farmers in weeding and pest/disease management	Completed seasonal activities for 2017-2018
4. Monitoring, sampling and harvesting (Done with activity 3 above)	Assist farmers to complete field forms Monitor the farmer-led actions Harvest or assist in harvesting of trials	Completed seasonal activities for 2017-2018
5. Monthly meetings (project team) & Training	Participate in monthly forum meetings, discussing problems and possible solutions to that and organisation of activities.	Participated in 2 project meetings and 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 12-13 March 2018.

Table 5.1: List of location and type of trials established in Ottosdal area, 2017/18 season

Trial Number:	**1**	**2**	**3**	**4**	**5**
Farmer co-worker:	**Cover crops**	**Crop Rotation**	**Maize cultivar evaluation**	**Convensional vs 90cm CA vs 50cm CA**	**Row width X plant density (MSc Study**
George Steyn	√	√	√		√
Piet v Vuuren				√	

7. Summary of expenses on August 2018

Description of Ottosdal CA project work packages	Total Actual YTD Aug 18	Total Budget YTD Sept18	Available to use
Soil	33 109	96 720	63 611
Cover crops	6 472	173 100	166 628
Agronomy	78 619	102 600	23 981
Grain SA	89 771	141 500	51 729
Farmer facilitator	83 258	107 040	23 782
Total	**291 229**	**620 960**	**329 731**

*** Expenses and invoices still expected which will affect the final amount until 30 September 2018.**