FINAL PROGRESS REPORT
FOR THE PERIOD: 1 JAN-30 SEPT 2018
OF
PROJECT FUNDED BY THE MAIZE TRUST

INVESTIGATING THE IMPACTS OF CONSERVATION AGRICULTURE PRACTICES ON SOIL HEALTH AS KEY TO SUSTAINABLE DRY LAND MAIZE PRODUCTION SYSTEMS ON SEMI-ARID SANDY SOILS WITH WATER TABLES IN THE NORTH WESTERN FREE STATE

30 September 2018

Compiled by:

DJ Beukes[1], AA Nel[2], G Trytsman[3], S Steenkamp[4], OHJ Rhode[4], AM Abrahams[4],
P van Staden[5] & B van Zyl[5]

[1]229 Emmarentia Street Meyerspark 0184
[2]22 Watsonia Street, Grimbeek Park, Potchefstroom 2520
[3]ARC-Animal Production Institute, Private Bag X05, Lynn East 0039
[4]ARC-Grain Crops Institute, Private Bag X1251, Potchefstroom 2520
[5]Senwes Pty (Ltd), 1 Charl de Klerk Street, Klerksdorp 2570

[1]Cell: 082 442 0484 [1]E-mail: danie.beukes122@gmail.com

ACKNOWLEDGEMENTS

The authors wish to extend their gratitude and appreciation to the following institutions and persons who made valuable inputs to the successful coordination and running of the project activities. They are:

Funding:

The Maize Trust

Project Team: Coordination, collaboration and contributions in kind:

Project leaders: Danie Beukes and Andre Nel
ARC-Grain Crops Institute: Sonia Steenkamp, Owen Rhode and Adrian Abrahams
ARC-Animal Production Institute: Gerrie Trytsman
Co-operating farmers: Danie Crous, Danie Minnaar, Lourens van der Linde and Thabo van Zyl
Grain SA: Hendrik Smith
OMNIA: Kobus van Zyl for sampling and analyses at no cost to the project
SENWES: Petrus van Staden and Boet van Zyl

Overall coordination and governance:

Chairperson: Sandy Soils Development Committee: Danie Minnaar
Treasurer: Danie Crous
Member of Chief Executive, Grain SA: Jaco Minnaar
Grain SA: Hendrik Smith
Co-operating farmers: Danie Crous, Danie Minnaar, Lourens van der Linde and Thabo van Zyl
L&L Agricultural Services: Leon du Plessis

Investigating the impacts of conservation agriculture practices on soil health as key to sustainable dry land maize production systems on semi-arid sandy soils with water tables in the north western Free State.

DJ Beukes[1], AA Nel[2], G Trytsman[3], S Steenkamp[4], OHJ Rhode[4], AM Abrahams, P van Staden[5] & B van Zyl[5]

[1]229 Emmarentia Street Meyerspark 0184
[2]22 Watsonia Street, Grimbeek Park, Potchefstroom 2520
[3]ARC-Animal Production Institute, Private Bag X05, Lynn East 0039
[4]ARC-Grain Crops Institute, Private Bag X1251, Potchefstroom 2520
[5]Senwes Pty (Ltd), 1 Charl de Klerk Street, Klerksdorp 2570

EXECUTIVE SUMMARY

The current project builds on previous projects funded by the Maize Trust, where the main objective had been the implementation and evaluation of various cultivation practice options for sustainable dry land maize production systems on semi-arid sandy soils with water tables in the north western Free State. These sandy soils developed from Aeolian parent material and were deposited between 1.8 and 5 million years ago on a Palaeolithic surface consisting of poorly drained clayey components of weathered dolerite, mudstone, calcrete and shale. These soils are known for their proneness to wind erosion, inherent compaction problem, low organic matter content and low nutrient and water retention capability. However, the presence of a shallow water table above the Palaeolithic surface, to serve as a water reservoir, contributes to stable crop yields under the highly variable rain fall conditions.

During the evaluation and planning sessions of 12, 22 August and 12 September 2016, several challenges (problems) that still remain in terms of implementing conservation agriculture (CA) practices for sustainable and profitable crop production on sandy soils were identified and prioritized. A shift to practices that improve and maintain soil health was emphasized. On the semi-arid sandy soils of the north western Free State a major portion of the maize yield of South Africa is produced. Against this background, new and innovative production practices should continuously be tested and implemented on these very unique and fragile soils to enhance and maintain their productivity in view of national food security.

For this purpose four farmers made available trial sites and agreed to implement trials using on-farm CA practices to evaluate/assess:

- *Trial 1: Regenerative CA crop-livestock integrated system with rotations of maize-summer-winter diverse ley crops (Farmer co-worker: Danie Crous, Deelpan).*
- *Trial 2: Reduced tillage, stubble-mulch, cash crop rotations with maize/forage sorghum/soybean (Farmer co-worker: Thabo van Zyl, Christinasrus).*
- *Trial 3: Comparison of reduced vs. no tillage under stubble-mulch with mono culture maize (Farmer co-worker: Lourens van Zyl, Klein Constantia).*
- *Trials 4 & 5: Interactions of plant row width and population density as component to the sustainable cultivation of mono culture maize on sandy soils (Farmer co-workers: Thabo van Zyl, Doornbult; Danie Minnaar, Hamiltonsrus).*
- *Trial 6: The optimum depth of ripping for the sustainable cultivation of mono culture maize on sandy soils (Thabo van Zyl, Doornbult).*

- *Trial 7: Effects of N fertilizer application on soybean growth and yield (Farmer co-worker: Thabo van Zyl, Ancona).*

The seasonal rainfall or the trial localities varied between 316 and 463 mm. Although the rainfall was much lower than during the previous season (average=610 mm), the seasonal distribution was very favourable for good growth and yields of crops.

Trial 1 (Deelpan - Danie Crous): Regenerative CA crop-livestock integrated system with rotations of maize/summer/winter diverse ley crops:

***Growth and yield of crops:** The maize and summer and winter annual cover crop mixtures established well due to the favourable seasonable distribution of rainfall, leading to very good biomass and maize grain yields. Dry biomass yields of all plant components ranged from 38.5 t ha^{-1} to 50.5 t ha^{-1} for the summer and winter cover crops, respectively. Maize biomass was highest (28.9 t ha^{-1}) under monoculture maize, followed by maize after summer cover crops (25.1 t ha^{-1}) and maize after winter cover crops (20.5 t ha^{-1}). The winter cover crops excelled with a water use efficiency (WUE) of 50.5 kg biomass ha^{-1} mm^{-1} compared to the summer cover crops (38.5 kg mm^{-1} ha^{-1}). In terms of grain mass, mono culture maize exhibited a higher WUE (12.8 kg ha^{-1} mm^{-1}) than maize following either summer or winter cover crops. Mean maize grain yield was 7 400 kg ha^{-1}.*

***Soil water and temperature studies:** The use of capacitance probes to measure soil water content (SWC) proved to be very successful. The results indicate that between rainfall events SWC quickly approached the permanent wilting point of these sandy soils. Temporal fluctuations in SWC were more pronounced under mono culture maize than under the summer cover crop stand, indicating higher water extraction under the maize. An almost full SWC profile was measured on the fallow land before planting of the winter cover crops. The highest soil temperatures and the largest diurnal temperature fluctuations were observed for the fallow land, contributing more to earth warming compared to the lands covered with crops. The seasonal march of soil temperatures show a gradual cooling of the soil at all depths from January to the end of May 2018.*

The periodic measurement of two water tables in the trial area revealed NO_3 values progressively increased to >200 mg L^{-1} by the end of May 2018, compared to low soil NO_3-N values, ranging from 7-14 mg kg^{-1}. The leaching of costly and health threatening NO_3-N on these sandy soils appears to be a serious problem. Other plant nutrients, like Ca, K, Mg and PO_4 were also present in both water tables at all dates of sampling. A study of a salt crust in the trial area revealed the presence (sometimes at high concentrations) of costly plant nutrients, such as NO_3, K, Ca and Mg.

***Soil sampling and analysis by OMNIA:** Although topsoil pH and acid saturation (AS) were at acceptable levels, subsoil acidity appears to be a problem with AS ranging from 13-20%. Low NO_3-N values, ranging from 9-14 mg kg^{-1} were measured, probably indicating the leaching of NO_3-N. Similar NO_3-N values were found under an adjacent natural grass stand receiving no N fertilizer. It is surmised that non-symbiotic N fixation by Azotobacter bacteria is responsible for this maintenance of soil N. However, grasses produce root exudates that inhibit nitrification, rendering soil N to remain in the relatively immobile NH_4 form, to contribute to low-NO_3 ecosystems to prevent excessive leaching of NO_3-N to pollute ground waters. High top- and subsoil P were measured – well above the sufficiency level of 30 mg P kg^{-1} required for maize. Potassium (K), Ca and Mg are well-supplied with the latter two nutrients decreasing with depth. Soil organic C (SOC) was lower under mono* *culture maize than under any of the cover crops, indicating the value of the latter crops to increase SOC on these sandy soils. The study also revealed that superior SOC values can be obtained under a natural grass stand.*

Root and crown rot severity study: *Compared to the 2016/17-season, higher root and crown rot severities were observed for the present season. qPCR analyses showed that 12 major root rot fungal pathogens were present.*

Plant-parasitic nematode study: *Nematode species present in the roots showed a high infection rate for both included root-knot nematodes and lesion nematodes. Lesion, ring and spiral nematodes also were present in the soil samples with lesion and spiral nematode numbers differing significantly among the various crop stands.*

Soil microbiological study: *Differences in the counts of bacterial, actinomycetes and fungal groups were induced by the various cropping systems. Counts for bacterial and actinomycetes counts were significantly higher in mono culture maize compared to the maize following cover crops. Filamentous fungal numbers were the highest under maize following a winter cover crop. The highest phosphatase and glucosidase enzymatic activities were measured under mono culture maize, while maize following winter cover crops had the highest urease activity.*

Enterprise financial analysis for Trial 1: *The margin to produce maize following summer cover crops was slightly higher than for mono culture maize. However, the margin for maize following winter cover crops was R576 ha^{-1} lower than under maize following summer cover crops. The poorer margin could be due to lower plant available because of water uptake by the winter cover crops.*

Trial 2 (Christinasrus - Thabo van Zyl): Local CA, ROR tillage, stubble-mulch, cash crop rotations with maize/soybean/forage sorghum:

Soil sampling and analysis by OMNIA: *In general soil pH values were rather low with concomitant high acid saturation values in both the top and subsoils. It is advised that soil acidity should be ameliorated with dolomitic agricultural lime because of the sub-optimal topsoil Mg status. Low NO_3-N values, ranging from 8-14 mg kg^{-1} were measured. Relatively high NH_4-N values, ranging from 29-41 mg kg^{-1} were measured. The use of urea or NH_4-fertilizers as N carrier on these sandy soils with their very poor acid buffer capacity should be discouraged.*

Phosphorus (P) were above the minimum P requirement for maize, while, in general, subsoil residual P is inadequately supplied. Both top and subsoil K are, in general, well-supplied. Both soil Ca and Mg were medium to low in both the topsoil and subsoil. Organic soil C was generally very low and ranged from 0.34-0.47%. Under maize and forage sorghum slightly higher SOC values were measured. Under an adjacent natural grass stand much higher SOC was measured.

Root and crown rot severity study: *Index values for average root and crown rot severity were 144 and 50, respectively. These values are not regarded as very high. Compared to the crop rotation systems, root and crown severity was the highest under mono culture maize. qPCR analyses showed a high presence of certain root rot fungal types mono culture maize. It was found that under crop rotation root rot fungal types were drastically reduced.*

Plant-parasitic nematode study: *Lesion, ring, spiral and dagger nematodes were present in the soil samples. No significant differences with regard to nematode numbers in the soil existed at the crop rotation trial. The soil in the crop rotation trial has shows a slight improvement in soil health, which is supported by the increase of C-p4 and C-p5 nematodes from 2017 to 2018. However, there is a significant increase in the herbivore population. This indicates that although the soil may be healthy, the plant-parasitic nematode numbers will still increase and will remain a problem. The only solution will be to include nematode-resistant cultivars in this type of crop production system.*

Soil microbiological study: *Bacteria and actinomycetes counts were higher under monoculture maize compared to maize/soybean and maize/forage sorghum cropping systems. Higher fungal counts were measured under maize/forage sorghum compared to mono culture maize. Comparing the various cropping systems, glucosidase activity was highest under forage sorghum, while phosphatase activity was highest under mono culture maize. The highest phosphatase and urease activities were measured under the adjacent natural grass stand.*

Agronomic observations, measurements and enterprise financial analysis: *Although differences among mean maize yields of the rotation systems were in some cases more than 1 t ha^{-1}, the statistical analysis indicated that yields were unaffected by the previous crop (or fallow). The coefficient of variation was relatively high at 20%, which can be an indication of soil variability of the trial area. Like maize, the yield of soybean was not affected by the crop rotation system.*

Maize (additional 40 kg N ha^{-1}) after fallow realized the highest yield of 5.57 t ha^{-1}, as well as the best margin of R2 395 ha^{-1}. Soybean following maize or fallow realized in both cases negative margins. In the case of forage sorghum, biomass should be determined in order to calculate a monetary value.

Trial 3 (Klein Constantia - Lourens van der Linde): Effects of tillage practices on mono culture maize cultivation: *Yields were relatively high in 2017/18 and ranged from 7.8 to 9.5 t ha^{-1}. The mean grain yield of the three ROR tillage treatments was 1.19 t ha^{-1} higher than the mean no-till yield, realizing a higher margin of R1 460 ha^{-1}. It should be mentioned that the best margins were achieved in 2016/17 under No-Till, while the best margin in 2017/18 was achieved under ROR tillage.*

Trial 4 (Doornbult - Thabo van Zyl): Interaction of plant row width and population density as component to the sustainable cultivation of monoculture maize on sandy soils: *For the present (second) season, plant population density increased linearly with increasing seeding rates. Likewise, plant density had no effect on the number of tillers that developed. For both the 2016/17- and 2017/18-season, grain yield increased curvi-linearly with increasing population density. A mean maize grain yield of 8.4 t ha^{-1} was achieved at 50 000 plants ha^{-1}. From the regression relationships optimal seeding density for a series of grain and seed prices can be calculated. A negative curvi-linear relationship was found for the mean yield per plant as related to population density. The curvi-linearity probably indicates that the cultivar used can display tolerance to stress caused by increasing planting densties.*

The best margin was realized by a 30 000 plant ha^{-1} stand at R6 459 ha^{-1} Comparable second best margins were achieved by stands of 25 000 and 40 000 plants ha^{-1} at margins *of R6 224 and R6 228 ha^{-1}, respectively. The reason for the similar margins can be ascribed to the low commodity price for maize.*

Soil water content (SWC) measurements with capacitance probes showed the response of SWC to rain events, as well as differences in water extraction by the maize as a function of population density.

***Trial 5 (Hamiltonsrus - Danie Minnaar): Interaction of population density as component to the sustainable cultivation of monoculture maize on sandy soils:** A curvi-linear relationship was found between population density and maize grain yield. Using this relationship, a series of possible seed and grain prices could be calculated for a specific yield potential. It was found that the optimal density increases with a grain price increase and/or a seed price decrease. Similarly to Trial 4, grain yield per plant decreased curvi-linearly with increasing population density.*

***Planting date 14 Dec 2017:** A population density of 30 000 plants ha^{-1} realized a higher margin at R9 230 ha^{-1} than 40 000 plants ha^{-1} at R8 721. The latter population density gave the same grain yield but at a higher seed cost of R515 ha^{-1} the recommended population will be 30 000 plants ha^{-1}. The 20 000 and 34 000 plant ha^{-1} populations gave similar margins at R8 869 and R8 874, respectively.*

***Planting date 28 Dec 2017:** A population density of 20 000 plants ha^{-1} realized a higher margin than 30 000 plants ha^{-1} (R8 031 vs R7 607 ha^{-1}). The latter population density gave a slightly higher yield, but at a higher seed cost of R515 ha-1 it does not make sense to increase the population to 30 000 plants ha^{-1}. A population density of 20 000 plants ha^{-1} gave a higher margin difference at R424 ha^{-1} compared to 30 000 plants ha^{-1}.*

***Trial 6 (Doornbult - Thabo van Zyl): The optimum depth of ripping for the sustainable cultivation of monoculture maize on sandy soils:** Diesel consumption increased curvi-linearly with increasing ripping depth. Increasing the ripping depth from 75 to 90 cm, led to an increased consumption of 7.3 L ha^{-1}. Ripping depth had no effect on plant height. While ripping depth led to a significant increase in maize grain yield in 2016/17, it had little effect in 2017/18 on grain yield. A probable explanation could be due adequate rain during the grain filling period to contribute to very good yields, ranging from 8.3 to 8.6 t ha^{-1} across ripping depths.*

The best margin was realized with a 90 cm deep ripping at R 7 355 ha^{-1}, compared to a margin of R7 231 ha^{-1} for a 75 cm ripping depth. In this comparison the additional capital cost to rip deeper was not taken into account, thereby probably eliminating the advantage of a 90 cm ripping depth. On the basis of the achieved margins, the recommendation would be not to rip shallower than 75 cm.

Soil water content (SWC) measurements with capacitance probes showed that the depth of ripping had an effect on the total water regime in the soil profile.

***Trial 7 (Ancona - Thabo van Zyl): Effects of N fertilizer application on soybean growth and yield:** An exceptionally high soybean yield of 4.2 t ha^{-1} was recorded. Nitrogen fertilization, at any rate, had no significant effect on yield. A probable explanation could be that the residual N plus the symbiotic N fixation satisfied the demand of the crop.*

***Transfer of project results:** A Farmers Day was held on 22 February 2018 on the farm, Springboklaagte, of Danie Minnaar to view and discuss field trials on planting density, root* *development as function of tillage in crop rotation trials and on subsurface irrigation. The farmer co-workers reported back on progress of their field trials in terms of sustainable crop production on sandy soils, prompting lively interaction and discussion by the delegates. The Farmers Day was attended by 78 farmers, input supply personnel, persons from organized agriculture and research personnel.*

Articles on the Farmers Day appeared in the Landbouweekblad of 23 March 2018 and in the April edition of the SA Grain journal.

The present project follows and builds on a completed project funded by the Maize Trust. Four articles from the previous project were published in the August 2017 and October 2017 editions of the SA Grain journal.

***Motivation for the continuation of the project:** The current report contains project results on the second experimental year. It is well-known that the beneficial effects of CA on soil health, nematode infestation, the occurrence of crown and root rot, soil microbiology and the build-up of soil organic C, will only be manifested after three to five years, and might take longer on these semi-arid sandy soils, in order to contribute to sustainable maize production systems.*

TABLE OF CONTENTS

LIST OF FIGURES

LIST OF PLATES

LIST OF TABLES

LIST OF ABBREVIATIONS

ANOVA	analysis of variance
ARC	Agricultural Research Council
AS	acid saturation
CA	conservation agriculture
C	carbon
DAP	days after planting
D	drainage
DM	dry matter
EC	electrical conductivity
ECEC	effective cation exchange capacity
ET	evapotranspiration
FWC	field water capacity
K	potassium
LSD	least significant difference
M (Mono)	mono culture maize
M (S/cov)	maize following summer cover crops
M (W/cov)	maize following winter cover crops
N	nitrogen
NT	no-till
P	phosphorus
p	statistical probability
R	rainfall
$R_{off/on}$	run-off/run-on
RDI	root disease index
ROR	rip-on-row
S/cov	summer cover crops
SOC	soil organic carbon
SOM	soil organic matter
Senwes	agricultural business company
SWC	soil water content
ΔSWC	change in soil water content
W/cov	winter cover crops
WUE	water use efficiency

1 IDENTIFICATION OF THE PROJECT AND THE PROJECT LEADER

1.1 Background

The current project builds on previously projects funded by the Maize Trust, where the main objective had been the implementation and evaluation of various cultivation practice options for sustainable dry land maize production systems on sandy soils in the North Western Free State. During the evaluation and planning sessions of 12, 22 August and 12 September 2016, several challenges (problems) that still remain in terms of implementing CA practices for sustainable and profitable crop production on sandy soils were identified and prioritized. A shift to practices that improve and maintain soil health was emphasized. On the semi-arid sandy soils of the north western Free State a major portion of the maize yield of South Africa is produced. Against this background, new and innovative production practices should continuously be tested and implemented on these very unique and fragile soils to enhance and maintain their productivity in view of national food security.

It has been envisaged that the project trials will bring together various leader farmers, experienced agriculturists and other role players in the search and implementation of sustainable production systems on the sandy soils.

1.2 Problem description and literature overview

The sandy soils of the North Western Free State are known for their inherent compaction problem, low organic matter content and low nutrient and water retention capability. Research results since the 1970's led to the implementation of the rip-on-the-row cultivation system that has been used predominantly by farmers on these semi-arid sandy soils, with the result of higher yields. This system comprised various depths of ripping, mostly on-the-row, in combination with shallow tillage practices. In most cases this system has made retention of crop residue mulch very difficult with resultant extreme soil losses and seedling damage due to wind erosion. The presence of fluctuating water tables on these soils could eliminate the positive effect of tillage. Furthermore, since the 1970's, agricultural machines used by farmers have increased dramatically in size and mass, thereby worsening the compaction problem with consequent increase in costs to break compaction layers. One of the immediate negative consequences of soil compaction is the inhibition of proper root development, causing poor nutrient and water uptake, leading to poor crop growth and yield.

Against this background, and during the evaluation and planning sessions of September 2016, it has become clear that a more comprehensive investigative initiative should be launched on these semi-arid water table sandy soils, based on CA principles and practices with the emphasis, on: (i) poor soil health, (ii) soil compaction, (iii) diversifying annual cropping systems to include legumes, perennial crops and forages in rotations, (iv) using cover crops in conjunction with row crops, (v) integrating livestock with cropping systems (vi) nematode infestation and prevalence of crown and root rot, and (vii) lack on profitability information of various CA systems and practices. Scientific and practical evaluation of innovative and alternative cultivation practices, based on CA principles and practices, are needed to address the persistent challenges and problems facing farmers in their efforts to find sustainable and regenerative production systems on the semi-arid water table sandy soils of the North Western Free State.

1.3 Project objectives

It was envisaged to achieve the following objective with sub-objectives during the 2017/18 growing season:

- To evaluate regenerative and locally adapted CA systems, e.g. no-till/rip-on-row tillage, permanent organic soil cover with diversified crop rotations, including cash crops, as well as multi-species cover crops with livestock integration with sub-aims:
    - To evaluate depth and frequency of ripping as ameliorative measures to alleviate soil compaction to optimize root growth of maize and other crops.
    - To quantify nematode infestation as a function of regenerative and locally adapted CA systems on maize and other crops.
    - To investigate the diversity and magnitude of crown and root rot as a function of regenerative and locally adapted CA systems.
    - To investigate microbial diversity and activity infestation as a function of regenerative and locally adapted CA systems.
    - To determine the optimum depth of ripping to alleviate soil compaction under maize.
    - To evaluate plant row width and population density of maize.
    - To determine water use efficiency of maize and other crops as a function of regenerative and locally adapted CA systems.
    - To monitor the quality of free water (water table) as a function of regenerative and locally adapted CA systems.
    - To monitor soil fertility and subsoil acidity as a function of regenerative and locally adapted CA systems.
    - To measure the profitability of the various regenerative and locally adapted CA systems.

1.4 Project leader

Danie Beukes and André Nel

2 ACTIONS THAT HAVE BEEN TAKEN WITH REGARD TO THE PROJECT

The following actions are of note:

- September 2017: Two feedback and planning sessions were held with stakeholders to refine the 2016/17 proposal to the Maize Trust on the impacts of conservation agriculture on soil health as a key factor to sustainable maize production on sandy soils of the north western Free State.
- September 2017: Application for financial assistance for the project proposal submitted to The Maize Trust.
- November-December 2017: Telephone and e-mail contacts with farmer co-workers on final trial lay-outs and planting conditions.
- November-December 2017: Trial preparation and planting done of the following trials:
    - Trial 1: Regenerative CA crop-livestock integrated system with rotations of maize-summer-winter diverse ley crops (Farmer co-worker: Danie Crous, Deelpan).
    - Trial 2: Reduced tillage, stubble-mulch, cash crop rotations with maize/soybean/forage sorghum (Farmer co-worker: Thabo van Zyl, Christinasrus).
    - Trial 3: Comparison of reduced vs. no tillage under mono culture maize (Farmer co-worker: Lourens van Zyl, Klein Constantia).
    - Trials 4 & 5: Interactions of plant row width, population density and cultivar as

    components to the sustainable cultivation of mono culture maize on sandy soils (Farmer co-workers: Thabo van Zyl, Doornbult; Danie Minnaar, Hamiltonsrus).
    - Trial 6: The optimum depth of ripping for the sustainable cultivation of mono culture maize on sandy soils (Farmer co-workers: Thabo van Zyl, Doornbult).
    - Trial 7: Effects of N fertilizer application on soybean growth and yield (Farmer co-worker: Thabo van Zyl, Ancona).

- December 2017: Preliminary approval of the project proposal.
- December 2017: The project team notified of the approval.
- December 2017-June 2018: Maintenance of trials in terms of N top-dressing, weeds and pests.
- January-August 2018: Eleven visits were paid to the trials to view and discuss the seasonal progress with the farmer co-workers.
- January-August 2018: Installation of instruments, measurements of soil and crop parameters and harvesting on selected trials by the technical team.
- January-February 2018: Planning and holding of Farmers Day and Information Session of Region 22 of Grain SA at Springboklaagte.
- February 2018: Meeting with ARC-GCI researchers to plan and coordinate their sampling and studies.
- March 2018: ARC-Grain Crops Institute: Sampling of root and plant material of Trials 1 and 2 at Deelpan and Christinasrus for microbiological, pathological en nematological studies.
- April 2018: Annual soil sampling of Trials 1 and 2 at Deelpan and Christinasrus by OMNIA, as well as Danie and André.
- February-March 2018: Collation of inputs, data processing, compilation of interim progress report and submission to the Maize Trust.
- June 2018: Approval of the interim progress report by the Maize Trust.
- June-August 2018: Harvesting of trials by farmers.
- September 2018: A feedback and planning session was held with stakeholders to review the progress of the past season and to plan for the 2018/19-season.
- August-September 2018: Collation of inputs, data processing, compilation of final progress report and submission to the Maize Trust.
- September 2018: Submission to The Maize Trust of a project proposal and application for financial assistance for 2019.

3 PROGRESS THAT HAS BEEN MADE WITH THE PROJECT

3.1 General farm operations and trial establishment

Secondary tillage and cultivation operations were performed at all trial sites according to the preferred practices on the particular farm. Standard on-farm agronomic practices (e.g. N top-dressing, fertilizer type and application, seed variety) at planting were followed. Primary tillage (deep ripping) was performed as specified in the trial plans. All trials were planted according to the agreed technical specifications. Maintenance operations (e.g. herbicide and pesticide) were carried out according to on-farm practices.

Planting dates were as follows:

Trial 1: Danie Crous: Maize: 11 Dec 2017; Summer cover crops: 9 January 2018; Winter cover crops: 21 February 2018.

Trial 2: Thabo: Maize/soybean/forage sorghum: Maize and forage sorghum: 2-3 December

2017; Soybean: 5 December 2017.
Trial 3: Lourens: Maize cultivation: Maize: 6 December 2017.
Trial 4: Thabo: 18 December 2017.
Trial 5: Danie Minnaar: 14 and 28 December 2017.
Trial 6: Thabo: 3 January 2017.
Trial 7: Thabo: 7 December 2017.

The farmer co-workers were visited in January 2018 to view and discuss the establishment of the trials. Eleven follow-up visits to the trials were made from January to August 2018 to view and discuss the seasonal progress with the farmer co-workers, to perform trial measurements, as well as to assist and attend in harvesting operations.

3.2 Research and technical activities

A list of monitoring and measuring of various soil, water and crop parameters is given in Table 1. These activities were performed by research personnel from ARC-GC and ARC-Irene, Mrr B van Zyl and P van Staden from Senwes, personnel from OMNIA, as well as Drr Beukes and Nel.

Table 1: Progress with research and technical activities.

Activities	Deliverables	Progress
1. Trial 1: Seasonal monitoring and measurements of cover crops.	Yield and dry matter data.	Completed.
2. Trials 1, 2, 4, 6: Installation of capacitance probes (Nov 2017-Jan 2018).	Continuous records of soil capacitance and temperature.	Completed.
3. Trials 1, 2, 4, 6: Monthly download of probe readings.	Processed data.	Completed.
4. Trial 1: Gravimetric soil water sampling and laboratory work to calibrate capacitance sensors.	Calibration equations.	Completed.
5. Trials 1, 2, 4, 6: Presentation of soil water and temperature data in graphs.	Soil water and temperature graphs as function of trial treatments.	Completed except for temperature data processing of Trials 2, 4 and 6.
6. Trial 1: Calculation of soil water balances.	Data on water use characteristics and water productivity of crops as function of trial treatments.	Completed.
7. Trials 1 & 2: Soil sampling in April 2018 and analysis by OMNIA.	Soil fertility and soil carbon data.	Completed.
8. Trial 1: Regular sampling and analysis of water table water.	Data on temporal chemical composition of water table.	Completed.
9. Trials 1 & 2: Sampling in April 2018 of plant biomass and root rhizosphere for root pathogens, microbiology and nematology.	Plant biomass data and soil samples.	Completed.
10. Laboratory work: Screening of plant material for root pathogens, as well as soil microbiological and nematological analyses.	Report on root and crown rot screenings, microbial populations and activity, as well as characterization and occurrence of nematodes.	Completed except for and microbial C biomass determination.

11. Collation and processing of economic data	Report on enterprise financial analyses.	Completed.
12. Trials 1, 4, 5 & 6: Harvest or attend harvesting of trials.	Biomass and grain yield data.	Completed.
13. Collation of co-worker inputs and compilation of progress report.	Report on all seasonal activities at all trial sites.	Completed.

3.3 Trial 1: Regenerative CA crop-livestock integrated system with rotations of maize/summer/winter diverse ley crops.

(Deelpan -Danie Crous; G Trytsman, AA Nel, DJ Beukes)

3.3.1 Partners Involved

Farmer co-workers, ARC, Grain SA, Maize Trust.

3.3.2 Objectives

- Trial implementation (trial plot identification, buying of seed and inoculum, getting equipment, planting the trial)
- Seasonal monitoring and measurements (harvesting the trial, determine dry matter
- Project meetings
- Reporting & admin
- Awareness events

3.3.3 Background

Regenerative agriculture CA systems, e.g. no-till, permanent organic soil cover with diversified crop rotations, including cash crops and multi-species cover crops, with livestock integration, utilised through ultra-high density grazing, will build and stabilise soil carbon on water table sandy soils.

Our approach was to adopt regenerative agriculture principles, a holistic land management practice that leverages the power of photosynthesis in plants to close the carbon cycle, and build soil health, crop resilience and nutrient density. Regenerative agriculture improves soil health, primarily through the practices that increase soil organic matter. This not only aids in increasing soil biota diversity and health, but increases biodiversity both above and below the soil surface, while increasing both water holding capacity and sequestering carbon at greater depths.

Plant material increases SOM, to an C:N ratio of 24 or higher, as annual grasses such as babala and sorghum tend to immobilize soil N. Bacteria will use available N to break the fibrous material down. Legumes fix atmospheric N in symbiosis 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 included both legumes and grasses can support SOM sequestration by supplying N as well as C.

Using livestock to utilize high-density cover crops, low frequency grazing will restore the soil carbon stock in the soil. The above ground chewing, tearing and trampling actions by grazers create wounds that the plants must heal. But the plants cannot 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 providing the roots with nutrients.

By letting livestock graze half of the available crop biomass, the diverse sward will regrow. Livestock manure 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, stable carbon pool, also called humus or "the very dead" SOM. By planting fodder crops, nutrients deep in the soil is returned (recycled) 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 micro-organisms breaking down unwanted chemical substances.

3.3.4 The progress that has been made with the project

According to the original planning of the trial, only maize would have been planted on all treatments for the 2017/18-season. However, after fruitless attempts to get a no-till planter to the site, defeat was eventually accepted, and the decision was made to plant a summer and winter mix again as in the 2016/17-season.

Compared to winter annuals (Plate 2), it is clear that summer annuals (Plate 1) produced residues which are much harder to breakdown. This will have a positive influence on the sealing of soil due to crust formation. Mulch will slow water movement and control erosion. The mulch is also a food and C source for the micro-organisms that break them down releasing plant assessable nutrients.

Plate 1: Conventional maize on summer annuals.

Both summer annuals (10 kg babala; 12 kg sorghum; 6 kg saia; 10 kg cowpea and 10 kg lablab) and winter annuals (15 kg rye, 15 kg black oats, 10 kg hairy vetch and 250 g of tillage radish) were planted. Barenbrug provided the seed in both instances and the summer annuals were sponsored for which we are very grateful. Summer annuals were planted on the 9th of January whiles the winter annuals were planted 22th of February. Plates 3 and 4 represent an image of the mixture use.

Plate 2: Conventional maize on winter annuals.

Plate 3: Summer annuals being mix.

Plate 4: Winter annual mixture.

Due to a lack of access to a fine seed planter both treatments were planted using a fertilizer spreader to broadcast the seed. The residues on the surface from the previous crops made it impossible to use implements such as spike tooth harrows to cover the seed with soil so a stalk chopper was used instead.

Probes for the measuring of soil water content and temperatures were installed on the different treatments to monitor these two important variables. Micro-organism and disease measurements were to be the responsibility of our ARC-GC co-workers and would be determined hundred days from the planting date.

3.3.5 Soil water, soil temperature and water table measurements

3.3.5.1 Soil water and soil temperature

Conducted by Drr DJ Beukes and AA Nel

Two Aquacheck probes were installed on the eastern and western sides on each of the mono culture maize (rip-on-row), summer cover crop (no-till), rip-on-row maize (summer cover crop in 2016/17), rip-on-row maize (winter cover crop in 2016/17) and winter cover crop (no-till) plots, respectively. These probes have capacitance sensors and thermistors on 10, 200, 300, 400, 600 and 800 mm depth, respectively. Installation dates were 4-5 Jan and 24-25 Jan 2018. Field downloading of data to a handheld logger was performed on 4-5 Jan, 24 Jan, 21 Feb, 22 March, 19 April, 18 May and 28 May 2018, followed by downloading to a laptop computer. All probes were removed on 28 May 2018 due to the possible onset of harvesting operations.

The calibration equation of the capacitance sensors was checked by an in-field determination of gravimetric soil water at two locations on the mono culture maize plot on 19 April 2018. Simple linear regression analyses (Gomez and Gomez 1984) were performed to determine the statistical relationship between soil water content and capacitance readings. Graphical displays of temporal soil water and temperature data were consequently done.

Plate 5: Installed capacitance probe (Arrow) in summer cover crops.

3.3.5.2 Water table sampling

Conducted by Drr DJ Beukes and AA Nel

A hole was augered on 4 Jan 2018 to a depth of 2000 mm on both the eastern and western sides of the experimental block adjacent to the winter cover crop land in a commercial maize stand. The holes were covered with plastic sheeting to keep out frogs, mice and insects. With each visit, the holes had to be cleared of sediment and had to be left overnight for the equilibration of the perched water tables. The water table depths were measured and samples taken on 5 Jan, 24 Jan, 21 Feb, 23 March, 6 April, 19 April, 18 May and 28 May 2018 at a depth of 100 mm measured from the top of the water table surface (Plate 5, left). A borehole about 350 m from the western water table sample point was sampled on 19 April 2018. On 5 Jan and 28 May 2018 the surface salt crust on the western side close to the water table sample point was sampled (Plate 5, right). All water samples were analysed by the ARC-SCW laboratory in Pretoria for chemical properties and elemental contents.

Plate 6: Taking a water table sample (left) and salt crust sample (right).

3.3.6 Evapotranspiration and water use efficiency

Conducted by Dr DJ Beukes

A water use efficiency (WUE, water productivity) study was done on the Cover Crop Trial (Trial 1) for the mono culture maize, maize rotated with summer cover crops, maize rotated with winter cover crops, as well as the summer and winter cover crops, respectively. The classical soil water balance was used to calculate evapotranspiration (ET, crop water use) and hence, WUE, for the growing seasons of the various crops, i.e. from planting to harvesting:

$$ET = R + \Delta SWC - D \pm R_{off/on} \qquad (1)$$

Where ET = evapotranspiration (crop water use), R = rainfall; ΔSWC = change in soil water content; D = drainage; $R_{off/on}$ = run-off/on

Although not ideal, drainage losses were regarded as part of ΔSWC, while $R_{off/on}$ was regarded as negligible, reducing the equation used in the study to:

$$ET = R + \Delta SWC \qquad (2)$$

Soil water content data for the growing seasons was calculated from the capacitance probe readings. Water use efficiency (WUE), or water productivity, was calculated as follows:

$$\text{WUE} = \text{Grain yield or Dry biomass yield (kg ha}^{-1})/\sum \text{(seasonal ET (mm))} \qquad (3)$$

3.3.7 Soil sampling and analysis by OMNIA

Transect soil sampling was done by OMNIA, Drr Beukes and Nel on 27 March and 6 April 2018, respectively. For soil fertility analysis, samples were taken at 0-200 and 200-500 mm depth intervals, respectively. For SOC analysis, samples were taken at 0-50, 50-100, 100-200 and 200-400 mm depth intervals, respectively, on some experimental plots, as well as in the adjacent natural grass stand. Standard soil fertility analyses (e.g. pH, P, cations, NH_4- and NO_3-N) were performed, as well as Walkley-Black (Allison 1965) analyses for SOC.

3.3.8 Root and crown rot severity study

Conducted by Dr AM Abrahams, ARC-Grain Crops, Potchefstroom

3.3.8.1 Sampling procedures

Two field trials were sampled as per requested by Dr DJ Beukes. These trials were located in Deelpan (Trial 1) and Christinasrus (Trial 2). The objective was to investigate the diversity and magnitude of crown and root rot as a function of regenerative and locally adapted CA systems. The Deelpan trial was established to determine if cover crops can improve soil health and accordingly, the yield of maize. The Christinasrus trial was established to compare the sustainability and profitability of mono cropped maize with two rotation systems.

Thirty randomly selected maize plants per plot were sampled at about 100 days after planting (6 April: Trial 1; 27 March 2018: Trial 2) and screened for plant and root weight, root and crown rot severity using a root disease index (RDI) and fungal biomass. The roots were washed under running tap water and subjected to visual screening. DNA was extracted (CTAB method) from representative samples of roots and crown material collected. qPCR was performed using Taqman probes and/or Sybr protocols to quantify the target DNA for the 12 common root rot fungal pathogens present within the root and crown material.

3.3.9 Plant parasitic nematode study

Conducted by Dr S Steenkamp, ARC-Grain Crops, Potchefstroom

3.3.9.1 Sampling procedures

Soil and root (if available) samples were collected at Kroonstad (Deelpan) and at Wesselsbron (Christinasrus) for nematode assessments for the 2016/17 and 2017/18 growing seasons. The first sampling interval at Deelpan was on the 8th of March 2017 and the second sampling interval on 6th April 2018. Sampling at Christinasrus was done on 6 April 2017 and on 27 March 2018, respectively.

3.3.9.2 Extraction of the nematodes

3.3.9.2.1 Soil samples

Nematodes were extracted from 200 cm^3 soil samples using the sugar-flotation method (Cobb, 1918) followed by the sugar flotation method (Caveness and Jensen 1955). Nematodes extracted from these samples were expressed as nematodes per 200 cm^3 soil.

3.3.9.2.2 Root samples

The method used for the extraction of plant-parasitic nematodes from the roots was described by De Waele *et al.* (1987). Nematodes obtained from this extraction technique were expressed as nematodes per 5g roots. Root-knot nematodes were extracted from roots using the adapted NaOCl method specifically developed for the extraction of these nematodes (Riekert 1995). The latter was expressed as root-knot nematodes per 50g roots.

3.3.9.3 Statistical analysis

GenStat was used for analysis of plant-parasitic nematodes present in roots and in the soil, subjecting this data to analyses of variance (ANOVA) to determine if significant differences existed between the crop rotation systems. Means were separated using the Tukey HSD test at $P < 0.05$. Data for the non-plant parasitic nematode populations was subjected to wood-web analysis using the Nematode Indicator Joint Analysis (NINJA).

3.3.10 Soil microbiological study

Conducted by Mr OHJ Rhode, ARC-Grain Crops, Potchefstroom

3.3.10.1 Materials and Methods

3.3.10.1.1 Sampling

Soil samples were taken approximately 100 days after planting (DAP) on 6 April 2018 at Deelpan and 27 March 2018 at Christinasrus, respectively. Thirty soil samples were randomly taken from within each treatment plot. Rhizosphere soil was sampled and combined into six composite samples for microbiological testing. Sampling of maize soil was randomly done on the cover crop and crop rotation trial, respectively. Soil was also sampled from an adjacent natural grass stand to serve as a control.

At Deelpan the treatments sampled were: Mono culture maize, maize following summer cover crops and maize following winter cover crops. Tillage consisted of rip-on-row (ROR) annually on the mono culture maize and ROR every second year on the two rotation treatments.

At Christinasrus the treatments sampled were (Real implementation in bold):

1. Maize – Maize (MMM): **Maize 2016/17; Maize 2017/18**
2. Maize – Maize - Forage sorghum (MMK1): **Maize 2016/17; Maize 2017/18**
3. Maize – Maize –Soybeans (MMK2): **Maize 2016/17; Soybeans 2017/18**
4. Wheat – Maize – Maize (MMK3): **Fallow 2016/17; Maize 2017/18**
5. Wheat – Maize – Maize – Wheat (MMK4): **Fallow 2016/17; Maize 2017/18**
6. Maize – Wheat – Soybean (MKS1): **Maize 2016/17; Forage sorghum 2017/18**
7. Wheat – Soybean – Maize (MKS2): **Fallow 2016/17; Soybeans 2017/18**
8. Wheat – Soybean – Maize - Wheat (MKS3): **Fallow 2016/17; Soybeans 2017/18**
9. Soybean – Maize - Wheat (MKS4): **Soybeans 2016/17; Maize 2017/18**

3.3.10.1.2 Conventional microbial counts

Standard aseptic microbiological procedures were employed for the isolation and enumeration of microbial groups. Different microbial growth media designed to be selective for heterotrophic microbes, actinomycetes and filamentous fungi were used in the microbial analyses. These microbial populations were subjected to the physiological ability of microbes to grow on each of the selective media. General heterotrophic plate counts were done on nutrient agar (NA), (Biolab, Midrand, South Africa). Actinomycetes were isolated and enumerated on Actinomycete isolation agar (Sigma-Aldrich, South Africa). To obtain filamentous fungal counts, malt extract agar (MEA), (Biolab (Merck), South Africa) was used supplemented with 30 mg L^{-1} chloramphenicol and 50 mg L^{-1} streptomycin. These various media were all sterilised at 121^{o}C for 15 min and made into pour plates, each consisting of a Petri dish (90 mm in diameter) containing an isolation medium. A soil dilution series ranging from 10^{-1} (using 1 g of soil in 9 ml of saline solution) to 10^{-5} was prepared in triplicate and a 100 µL aliquot of each dilution was aseptically spread on the isolation plates for each composite soil sample. The various isolation plates were incubated at room temperature and enumerated after 3 days for the bacteria, and 5-7 days for the actinomycetes and fungi. Values of colony forming units per gram (cfu g^{-1}) soil were logarithmically transformed for analyses.

3.3.10.1.3 Enzyme assays

The microbial activities of β-glucosidase, and alkaline phosphatase were determined using 1 g of air-dried soil and incubated for 1 h (37 °C) with the appropriate substrate for each enzyme at their respective optimal pH values (Tabatabai, 1982). In the case of urease 5g of air-dried soil was used. Methods used are summarised in Table 2. These selected enzymes have been implicated in the carbon (β-glucosidase), nitrogen (urease) and phosphorous (alkaline phosphatase) soil cycles, respectively. Each of these enzymes plays a crucial role in carbon, nitrogen and phosphate conversion in soil, respectively.

Table 2: Methods used to determine enzyme activity in soils.

EC number[a]	Recommended name[b]	Assay conditions[c] [Substrate]	Optimum pH
3.1.3.2	Alkaline phosphatase	*p*-Nitrophenyl phosphate [25mM]	11.0
3.2.1.21	β-glucosidase	*p*-Nitrophenyl- β-glucopyranoside [25mM]	6.0
3.5.1.5	Urease	Urea [80mM]	Non-buffered

[a] EC number denotes enzyme class

[b] Methods according to Tabatabai (1982) and Tabatabai (1994)

[c] Values in parentheses are substrate concentrations under the respective assay conditions. The product of reactions for glucosidase and phosphatase is *p*-Nitrophenol = PN

3.3.10.1.4 Statistical analysis

The experimental layout of the cover crop trial is a randomized complete block design. For this study the treatment design that was sampled was as follows for the cover crop trial: Factorial design (two factors) with four replicates. Analysis of variance was performed on the data using Statgraphics software package to test for statistically significant differences between treatments using Fisher variance ratios (F), as well as to test for least significant differences (LSD) at $p \leq 0.05$ between treatment means.

3.4 Trials 2 and 3: Local CA, ROR and reduced tillage, stubble-mulch, cash crop rotations with maize/soybean/forage sorghum, as well as comparing the effects of tillage practices on mono culture maize cultivation.

(Trial 2 at Christinasrus-Thabo van Zyl; Trial 3 at Klein Constantia-Lourens van der Linde)

3.4.1 Rationale and trial establishment

Reporting by Dr AA Nel

Trial 2: The objective of this trial was to compare the sustainability and profitability of maize in monoculture with two rotation systems namely, a maize – wheat - soybean and a maize – maize – wheat rotation system. The expectation was that the soil health will improve due to crop rotation which will then improve the sustainability and profitability.

A field trial with the above-mentioned crop systems was planned and the trial established on the farm Christinasrus near Wesselsbron on a land where fodder sorghum was grown in 2015/16. A randomized complete block design with three replicates was used for the layout. Plots were 80 X 24.4 m in size. Crop systems were assigned to plots and each crop within each system, representing a different stage, was assigned to a plot to be able to distinguish between seasonal and rotational effects. Maize (cultivar DKC 77-77 BR at 27 000 seeds ha^{-1}) and soybean (cultivar

PAN 1623 at 300 000 seeds ha^{-1}) were planted 13 December 2016 in 1.016 m spaced rows in a rip-on-row (75 cm depth) system. The fertilization rates were as follows: N at 133 kg ha^{-1}, P at 25 kg ha^{-1} and K at 15 kg ha^{-1}. Due to unfavourable conditions wheat could not be planted in 2017 and the plots allocated to wheat were left fallow. For economic reasons and the risk and effort to grow a few small plots of wheat while none is grown in the area any more, it was decided to replace wheat with forage sorghum in 2017/18. The crop systems applied in 2017/18 and intended for 2018/19 onwards are shown in Table 3.

Trial 3: The objective was to determine if rip-on-row, rip between rows and no-till and, if changing from one system to another over seasons, affects the yield of maize at Klein Constantia near Wesselsbron. Unfortunately, a randomized layout of the 0.8 ha plots was not used and a statistical analysis was not possible. A row width of 1.16 m was used at a plant population density 24 000 ha^{-1}. Yields were measured in 2016/17 and in 2017/18 seasons. Tillage systems consisted of rip-on-row, no-tillage and rip-between-rows. The ripping depth was 0.75 m. In 2016/17, the cultivar DKC 78-87B was planted on 28 December 2016 with 200 kg 3:2:1 ha^{-1} with 150 kg LAN (28) pre-planted. In 2017/18, 130, 23 and 15 kg ha^{-1} N, P and K, respectively, were applied. Three, two and one plot (s) per replicate are assigned to crop systems with three, two and one season lengths, respectively.

Table 3: Crops planted in 2016/17 and 2017/18 and intended rotation system from 2018/19 onwards at Christinasrus.

Abbreviation	2016/17	2017/18	2018/19 onwards
MMS 1	Fallow	Maize	Soybean-maize-maize
MMS 2	Maize	Soybean	Maize-maize-soybean
MMS	Soybean	Maize	Maize-soybean-maize
MS	Soybean	Maize	Soybean-maize
MS	Maize	Soybean	Maize-soybean
MM	Maize	Maize	Maize monoculture
MVS	Soybean	Maize	F.sorghum*-soybean-maize
MVS	Maize	F.sorghum	Maize-f.sorghum-soybean
MVS	Fallow	Soybean	Soybean-maize-f.sorghum

*Forage sorghum

3.4.2 Soil sampling and analysis by OMNIA (Trial 2)

Transect soil sampling of selected plots of the maize/wheat/soybean and maize/maize/wheat rotations was done by OMNIA, Drr Beukes and Nel on 5 April 2017. For soil fertility analysis, samples were taken at 0-200 and 200-500 mm depth intervals, respectively. For SOC analysis, samples were taken at 0-50, 50-100, 100-200 and 200-400 mm depth intervals, respectively, on some experimental plots, as well as in the adjacent natural grass (*Cynodon dactylon*) stand. Standard soil fertility analyses (e.g. pH, P, cations, NH_4- and NO_3-N) were performed, as well as Walkley-Black (Allison 1965) analyses for SOC.

3.4.3 Root and crown rot severity study (Trial 2)

Conducted by Dr AM Abrahams, ARC-Grain Crops, Potchefstroom

3.4.3.1 Sampling procedures

See Section 3.3.8.1.

3.4.4 Plant parasitic nematode study (Trial 2)

Conducted by Dr S Steenkamp, ARC-Grain Crops, Potchefstroom

3.4.4.1 Sampling procedures

See Section 3.3.9.1.

3.4.4.2 Extraction of the nematodes

See Section 3.3.9.2.

3.4.4.3 Statistical analysis

See Section 3.3.9.3.

3.4.5 Soil microbiological study (Trial 2)

Conducted by Mr OHJ Rhode, ARC-Grain Crops, Potchefstroom

3.4.5.1 Materials and Methods

3.4.5.1.1 Sampling

See Section 3.3.10.1.

3.4.5.1.2 Conventional microbial counts

See Section 3.3.10.1.2.

3.4.5.1.3 Enzyme assays

See Section 3.3.10.1.3.

3.4.5.1.4 Statistical analysis

The experimental layout of the crop rotation trial was a factorial design (two factors at two and four levels, respectively) with two replicates. Analysis of variance was performed on the data using Statgraphics software package to test for statistically significant differences between treatments using Fisher variance ratios (F), as well as to test for least significant differences (LSD) at $p \leq 0.05$ between treatment means.

3.5 Trials 4 and 5: Interactions of plant row width, population density and cultivar as component to the sustainable cultivation of mono culture maize on sandy soils.

(Trial 4 at Doornbult, Thabo van Zyl; Trial 5 at Vlakvlei, Danie Minnaar)

3.5.1 Rationale and trial establishment

Reporting by Dr AA Nel

The objective of the trial was to find the optimal combination of row width and plant population for maize. Two trials were established in 2016/17: Trial 4 at Doornbult near Bothaville and Trial 5 at Vlakvley near Kroonstad where two cultivars were used instead of row widths.

Trial 4: At Doornbult, mean row widths were 1.016 and 1.524 m and seeding densities were 15, 20, 25, 30, 40 and 50 thousand ha^{-1} in 2016/17. In 2017/18, similar seeding densities were used but a single row width of 1,016 m. A randomised complete block layout was used with two replications. The plot size was 0,18 ha. Maize cultivar DKC78-87B was planted on 30 November 2016 and on 3 January 2018 in a rip-on-row system (75 cm deep). Fertilisation rates were 133 kg N ha^{-1}, 25 kg P ha^{-1} and 14.5 kg K ha^{-1}. The trial was harvested on 1 August 2017 and again on 3 August 2018 with a combine harvester.

Trial 5: At Vlakvley, the two cultivars planted were DKC78-87 and DKC78-17 in 1,5 m spaced rows.

A complete randomised layout was used and seeding densities varied from 12 000 to 26 000 ha^{-1} with three replications. Treatments consisted of twelve adjacent rows which stretched over the length of the land in a rip-on-row tillage system. The planting date was 23 November 2016 and harvesting date 27 June 2017. The fertilisation rate was 200 kg 15:10:6 (31) + Zn + B at planting while urea was applied in a pre-plant action. Plant densities and number of tillers were determined during March 2017 while the total grain yield was measured by combine harvester on 26 June 2017. Small plots of 12 m^2 were hand-harvested to determine the yield of main stems and tillers. A similar trial was done in 2017/18 on the farm Hamiltonsrus with the similar inputs as in 2016/17. Plant population densities varied from 15 000 to 40 000 plants ha^{-1}. Cultivar DKC 75-65BR was planted on 17th December 2017 and harvested on 23 July 2018.

3.6 Trial 6: The optimum depth of ripping for the sustainable cultivation of mono culture maize on sandy soils.

(Doornbult, Thabo van Zyl)

3.6.1 Rationale and trial establishment

The objective was to determine the optimal ripping depth for maize. A field trial was established at Doornbult near Bothaville with ripping depths of 0.45, 0.60, 0.75 and 0.90 m. A randomised complete block design with five replications with an individual plot size of 0.11 ha was used. Maize cultivar DKC78-87B was planted on 30 November 2016 in 1.016 m spaced rows at a seeding density of 24 000 ha^{-1}. Diesel consumption was measured during ripping in early Spring. Crop height was measured on 1 February 2017 and yields were determined by combine harvester on 1 August 2017. In 2017/18 the trial was repeated and planted on 3 January 2018 on the same plots as the previous season. The plant population density was 21 000 ha^{-1}. The trial was harvested on 3 August 2018. Results from all trials were subjected to analyses of variance and regression analyses where applicable.

3.7 Trial 7: Effects of N fertilizer application on soybean growth and yield.

(Ancona, Thabo van Zyl)

Soybean (cultivar Pan 1623) was planted on 8 December 2017 on the farm Ancona in the Wesselsbron district to determine if there would be any financial gain by fertilising soybean with nitrogen. The trial consisted of six replicates and six nitrogen application rates, by using Greensulf (35) in a randomised complete block layout. Application rates were 0, 19, 38, 57, 98 and 143 kg N ha-1 on plots of 0.28 ha as a top dressing. The seed was inoculated with a Rhizobium. At planting all plots received the following nutrients: 11.1 kg N ha^{-1}, 24.4 kg P ha^{-1}, 41.6 kg K ha^{-1}, 17.5 kg S ha^{-1} and 22.5 kg Ca ha^{-1}. The trial was harvested in May with a combine.

3.8 Enterprise financial analyses

Data for the enterprise financial analyses for Trials 1 to 5 and 6 was collated by Mr Boet van Zyl from Senwes in July and Aug-Sept 2018 during meetings with the farmer-co-workers. The compiled statements are included in Appendices 1 to 6.

3.9 Soil water content measurements with capacitance probes

Conducted by Petrus van Staden, Senwes

3.9.1 Objective

Measuring SWC within the plant population and rip trials continuously, to get an indication of changes in SWC.

3.9.2 Actions taken

DFM probes (1.2 m length) were installed in the following treatments:

- On plots with population densities of 50 000, 25 000 and 15 000 plant ha^{-1}.
- On plots of the 45 cm and 90 cm ripping depths of the rip trial.

The probes were installed on 29 January 2018 (plant population) and on 24 January (rip) trials, respectively.

4 RESULTS THAT HAVE BEEN ACHIEVED

4.1 Seasonal rainfall

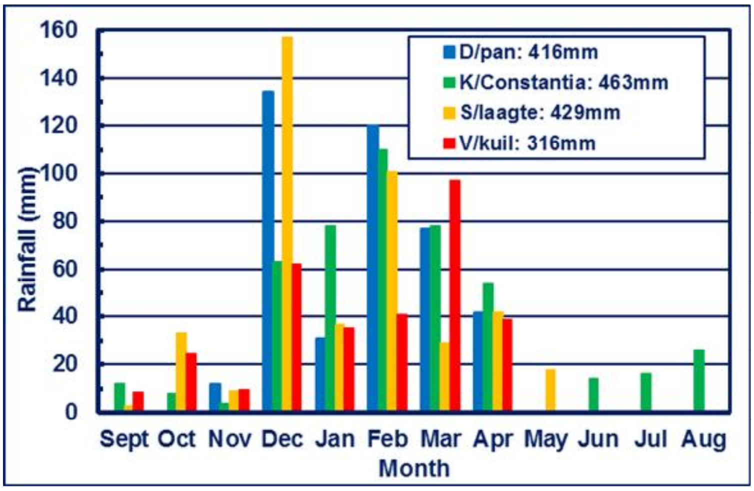


Figure 1: Monthly rainfall at trial localities (D/pan=Deelpan; K/Const=Klein Constantia; S/laagte=Springboklaagte; V/kuil=Visagieskuil).

The seasonal rainfall (Figure 1) for the trial localities varied between 316 and 463 mm. Although the rainfall was much lower than during the previous season (average=610 mm), the seasonal distribution was very favourable for good growth and yields of crops. At Visagieskuil, for example, the very good rainfall during March of 97 mm led to an unexpected good performance of maize at a shallow ripping depth of 450 mm. Notable is the variation in monthly rainfall among the trial localities.

Plate 7: Promising rain clouds over the NW Free State in Jan 2018.

4.2 Trial 1: Regenerative CA crop-livestock integrated system with rotations of maize/summer/winter diverse ley crops.

(Deelpan - Danie Crous)

4.2.1 Vegetative growth of cover crops

Reporting by G Trytsman

The summer annual cover crops established successfully as can be seen in Plate 8. Excellent growth (Plate 10) was obtained by the harvesting date on 3 May 2018. Due to the fast rotation of the agitator and forces it created a devastative effect was exerted on the cowpea seed. A lot of the seed split in half as demonstrated in Plate 9.

Plate 8: Summer annual mixture.

Monitoring the soil water content and soil temperatures at the trial site was done at regular intervals. The farmer's day at Mr D. Minnaar was also attended.

Biomass harvesting of the maize (10 row plants) and summer annuals (per m^2) was done on 3 May 2018 by cutting all above-ground plant parts and weighing it. Subsamples were taken, weighed and the oven-dry mass at $65^{o}C$ determined. Dry matter yields per ha were then calculated.

Plate 9: Damaged cowpea seeds.

Plate 10: Summer annuals before harvest.

The harvesting of the winter annuals took place on 23 July 2018. Plate 11 shows a very good stand at time of harvesting. The procedure of sampling and determining dry matter yields per ha was the same as for the summer annuals.

Plate 11: Winter annuals before harvest.

4.2.2 Yields obtained from cover crops and monoculture maize

Reporting by G Trytsman

Figure 2 gives an indication of the DM biomass yields that were obtained for the summer annuals. Soil differences in terms of depth had a marked influence on the summer annuals. The winter annuals were less affected. Soil on the western side is deeper before reaching the impermeable clay layer. A yield of 17,3 t ha^{-1} and 12,6 t ha^{-1} on the deeper top soil and the shallower soil materialized, respectively. For the winter annuals the shallower soils on the eastern side, close to the impermeable layer produced an excellent DM biomass yield of 10,5 t ha^{-1}.

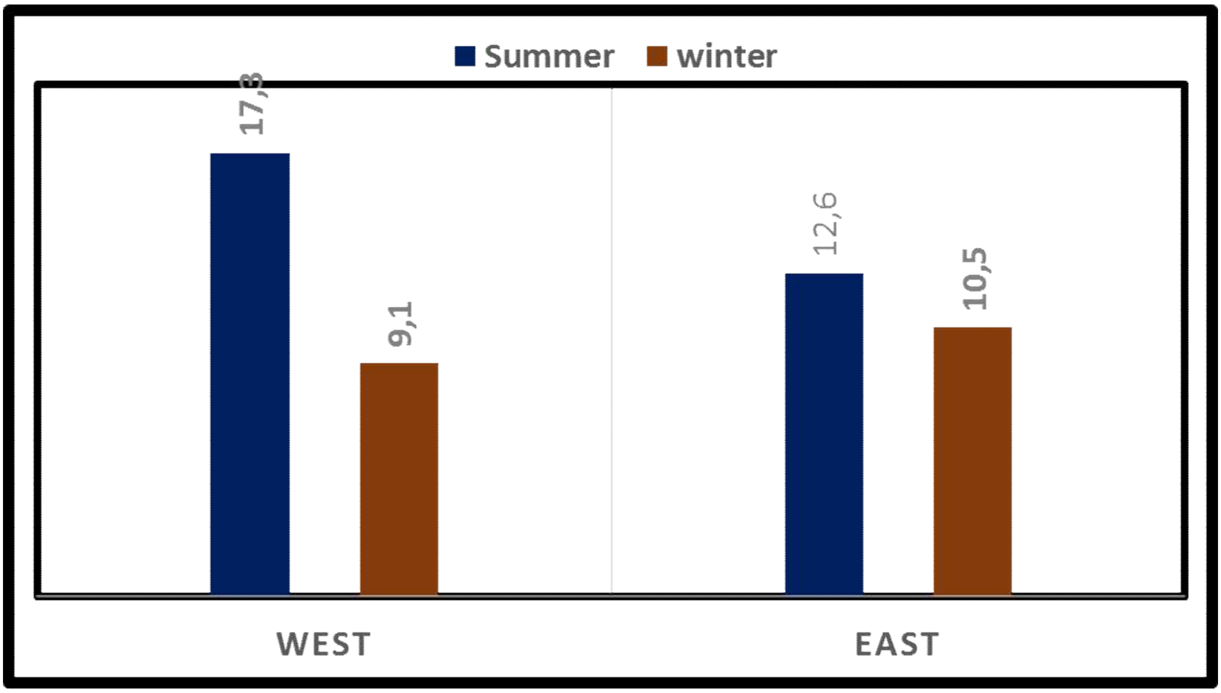


Figure 2: Dry matter biomass yields (t ha^{-1}) for summer and winter annuals.

The different treatments for the maize were also harvested on 3 May 2018 to determine the DM biomass production. The monoculture maize plants looked bigger than those following the summer annuals, whereas those after the summer annuals looked bigger than those following the winter annuals. The number of plants, tillers, big ears and small ears were also counted. It is clear from Figure 3 that the observation mentioned previously was confirmed. Maize following winter annuals also had much fewer big ears that the other two treatments.

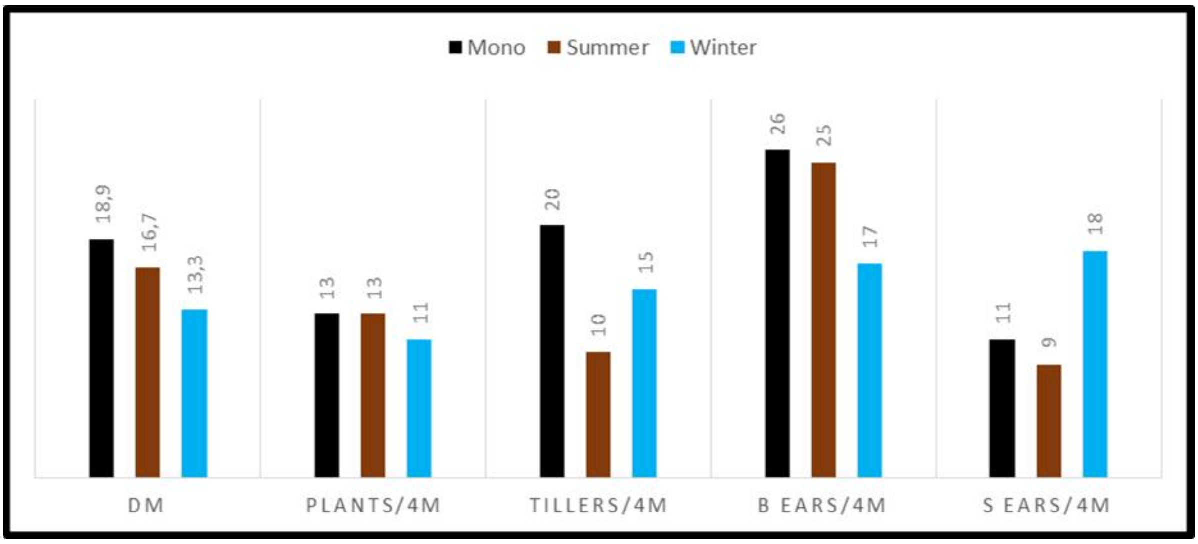


Figure 3: Dry matter biomass yields (t ha^{-1}) for the different maize components of the various treatments.

Maize grain yields, as determined by the harvester, were 7,54, 7,46 and 7,2 t ha^{-1} for the mono culture maize and maize following summer and winter annuals, respectively.

Dr Sandra Lampbrecht from the ARC-PPR took maize samples to determine crown and root rot incidents on the different treatments.

It is clear from the data presented in Figure 4 that there was a considerable increase in the root rot organisms during the sampling dates for the monoculture maize. At the opposite end maize following winter annuals, the latter consisting mainly of brassicas, had much less infection. Disease incidence on the maize following summer annuals was intermediate. Plate 12 shows the lodging of maize in the mono culture treatment.

Plate 12: Maize lodging in the monoculture treatment due to root rot.

4.2.3 Evapotranspiration and water use efficiency

Reporting by Dr DJ Beukes

Figure 4a shows that, in terms of dry biomass, mono culture maize had a higher WUE (28,9 kg ha^{-1} mm^{-1}) than maize following either summer or winter cover crops. The winter cover crops excelled with a WUE of 50,5 kg ha^{-1} mm^{-1} compared to the summer cover crops. Figure 4b shows that, in terms of grain mass, mono culture maize exhibited a higher WUE (12,8 kg ha^{-1} mm^{-1}) than maize following either summer or winter cover crops. Daily ET values to produce maize biomass were similar, while the summer and winter cover crops exhibited lower ET values at 3,4 and 2,7 mm day^{-1}, respectively (Figure 4a). Daily ET values to produce maize grain were similar, ranging from 3,9-4,3 mm day^{-1} (Figure 4b).

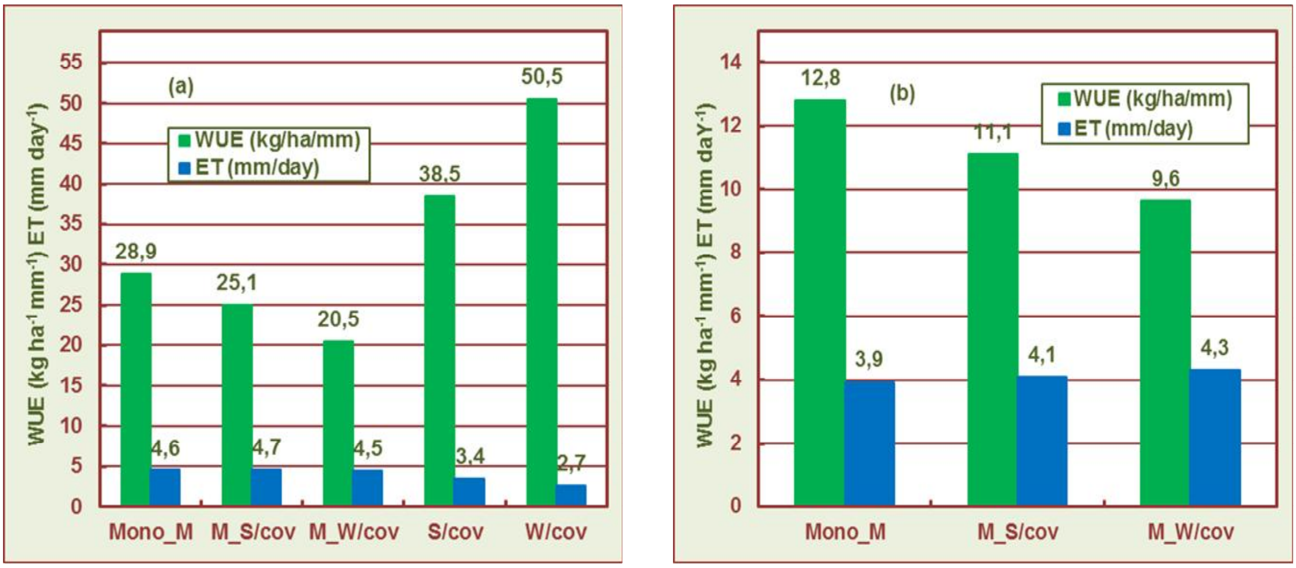


Figure 4: WUE and ET for: (a) Dry biomass, and (b) Maize grain (Mono_M= Mono culture maize; M_S/cov=Maize after summer annuals; M_W/cov=Maize after winter annuals; S/cov=summer annuals; W/cov= winter annuals).

4.2.4 Soil organic carbon sequestration

Reporting by Dr DJ Beukes

Figure 5 shows that under mono culture maize (See arrow), soil organic C was lower in the 0-50 mm soil layer than any of the treatments that include cover crops (0,38% vs. 0,49-0,65% organic C). Under the pristine grass cover soil organic C was the highest at 1,05% in the 0-50 mm soil layer, exceeding all organic C values under cultivation.

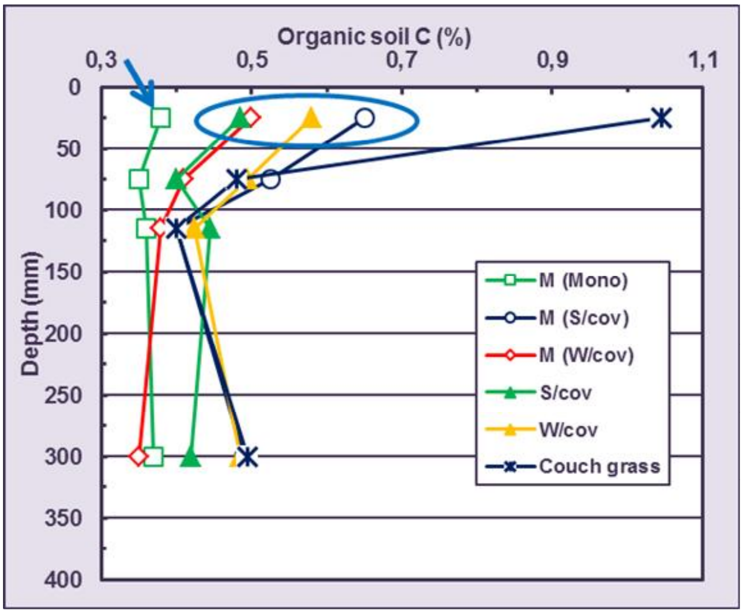


Figure 5: Soil organic C for different treatments.

4.2.5 Soil water, soil temperature and water table measurements

4.2.5.1 Soil water measurements

Reporting by Drr DJ Beukes and AA Nel

In Figure 6 the t-value of 14,01 indicates that the linear response of soil water content to capacitance readings within the range of 25,57 to 86,87 mHz, is highly significant at p≤0,001. The regression coefficient (r=0,8789) that is a measure of the closeness of fit between the estimated regression line and the observed points is highly significant at p≤0,01. The computed r value indicates that 76% of the variation (=R^2) in soil water content is accounted for by the linear function of capacitance readings. It was decided that the regression equation could be used with confidence to process capacitance readings into soil water content values. The values for the calibration check in April 2018 are very much in agreement with the 2017 calibration run (open circles).

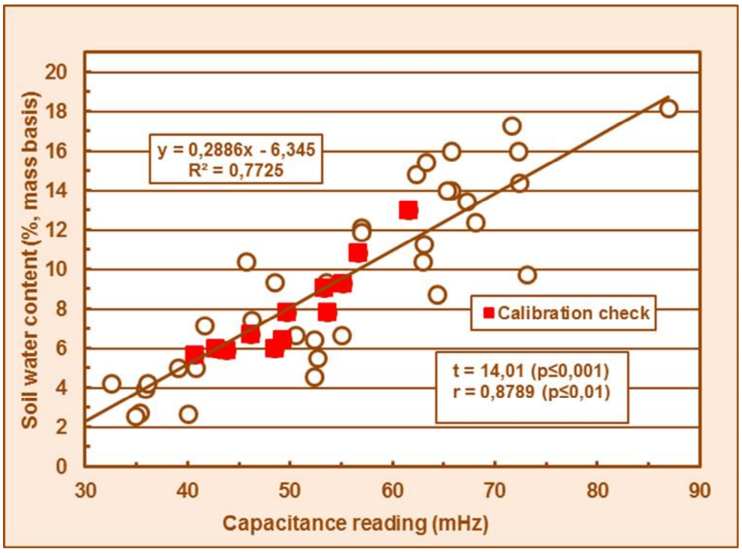
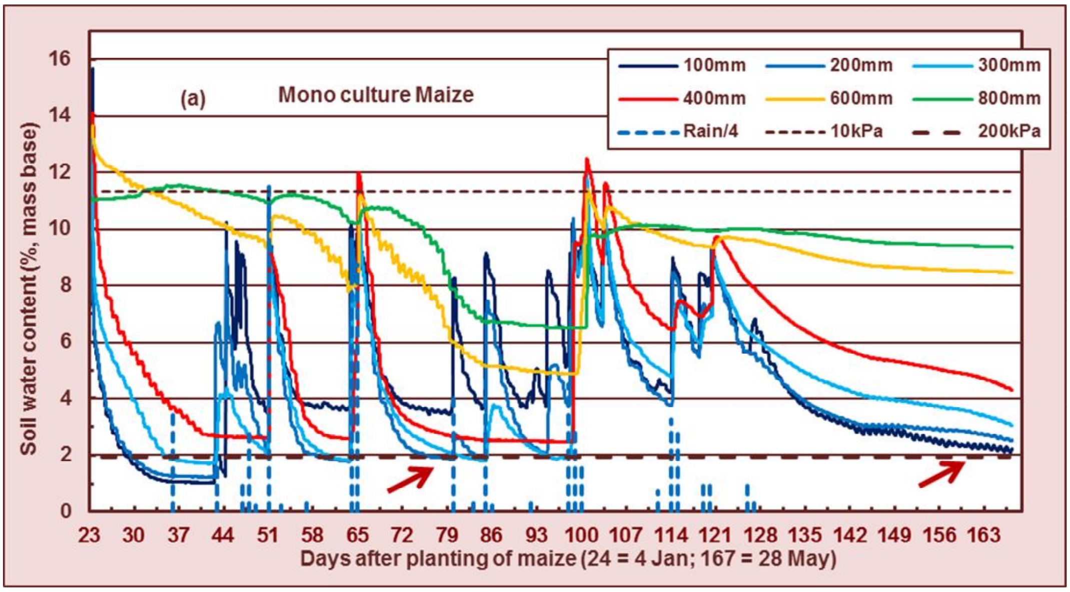
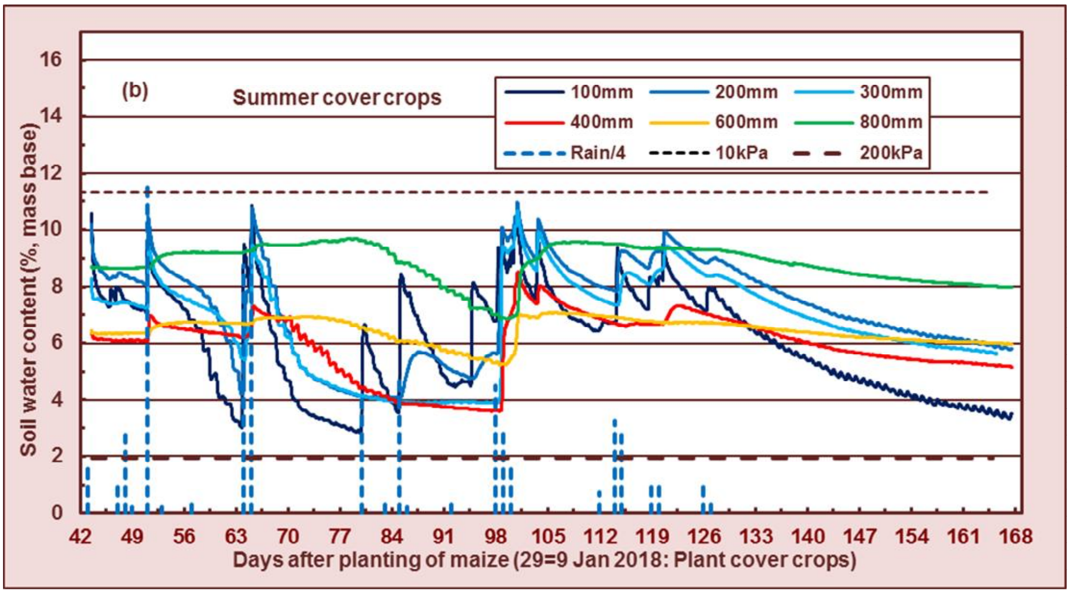


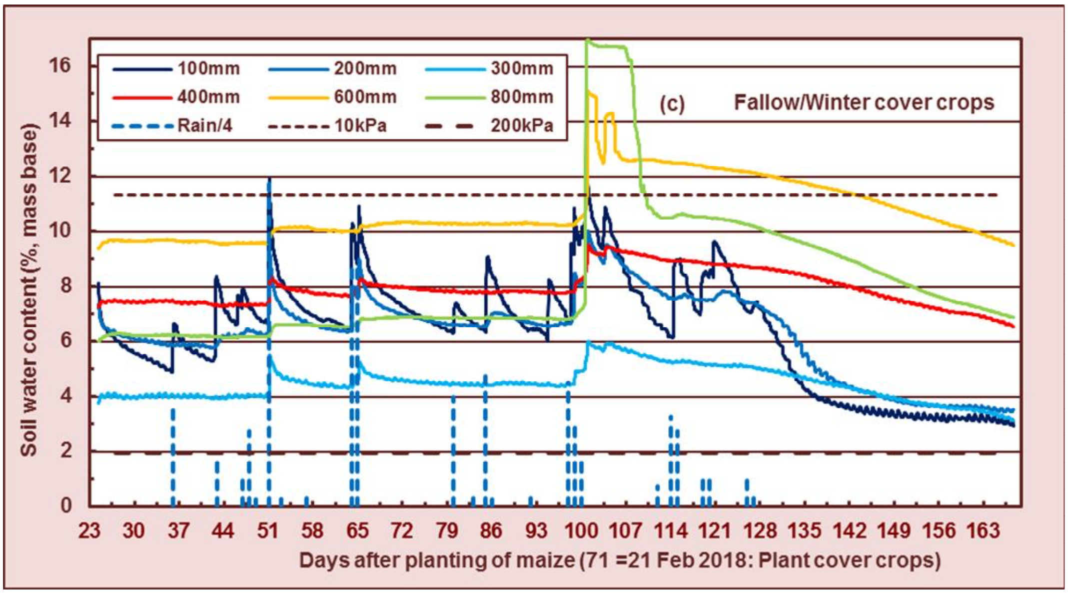
Figure 6: Relationship of capacitance readings vs. soil water content.

Figures 7a-c display seasonal soil water fluctuations at various depths between 100 and 800 mm under monoculture maize (Fig 7a), summer cover crops (Fig 7b) and winter cover crops (Fig 7c), as recorded by capacitance probes. Dotted lines depict soil water contents at 10 kPa and 200 kPa as approximations of the upper ("field water capacity", FWC) and lower ("permanent wilting") limit of plant available water. Actual rainfall is obtained by the graph value and multiplying by 4. The following observations can be made from Figures 7a-c:

- The soil profiles under the three crop systems were well recharged after the good rain spells between 44 and 126 days after planting (DAP).
- After a good rainfall event, soil water content levelled off due to crop water uptake and soil surface evaporation within 14 days and approached "permanent wilting" (See Fig 7a: DAP: 65-79 as example).
- Figure 7c shows that during the fallow period (up till DAP=72) little fluctuations in SWC were evident while SWCs remained at high values.
- Due to lack of rain from DAP=126 the profiles under all crops dried out to values approaching "permanent wilting".







Figures 7a-c: Seasonal soil water fluctuations under: (a) Monoculture maize; (b) Summer cover crops; (c) Winter cover crops.

Figure 8 depicts early-season soil water fluctuations (up to 72 DAP: 21 Feb) at 100 mm depth under monoculture maize, summer cover crops and winter cover crops, respectively. The following observations can be made:

- The data shows a relative full profile at 100 mm depth on the fallow plot (winter cover crops planted on 21 Feb (71 DAP)).
- Water uptake by the maize, evaporation and due to lack of meaningful rainfall totally depleted (below "permanent wilting") SWC under the mono culture maize during the period 30-46 DAP. The interval between rain events should be about 14 days to prevent the onset of an empty profile. This time lapse is similar to the on-farm observation that rainfall is needed every 14 days on these sandy soils for successful crop production.

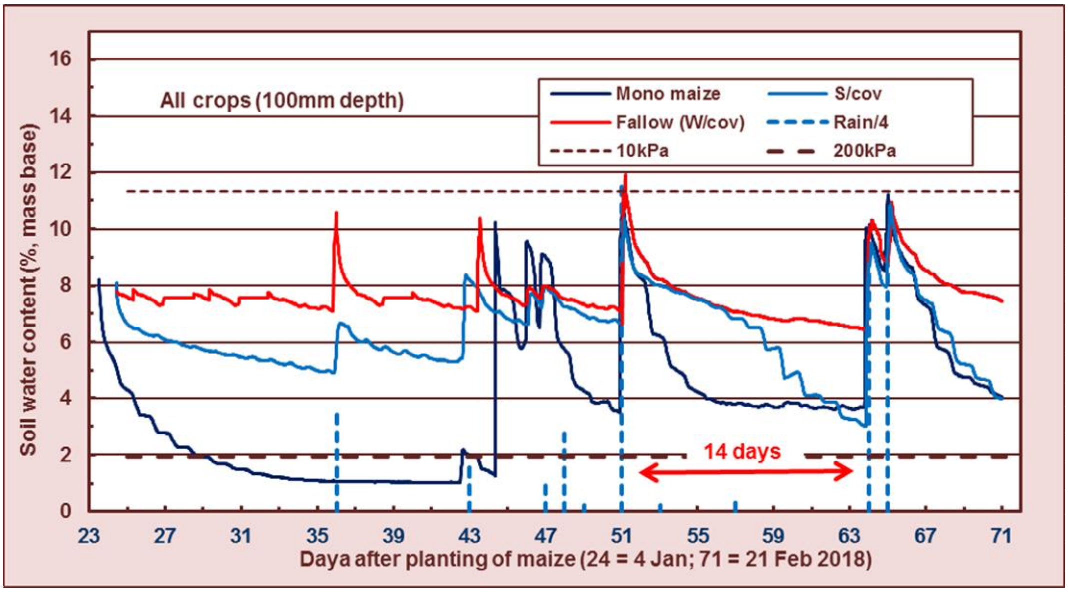


Figure 8: Early-season soil water fluctuations at 100mm depth under monoculture maize, summer cover crops and fallow period (winter cover crops).

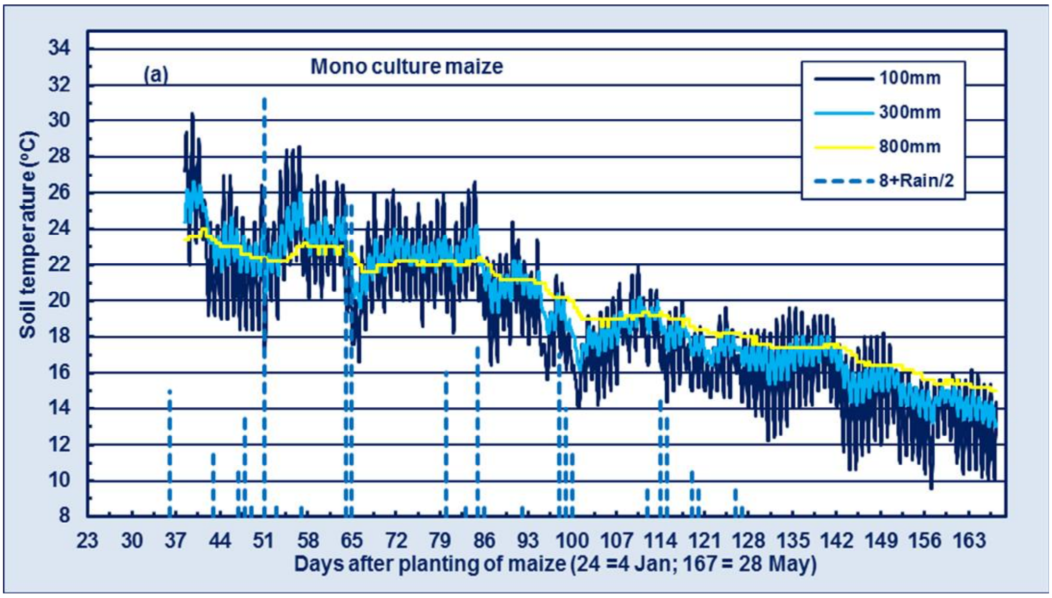
4.2.5.2 Soil temperature measurements

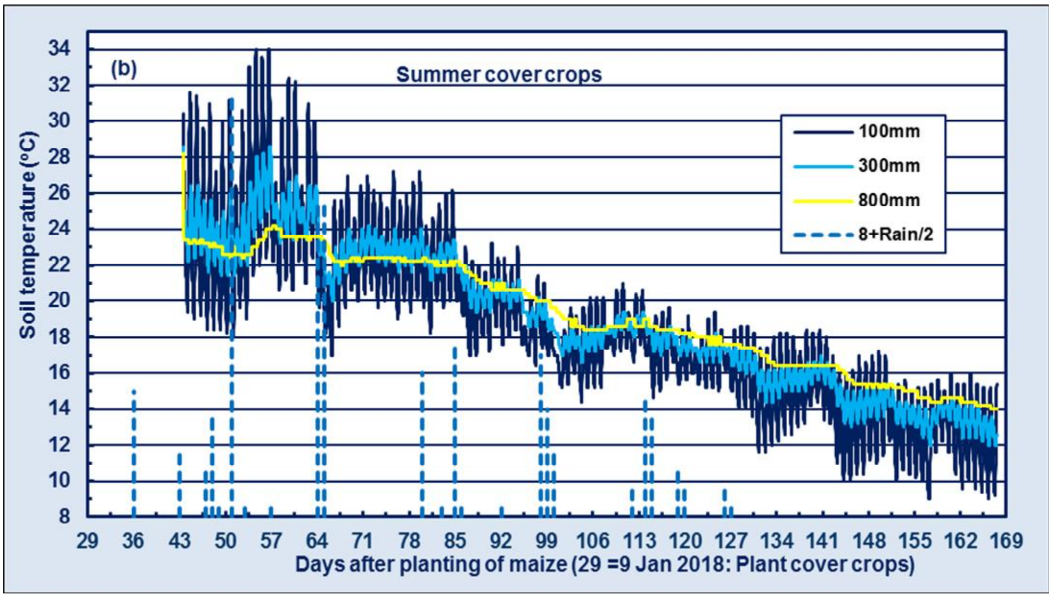
Reporting by Drr DJ Beukes and AA Nel

The amount of heat flow in soil influences soil temperature. The temperature of the soil is related to the temperature of the air and *vice versa*. Net radiation from the sun is the source of energy (heat) in the air and environment. Soil temperature is a measure of the intensity of heat in the soil. The heat capacity of a soil is the amount of heat required to raise the soil temperature. The former is affected, *inter alia,* by the soil water content and soil bulk density (Hanks and Ashcroft 1980).

Figures 9a-c display seasonal soil temperature fluctuations at 100, 300 and 800 mm depths under monoculture maize (Fig 9a), summer cover crops (Fig 9b) and fallow land/winter cover crops (Fig 9c), as recorded by capacitance probes. Actual rainfall is obtained by subtracting 8 from the graph value and multiplying by 2. The following observations can be made from Figures 9a-c:

- Maximum soil temperatures at 100 mm depth were reached up to 64 DAP (14 Feb). On the fallow land maximum temperature of 35^{o}C was reached at 35 DAP (15 Jan).
- The seasonal march of soil temperatures shows a gradual cooling of the soil at all depths from January to end of May.
- Diurnal temperature fluctuations decreased sharply with soil depth, with much reduced fluctuations at 800 mm depth. This phenomenon is explained by the fact that the resistance of heat conduction in the soil tends to damp the amplitude of the diurnal temperature cycle with depth (Hanks and Ashcroft 1980).
- A close scrutiny of the temperature data will reveal a diurnal time lag of soil temperature with increasing depth. This is explained by the fact that a temperature gradient must develop before heat begins to flow to lower depths, causing a time lag before maximum temperature occurs at the lower depths (Hanks and Ashcroft 1980).
- From 100 DAP (21 March) onwards, the cooling of the soil at shallower depths was much more pronounced than at 800 mm depth.





Figures 9a-b: Seasonal soil temperature fluctuations under: (a) Monoculture maize; (b) Summer cover crops.

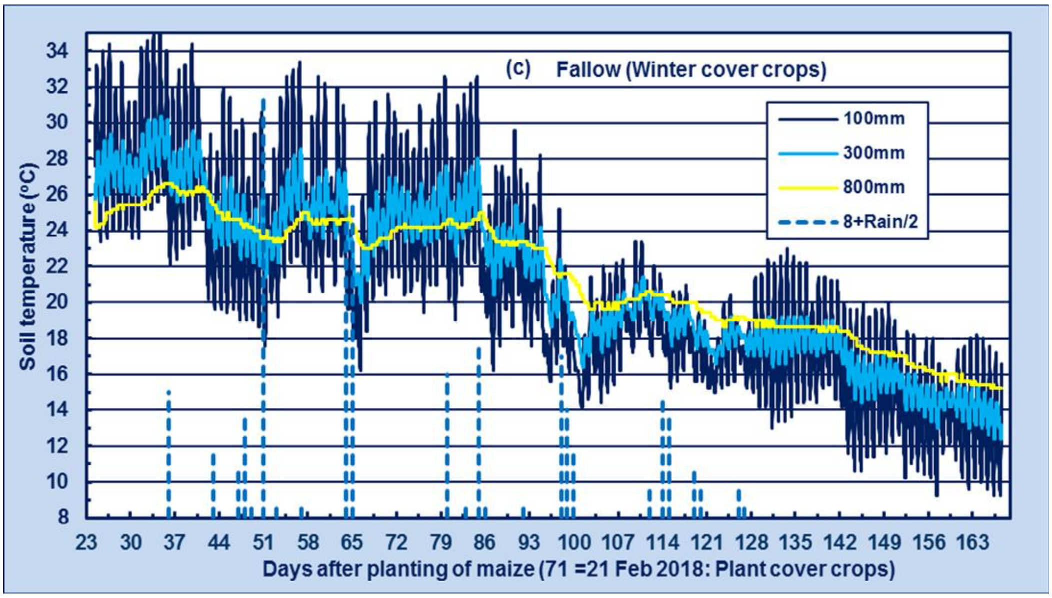


Figure 9c: Seasonal soil temperature fluctuations under: (c) Fallow (Winter cover crops).

Figure 10 depicts early-season soil temperature fluctuations (up to 71 DAP: 21 Feb) at 100 mm depth under monoculture maize and fallow land (winter cover crops), respectively. The following observations can be made:

- The cooling of soil after rain events.
- The largest diurnal temperature fluctuations were observed for the fallow land (winter cover crops not planted yet). For example, on 46 DAP the bare soil was (on the warmest part of the day) 5.4°C warmer than under the mono culture maize.

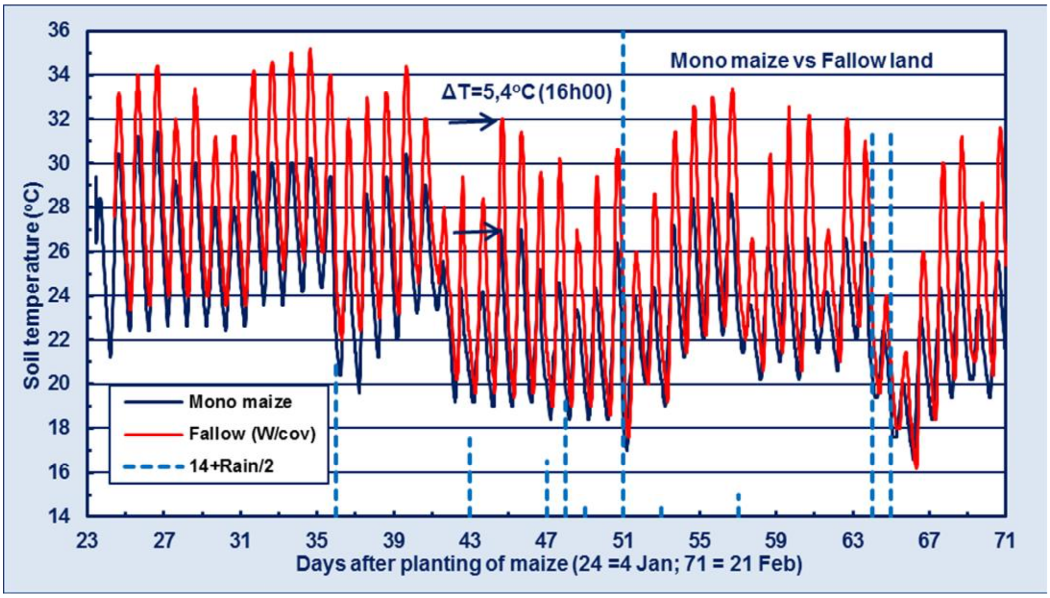


Figure 10: Early-season soil temperature fluctuations at 100mm depth under mono culture maize and fallow (winter cover crops) land.

4.2.5.3 Water table sampling

Reporting by Drr DJ Beukes and AA Nel

The sandy soils of the north western Free State were deposited some 1.8-5 million years ago on an undulating Palaeolithic surface consisting of clayey components of weathered dolerite, mudstone, calcrete and shale, all with poor drainage capability (Henning 1991). The latter property may cause temporary, or perched/'hanging' water tables that are common in this region. Although the two water tables that were studied are adjacent to one another on the north eastern (NE) and north western (NW) sides of the trial site, respectively, they are separate water bodies due to the undulating subsurface. Consequently, they exhibit different chemical characteristics. The soil surface reliefs are at 1347 and 1344 m, respectively. Values of some chemical properties are shown in Figures 11a-g. The following observations can be made:

- Water tables levels subsided from 130 to 185 cm (NE), and from 74 to 115 cm (NW), over the period of observation (Fig 11a).
- Except for the 5 Jan value, NO_3 values progressively increased to >200 mg L^{-1} by 28 May. (Fig 11b). A probable explanation for this increase could be the fact that NO3-uptake by the summer crops was completed. Low soil NO_3-N values, ranging from 7-14 mg kg^{-1} were observed (See Section 4.2.6). Leaching of costly and health threatening NO_3-N on these sandy soils appears to be a serious problem. If consumed, water NO_3 concentrations >20 mg NO_3 may be carcinogenic for humans. In a water table study over three years (1987-89) at nine sites in the north western Free State, Henning (1991) reported a mean value of 38.2 mg NO_3 L^{-1} for January and a single occurrence of a maximum value of 80 mg NO_3 L^{-1}.
- Figure 11c shows that even PO_4 ended up in the water tables. In the NW water table, PO_4-values increased from 5 to 40,6 mg L^{-1} by 28 May - again a leaching of a costly nutrient.
- Other plant nutrients, like K, Ca and Mg were also present in both water tables at all dates of sampling, with Ca and Mg at relatively high concentrations (Fig 11 d-f). Both the latter elements exhibited relatively high values in the topsoil (See Section 4.2.6).
- High SO_4 concentrations were measured, ranging from 160 to 1963 mg L^{-1} (Fig 11 g). If consumed, concentrations >200 mg L^{-1} may cause diarrhoea in humans. The trial site has a

history of the cultivation of potatoes in rotation with maize. It is a farm practice to apply gypsum to boost soil Ca for successful potato cultivation. The trial site received 2t gypsum ha^{-1} a few years ago, probably explaining the high SO_4 levels in the water tables.

- The salt crust (Plate 5) close to the NW water table may be regarded as a direct consequence of the capillary rise of water, carrying the above-mentioned salts, from the water table with consequent surface deposition of salts. Analysis of the salt crust (Figure 11h) reveals the presence (sometimes at high concentrations) of costly plant nutrients, such as NO_3, K, Ca and Mg. The undesirable high concentrations of Na and Cl cannot be explained yet. As expected (See bullet 5 above), SO_4 was present in an extremely high concentration of 5600 mg L^{-1}.
- As would be expected from the relatively high cation and anion concentrations, high EC values were measured (Fig 11i). Water with values >75 mS m^{-1} is of questionable quality for irrigation purposes.

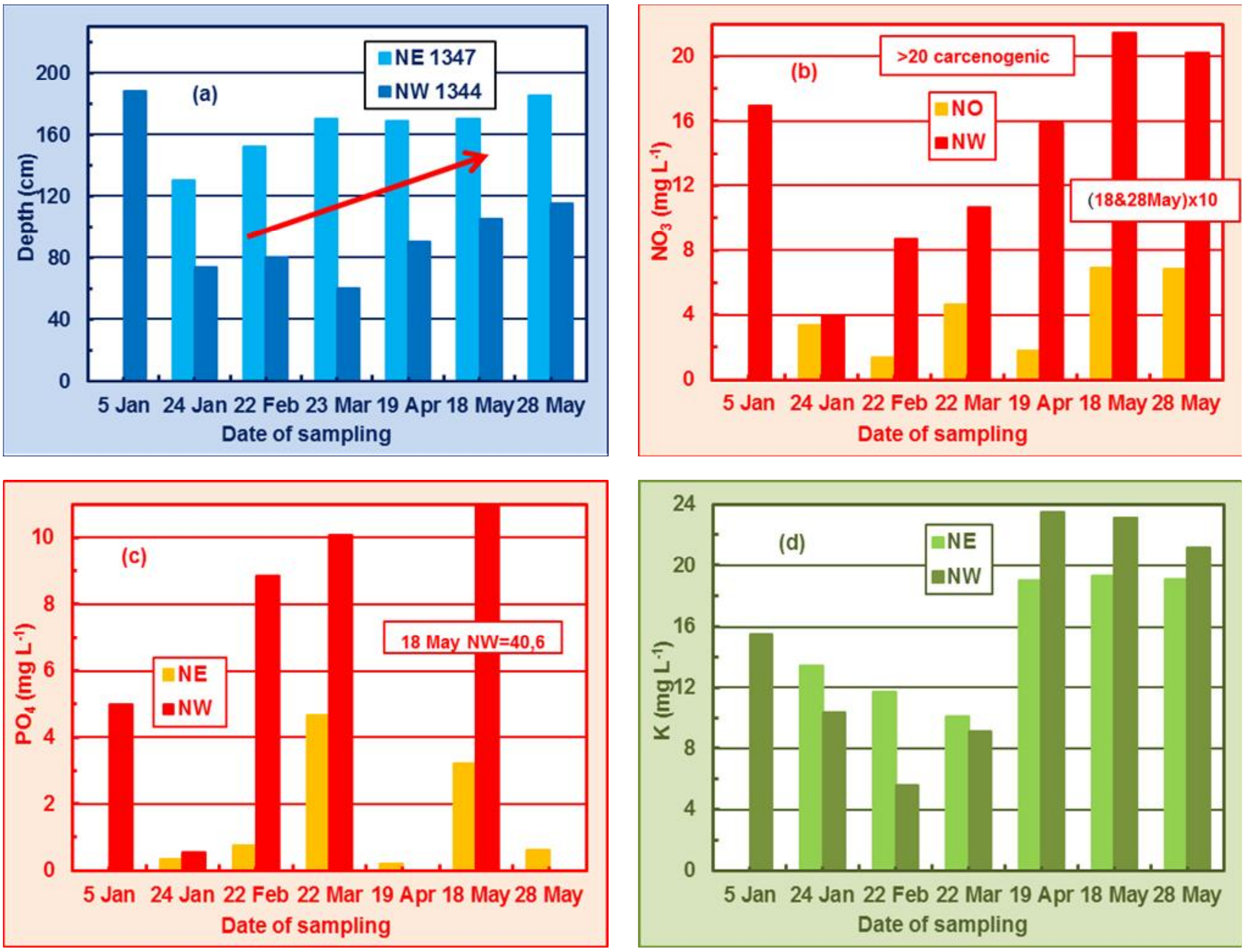


Figure 11a-d: Chemical characteristics of water table.

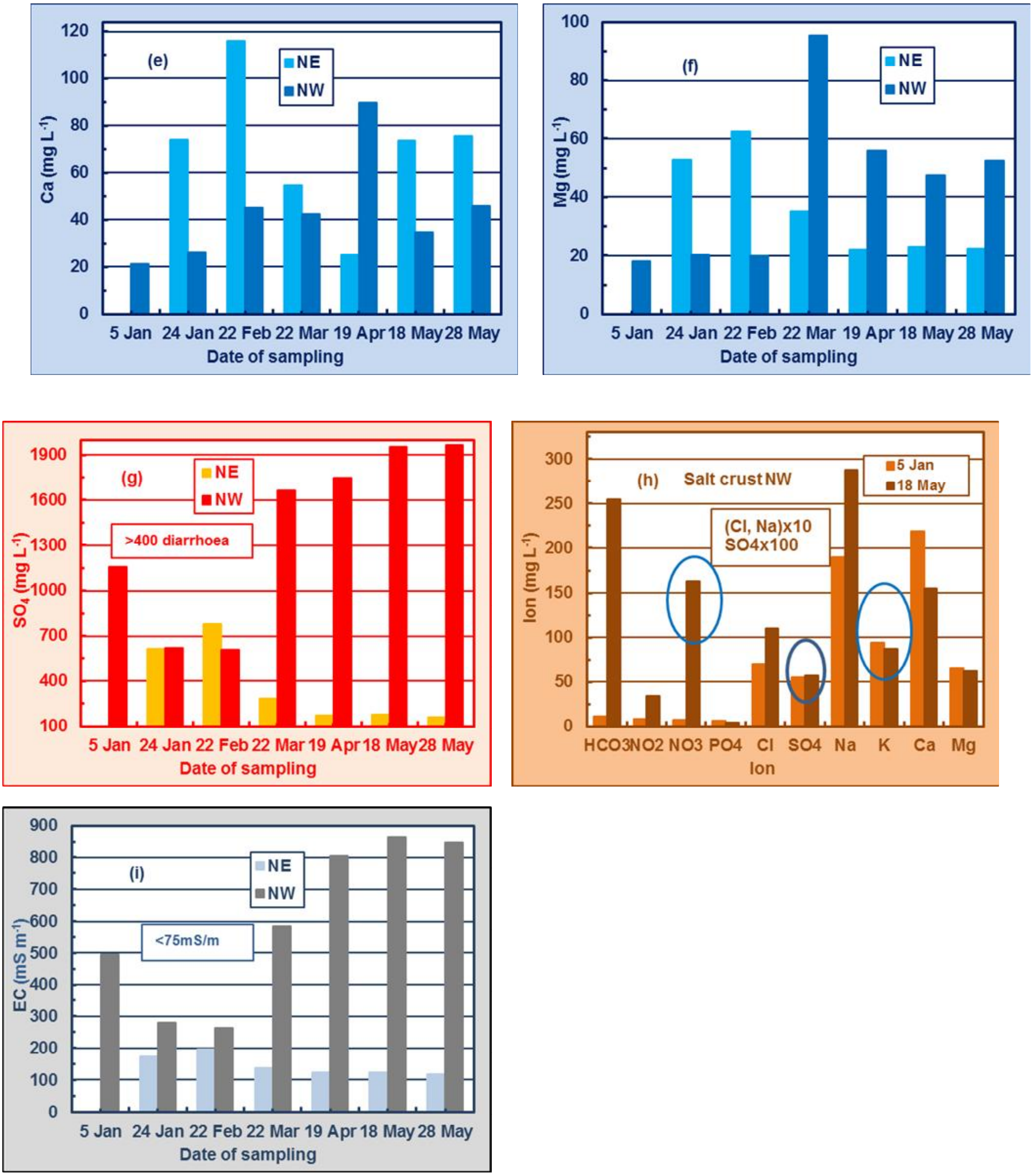


Figure 11e-i: Chemical characteristics of water table and salt crust.

4.2.6 *Soil sampling and analysis by OMNIA*

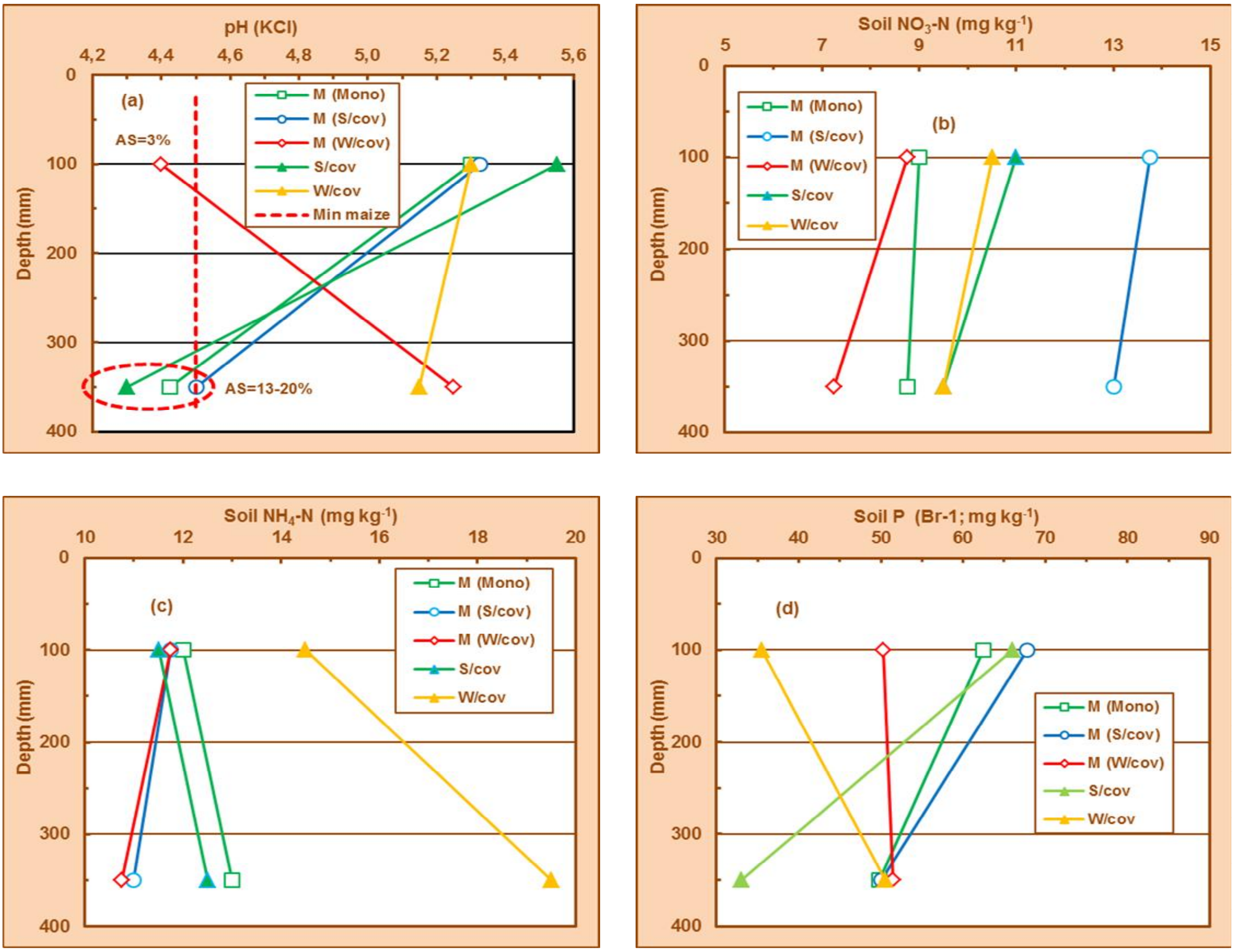
4.2.6.1 Soil fertility status

Soil pH (KCl) and some soil nutrient values are displayed in Figures 12a-e. The interpretation of the values in terms of sufficient or minimum requirements for maize growth is based on norms from the FSSA (2007) and does not necessarily represent the viewpoints of OMNIA.

- Soil pH (KCl) (Fig 12a): Except for M (W/cov), topsoil pH values were above the critical norm of 4.5. Under some crop stands, subsoil pH values were below 4,5, indicating AS ranging from 13 to 20%.

- Inorganic N (NO_3 and NH_4) (Fig 12b-c): Relatively low values, ranging from 9-14 (NO_3-N) and 11-20 (NH_4-N) mg kg^{-1}, were measured. Leaching of NO_3-N on these sandy soils appears to be a serious problem (See Section 4.2.5.3). The N carrier for the liquid fertilizer applications at planting and as top dressing is apparently 75% NH_4-based, probably explaining the higher residual soil NH_4-N. These sandy soils exhibit very poor acid buffering. The use of NH_4-fertilizers, therefore, should be discouraged.
- Phosphorus (P) (Fig 12d): High top- and subsoil P values were measured – well above the sufficiency level of 30 mg kg^{-1} required for maize (FSSA, 2007).
- Potassium (K) (Fig 12e): Both top- and subsoil K values are well above the minimum requirement of 80 mg kg^{-1} for maize (FSSA, 2007). The increase in soil K with depth is probably due to leaching of K, a phenomenon well-known on sandy soils (Also see Section 4.2.5.3).
- Both soil Ca and Mg are relatively well-supplied in the topsoil, but both decrease with depth (data not shown), contributing to an increase in AS.

Mean ECEC was 2,93 $cmol_c$ kg^{-1} in the topsoil and 2,47 $cmol_c$ kg^{-1} in the subsoil. Mean sand, silt and clay contents were 87%, 2% and 11% in the topsoil, and 86%, 1% and 13% in the subsoil, respectively. Notable is the almost total absence of silt in these soils.



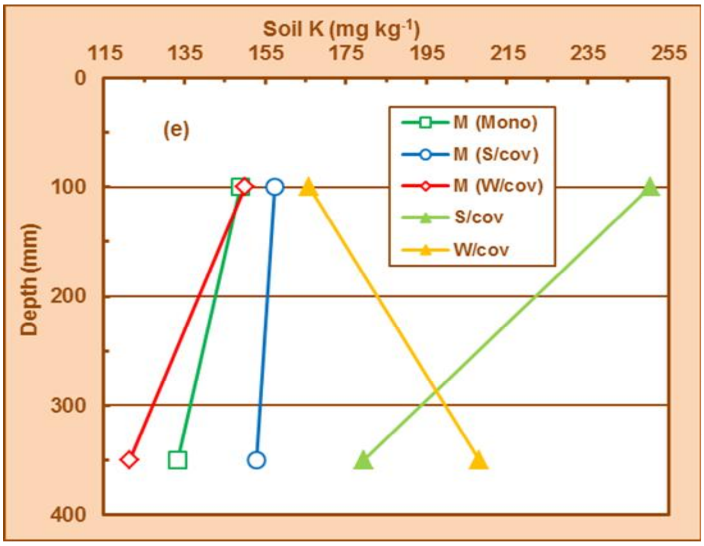


Figure 12a-e: Soil analysis values on Trial 1 (Deelpan).

4.2.6.2 Nitrogen cycle and soil health

A scrutiny of the inorganic N (NO_3 and NH_4) data revealed that under the crops and the natural grass stand (*Conydon dactylon,* couch grass) similar soil NO_3-N values were evident (Fig 12f), despite the fact that the crops received 83 kg N ha^{-1} as a fertilizer amendment compared to no N application on the grass stand. Although the mineralization of grass litter can contribute to soil N, it is presumed that the maintenance of soil N under natural grass stands can be contributed to non-symbiotic N fixation by free-living bacteria, *inter alia* of the genus *Azotobacter* (Botha 1963). Atmospheric N_2 is converted to relatively immobile NH_4, followed by the nitrification of the latter to highly mobile NO_3 that is highly susceptible to loss from the root zone by leaching. This loss of N from the root zone has large economic implications, as well as environmental consequences such as NO_3 pollution of ground water (See Section 4.2.5.3).

However, plants, and specifically grasses, produce root exudates that inhibit nitrification, rendering soil N to remain in the immobile NH_4 form (Theron 1951; Subbarao et al. 2007). This conservation of soil N through biologically nitrification inhibition (BNI) can be regarded as a major driving force for the development of low-NO_3 ecosystems under grass lands. This phenomenon is manifested in Fig 12g: Higher soil NH_4-N values were measured under the grass stand compared to the values under the crops. According to Subbarao et al. (2007), sorghum and pearl millet also show BNI. In the present study, sorghum was included in the summer cover mixture, thereby contributing to soil health in terms of preventing ground water pollution.

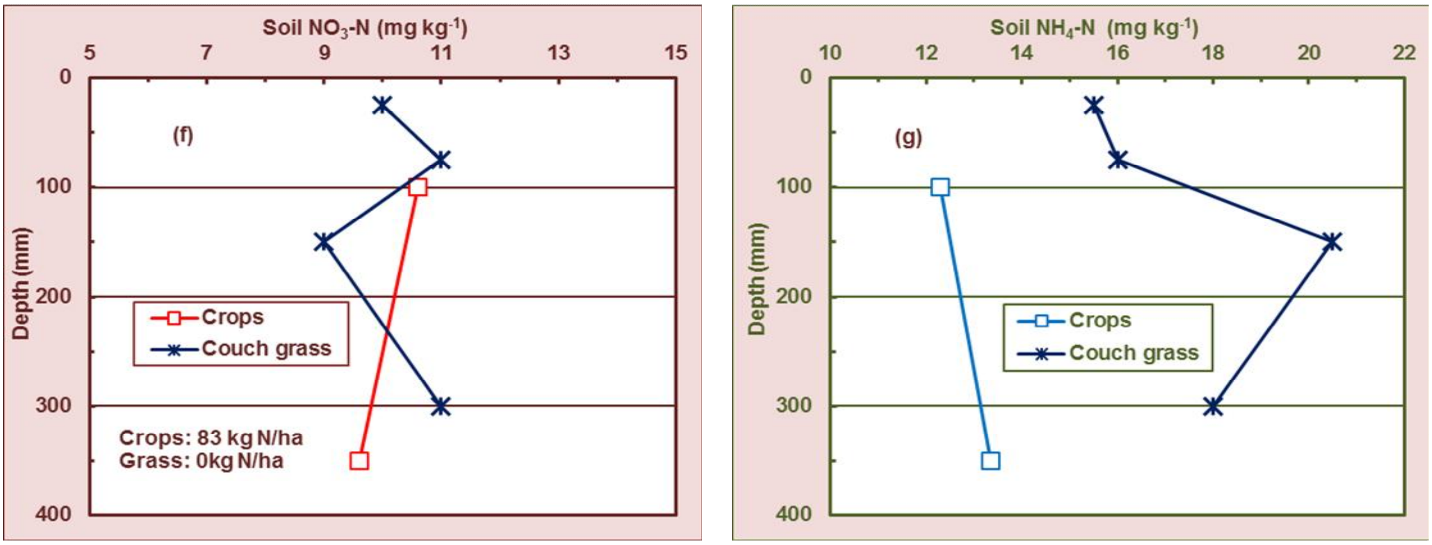


Figure 12f-g: Soil N values under crops and under a grass stand (Deelpan).

4.2.7 Root and crown rot severity study

Reporting by: Dr AM Abrahams, ARC-Grain Crops, Potchefstroom

An average plant biomass of 1.61 kg plant^{-1} was obtained, whilst the average root mass was 0.35 kg plant $^{-1}$. Compared to the 2016/17-season, higher root and crown rot severities were observed for the present season (34% and 11%, respectively) with the average root rot severity score being 166 and crown rot severity score being 18 (index values). qPCR analyses showed that of the 12 major root rot fungal pathogens were present, with *Fusarium equiseti* and *F. oxysporum* being the most prominent.

4.2.8 Plant-parasitic nematode study

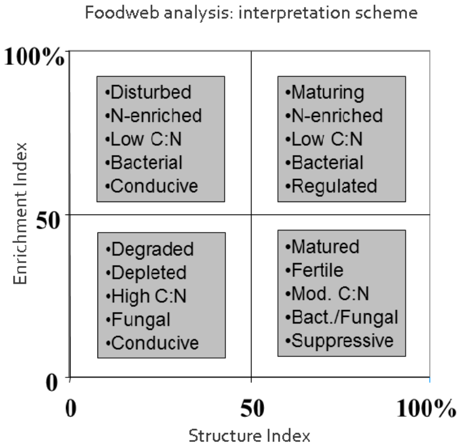
Reporting by: Dr S Steenkamp, ARC-Grain Crops, Potchefstroom

4.2.8.1 Background

The herbivore feeding type referred to throughout this report represents the plant-parasitic nematodes while the rest of the feeding types represent the free-living nematodes found in the soil. Those include fungivores, bacterivores, omnivors and predators. All of them are classified in the coloniser persister classification. According to Bongers (1990) and Bongers (1995), this classification is based on the life cycle properties of nematodes. Herbivores are classed as P-p and the free-living nematodes C-p. A nematode with a C-p/P-p of 1 has a short life cycle and is regarded as enrichment opportunists. These types of nematodes are often found in disturbed environments. C-p/P-p5 nematodes are on the other side of the spectrum. They have longer life cycles and tend to inhabit stable, mature ecosystems. Throughout this report all numbers higher during 2018 compared to that in 2017 are highlighted in yellow and numbers lower during 2018 in green, irrespective of the feeding type.

The metabolic footprints (foodweb analysis) are a quantification of the amplitude of carbon utilisation by the different food web components. The point in the middle of the square represents the point where the enrichment index and the structure index intersect. The length of the vertical axis corresponds to the footprints of the enrichment index and the horizontal axis that of the structure index (Ferris 2010).

The food web analysis used over the growing seasons should be interpreted as follows:



Soil of samples that falls in the lower, left hand square is degraded, depleted, high C:N, fungal and conductive while those in the lower, right hand square is matured, fertile, moderate C:N, bacterial/fungal and suppressive. Soil samples in the upper square on the left is disturbed, N enriched, low C:N, bacterial and conductive. That in the upper right square will be maturing, N enriched, low C:N, bacterial and regulated. The latter square is the most desirable square for a sample to fall in and the lower, left hand square, the least desired.

4.2.8.2 Treatments sampled

Treatments for the cover crop trial at Deelpan consisted of:

1. ROR maize – Rip on rip (ROR) maize – ROR maize – ROR maize.
2. Summer cover crop – No till (GB) maize – winter cover crop – GB Maize.
3. Summer cover crop – ROR maize – winter cover crop – ROR Maize.
4. Winter cover crop – GB maize – winter cover crop – GB Maize.
5. Winter cover crop – ROR maize – winter cover crop – ROR Maize.

4.2.8.3 Nematodes in the soil

The feeding type composite of the nematode assemblage for the cover crop trial over the 2016/17 (onwards indicated as 2017) and 2017/18 (onwards indicated as 2018) summer growing seasons are provided in Tables 4 and 5. The C-p (for the free-living nematodes) and the P-p (for the herbivore/plant-parasitic nematodes) classes for each of the nematodes identified in the soil are also included in these tables.

Table 4: Nematode feeding types and their C-p (non-parasitic) / P-p (plant-parasitic) classes present in soil samples (2016/17 growing season).

Feeding type	Nematode genus	C-p class	P-p class
Herbivore ectoparasite	Belonolaimidae	0	3
	Criconematidae	0	3
	Longidorus	0	5
	Paratylenchus	0	2
	Trichodoridae	0	4
Herbivore epidermal/root hair feeders	*Neothada*	0	2
	Tylenchidae	0	2
Herbivore semi endoparasites	*Helicotylenchus*	0	3
Herbivore migratory endoparasites	*Pratylenchus*	0	3
Herbivore sedentary endoparasites	*Meloidogyne*	0	3
	Rotylenchulus	0	3
Herbivore algal/lichen/moss feeders	*Tylenchus*	0	2
Fungivores	*Aphelenchoides*	2	0
	Aphelenchus	2	0
	Ditylenchus	2	0
	Nothotylenchus	2	0
Bacterivores	*Acrobeles*	2	0
	Acrobeloides	2	0
	Cephalobidae	2	0
	Cervidellus	2	0
	Diplogasteridae	1	0
	Eucephalobus	2	0
	Mesorhabditis	1	0
	Monohystera	2	0
	Panagrolaimus	1	0
	Plectus	2	0
	Rhabditis	1	0
	Zeldia	2	0
Omnivores	Dorylaimidae	4	0

Table 5: Nematode feeding types and their C-p (non-parasitic) / P-p (plant-parasitic) classes present in soil samples (2017/18 growing season).

Feeding type	Nematode genus	C-p class	P-p class
Herbivore ectoparasite	Belonolaimidae	0	3
	Criconematidae	0	3
	Trichodoridae	0	4
Herbivore epidermal/root hair feeders	Tylenchidae	0	2
Herbivore semi endoparasites	Hoplolaimidae	0	3
Herbivore migratory endoparasites	*Pratylenchus*	0	3
Herbivore sedentary endoparasites	*Meloidogyne*	0	3
	Rotylenchulus	0	3
Herbivore algal/lichen/moss feeders	*Tylenchus*	0	2
Fungivores	*Aphelenchoides*	2	0
	Aphelenchus	2	0
	Nothotylenchus	2	0
Bacterivores	*Acrobeles*	2	0
	Acrobeloides	2	0
	Cephalobidae	2	0
	Cephalobus	2	0
	Cervidellus	2	0
	Chiloplacus	2	0
	Diplogasteridae	1	0
	Eucephalobus	2	0
	Heterorhabditidae	1	0
	Mesorhabditis	1	0
	Monohystera	2	0
	Panagrolaimus	1	0
	Rhabditis	1	0
	Zeldia	2	0
Omnivores	Dorylaimidae	4	0
	Labronema	4	0
Predators	*Discolaimus*	5	0

The percentage of each feeding type present in the nematode assemblage found in the soil samples from the cover crop trial during 2017 is provided in Table 6. The feeding type composition of the nematode assemblages in the trial consisted of herbivores, fungivores, bacterivores and omnivores over both growing seasons (Table 4). Predators appeared in treatments 3 and 5 during 2018 (Table 6).

The nematode assemblages were dominated by bacteriovores except in treatment 1 during 2017 (Table 6). All of these nematodes belonged to the low 1 and 2 C-p classes (Table 3). Their numbers increased during 2018 in all of the treatments except in treatment 5. The fungivores (C-p 2; Table 5) increased in treatments 1 and 2 during 2018 (Table 4).

Following the bacterivores, the herbivores represented the second largest feeding type in the nematode assemblages during both growing seasons (Table 6). There was a decrease in percentage herbivores during 2018 in treatments 1, 2 and 3 but they increased in treatments 4 and 5 (Table 6).

Table 6: Percentage feeding type composition of nematode assemblages in the soil during 2017 and 2018.

Treatments	Herbivores		Fungivores		Bacterivores		Predators		Omnivores	
	2017	**2018**	2017	**2018**	2017	**2018**	2017	**2018**	2017	**2018**
1	72.1	**41.3**	4.7	**5.5**	22.6	**51.9**	0	**0**	0.6	**1.4**
2	41.3	**38.4**	1.3	**6.2**	32.6	**45.7**	0	**0**	24.8	**9.7**
3	34.7	**24.3**	4.6	**0**	45.2	**70.8**	0	**0.1**	15.5	**4.9**
4	9.9	**18.7**	17.9	**0.1**	52.7	**71.3**	0	**0**	19.5	**9.9**
5	7.6	**49.0**	23.6	**0.1**	60.5	**40.5**	0	**0.6**	6.4	**9.8**

The herbivore population composition in the soil of the cover crop trial over both growing seasons is provided in Table 5. Soil from all of the treatments contained ectoparasites, semi endoparasites, migratory endoparasites, sedentary endoparasites and algal feeders (Table 7). Except for treatment 5, the ectoparasites (Belonolaimidae, Criconematidae and Trichodoridae) dominated during 2017 (Table 7). All of the treatments showed a decline in ectoparasites during 2018, however and was now, except in treatment 2, dominated by migratory endoparasites (Pratylenchus spp.) (Table 7). These migratory endoparasites increased in all of the treatments except in treatment 2. The sedentary endoparasites (Meloidogyne spp. and Rotylenchulus spp.) also increased in all of the treatments during 2018 (Table 7).

Table 7: Percentage composition of herbivore (plant-parasitic) population in the soil during 2017 and 2018.

Herbivore	Treatment 1		Treatment 2		Treatment 3		Treatment 4		Treatment 5	
	2017	**2018**	2017	**2018**	2017	**2018**	2017	**2018**	2017	**2018**
Ectoparasites	34.7	**19.8**	54.0	**35.6**	43.5	**19.0**	48.5	**28.8**	21.3	**6.3**
Epidermal/root feed	0	**0.1**	0	**0.4**	0	**0**	0	**0.7**	7.6	**0.1**
Semi endoparasite	21.8	**0.8**	2.2	**0.5**	0.6	**0.5**	3.0	**3.4**	15.7	**0**
Migrator. endoparasites	34.7	**68.3**	38.3	**31.1**	37.9	**50.4**	33.0	**54.4**	21.3	**88.5**
Sedentar. endoparasites	8.0	**9.4**	3.9	**21.7**	1.5	**28.5**	0	**10.0**	0	**2.3**
Algal/lichen/moss feed	0.8	**1.7**	1.5	**10.7**	16.6	**1.6**	15.5	**2.6**	34.0	**2.8**

The life strategy structure of the herbivore nematode assemblage in soil samples during 2017 and 2018 obtained from the cover crop trial is provided in Table 8. None of the treatments maintained P-p1 nematodes during 2017 or during 2018. The percentage P-p2 nematodes decreased during 2018 but that of the P-p3 nematodes increased in all of the treatments (Table 8). These results are in line with those provided in Table 7 because the P-p3 nematodes consist of the sedentary endoparasites *Meloidogyne* spp. and *Rotylenchulus* spp. and the migratory endoparasites, *Pratylenchus* spp. (Table 5), all of which increased during 2018. During 2018 *Pratylenchus* spp. dominated in the soil samples of all of the treatments except for treatment 2 (Table 8). Trichodoridae, which are ectoparasites that belong to P-p4 (Table 5), increased in all of the treatments except treatment 3 during 2018 (Table 6). The P-p5 ectoparasite Trichodoridae (Table 4) was present in treatment 3 during 2017 but disappeared during 2018 (Table 8).

Table 8: Life strategy structure (%) of herbivores (plant-parasitic) nematode assemblage in the soil during 2017 and 2018.

Treatments	P-p1 (%)		P-p2 (%)		P-p3 (%)		P-p4 (%)		P-p5 (%)	
	2017	**2018**	2017	**2018**	2017	**2018**	2017	**2018**	2017	**2018**
1	0	**0**	35.5	**1.8**	64.5	**90.1**	0	**8.1**	0	**0**
2	0	**0**	39.8	**11.1**	56.8	**80.9**	3.3	**8.0**	0	**0**
3	0	**0**	54.5	**1.6**	41.6	**95.5**	3.4	**2.9**	0.6	**0**
4	0	**0**	48.5	**3.3**	36.0	**96.7**	15.5	**0.0**	0	**0**
5	0	**0**	62.9	**2.9**	37.1	**95.6**	0	**1.5**	0	**0**

The percentage coloniser-persister structure of the free-living nematode assemblage in the soil collected from Kroonstad over both growing seasons is provided in Table 6. The C-p1 nematode percentage increased during 2018 in all of the treatments (Table 9). C-p2 percentages increased in treatment 2 and 3 but decreased in treatments 1, 4 and 5 (Table 9). Nematodes that belong to the C-p4 class decreased in treatments 2, 3 and 4 but increased in treatments 1 and 5 while in treatments 3 and 5 there was an increase in C-p5 nematodes (Table 9). Nematodes from the C-p2 class (Tables 4 and 5) dominated the free-living nematode assemblage in the soil from all of the treatments, however (Table 9).

Table 9: Coloniser-persister structure (%) of free-living nematode assemblage in the soil during 2017 and 2018.

Treatments	C-p1 (%)		C-p2 (%)		C-p3 (%)		C-p4 (%)		C-p5 (%)	
	2017	**2018**	2017	**2018**	2017	**2018**	2017	**2018**	2017	**2018**
1	7.7	**15.1**	90.1	**82.5**	0	**0**	2.2	**2.4**	0	**0**
2	0	**1.7**	57.8	**82.6**	0	**0**	42.2	**15.8**	0	**0**
3	17.9	**22.0**	58.3	**71.5**	0	**0**	23.8	**6.4**	0	**0.1**
4	5.5	**15.9**	72.9	**71.9**	0	**0**	21.6	**12.2**	0	**0**
5	3.0	**5.7**	87.9	**73.8**	0	**0**	9.1	**19.2**	0	**1.3**

4.2 8.4 Plant-parasitic nematodes in the roots.

The plant-parasitic nematodes that were present in root samples from the Kroonstad trial during 2017 and 2018 are represented in Table 10. Although both the sedentary endo parasite *Meloidogyne* spp. (which dominated in root samples during 2017) and the migratory endo parasite *Pratylenchus* spp. were present in root samples from all of the treatments, *Pratylenchus* spp. dominated during 2018 (Table 10). This was also the case in the soil samples from 2018 (Table 7).

Table 10: Nematode numbers in root samples during 2017 and 2018.

Treatments	[1]*Meloidogye* / 50g roots		*Meloidogyne* / 5g roots		[2]*Pratylenchus* / 5g roots	
	2017	**2018**	2017	**2018**	2017	**2018**
1	1 708	**193**	0	**0**	630	**327**
2	11 084	**152**	70	**12**	569	**741**
3	680	**105**	70	**6**	665	**251**
4	No roots	**70**	No roots	**23**	No roots	**280**
5	No roots	**273**	No roots	**6**	No roots	**222**

[1]Root-knot nematodes [2]Lesion nematodes

4.2.8.4 Foodweb analysis

The analysis of the foodweb during 2017 and 2018 are presented in Figures 13 and 14, respectively. Treatments 2 and 4 occurred in the lower, right hand square during 2017 (Figure 14) but during 2018 all of the treatments moved into the lower, left hand square during 2018 (Figure 15).

4.2.8.5 Conclusion for the cover crop trial at Deelpan

According to the foodweb analysis, soils irrespective of their current treatments, remain degraded. These results are supported by the high numbers of P-p2 and C-p2 nematodes that persisted throughout the two seasons in all of the treatments.

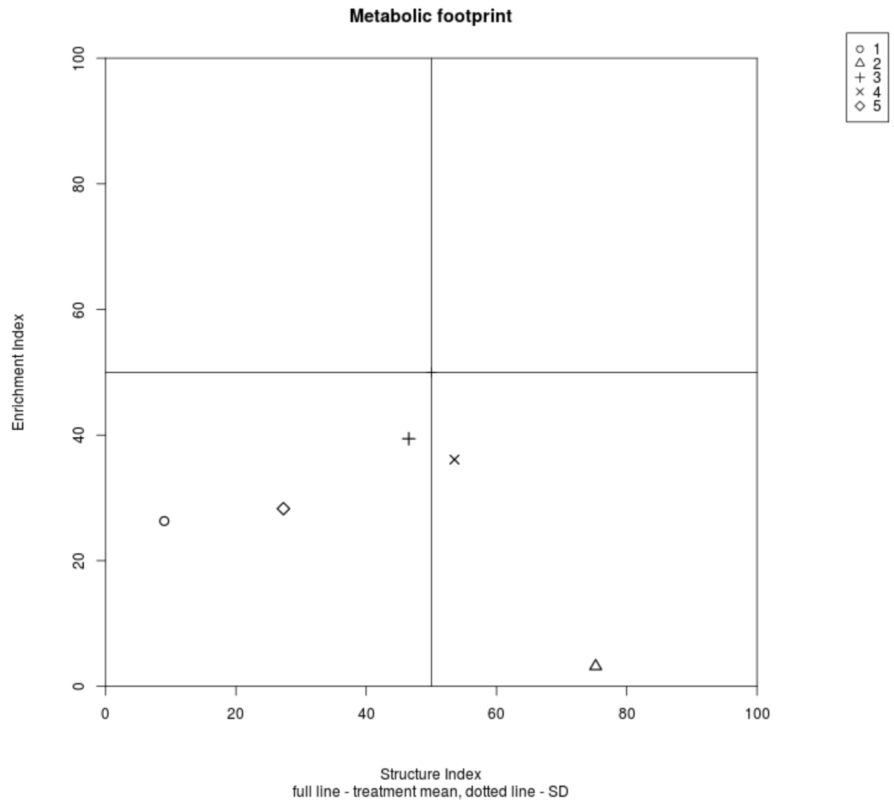


Figure 13: Metabolic footprint (foodweb analysis) for the cover crop trial (2017).

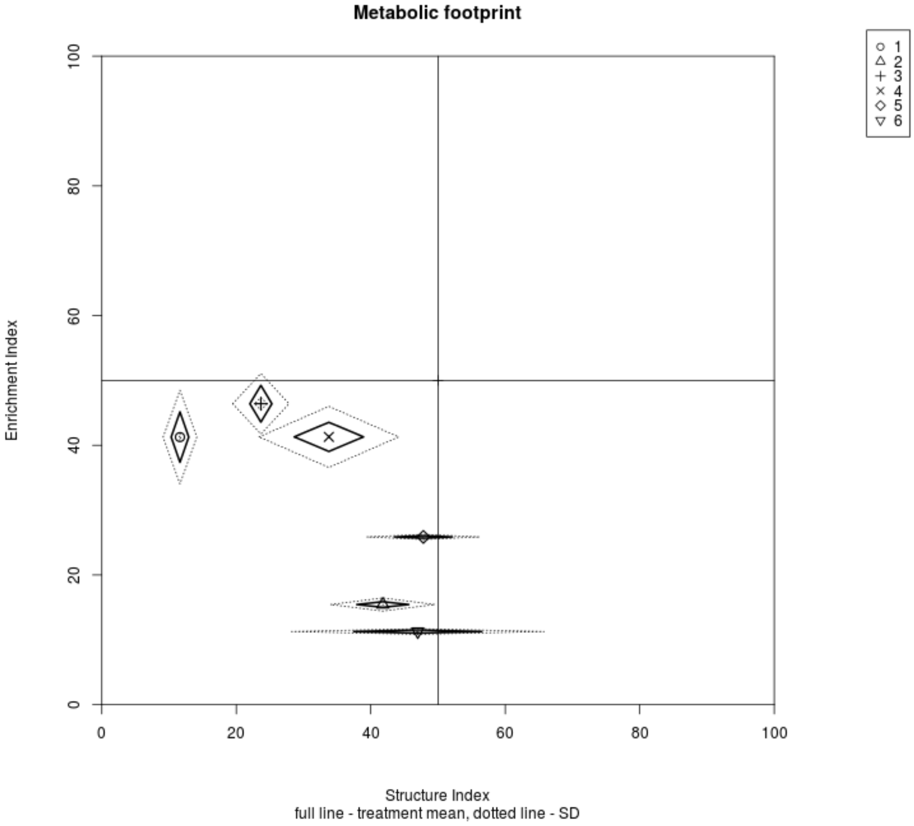


Figure 14: Metabolic footprint (foodweb analysis) for the cover crop trial (2018).

4.2.9 Soil microbiological study

Reporting by: Mr OHJ Rhode, ARC-Grain Crops Institute, Potchefstroom

4.2.9.1 Microbial groups

The cover crops had significant effects (Table 11: F ratio = 3.97 (p = 0.04); 2.87 (p = 0.08); 4.85 (p = 0.02)) on bacteria, actinomycetes, filamentous fungi counts, respectively. Compared to actinomycetes and fungi, bacteria had the highest incidence of occurrence under maize following summer cover crops (Table 11, Fig 15). Although not statistically significant, bacteria and actinomycetes had the highest incidence under maize mono culture, while filamentous fungi counts were the highest under maize following winter cover crops.

4.2.9.2 Enzyme activity

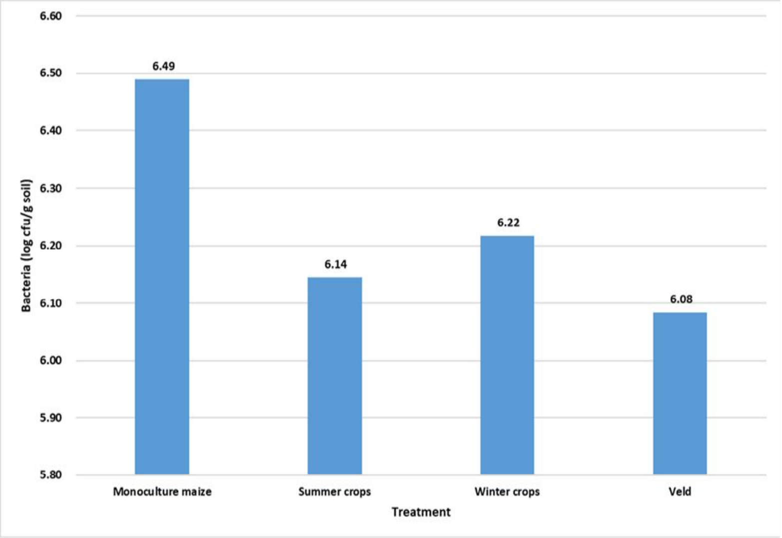
The cover crops had a significant effect on glucosidase, phosphatase and urease activity (Table 12: 7.58 (p = 0.003); 12.29 (p = 0.00); 0.68 (p = 0.52)), respectively. Fields under mono culture maize showed higher activities for glucosidase and phosphatase, while maize following winter cover crops showed significantly higher urease activity (Table 12; Figure 16).

Table 11: Statistical parameters for microbial counts.

Source of variation	**F ratio (probability)**		
	Property		
	Bacteria	**Actinomycetes**	**Fungi**
Cover crop	4.85(0.007)	4.25(0.013)	5.22(0.005)
Practice	**Treatment means**		
	(cfu g soil^{-1})	**(cfu g soil^{-1})**	**(cfu g soil^{-1})**
Monoculture maize	6.49a	6.28a	4.15b
Maize (S/cov crops)	6.14ab	5.79a	4.28ab
Maize (W/cov crops)	6.22ab	6.07a	4.81a
Natural grass stand	6.08b	5.85a	4.52ab
LSD(0.05)			

Table 12: Statistical parameters for enzymatic activity.

Source of variation	**F ratio (probability)**		
	Property		
	Glucosidase	**Phosphatase**	**Urease**
Cover crop	1.61 (0.21)	3.64 (0.02)	9.92(0.001)
Practice	**Treatment means**		
	(mg kg $^{-1}$ hr^{-1})	**(mg kg $^{-1}$ hr^{-1})**	**(mg kg $^{-1}$ 2hr^{-1})**
Monoculture	1590.60a	162.61a	41.65b
Maize (S/cov crops)	927.90a	47.40b	39.58b
Maize (W/cov crops)	733.40a	40.69b	109.23a
Natural grass stand	986.40a	91.50ab	36.95b
LSD(0.05)			



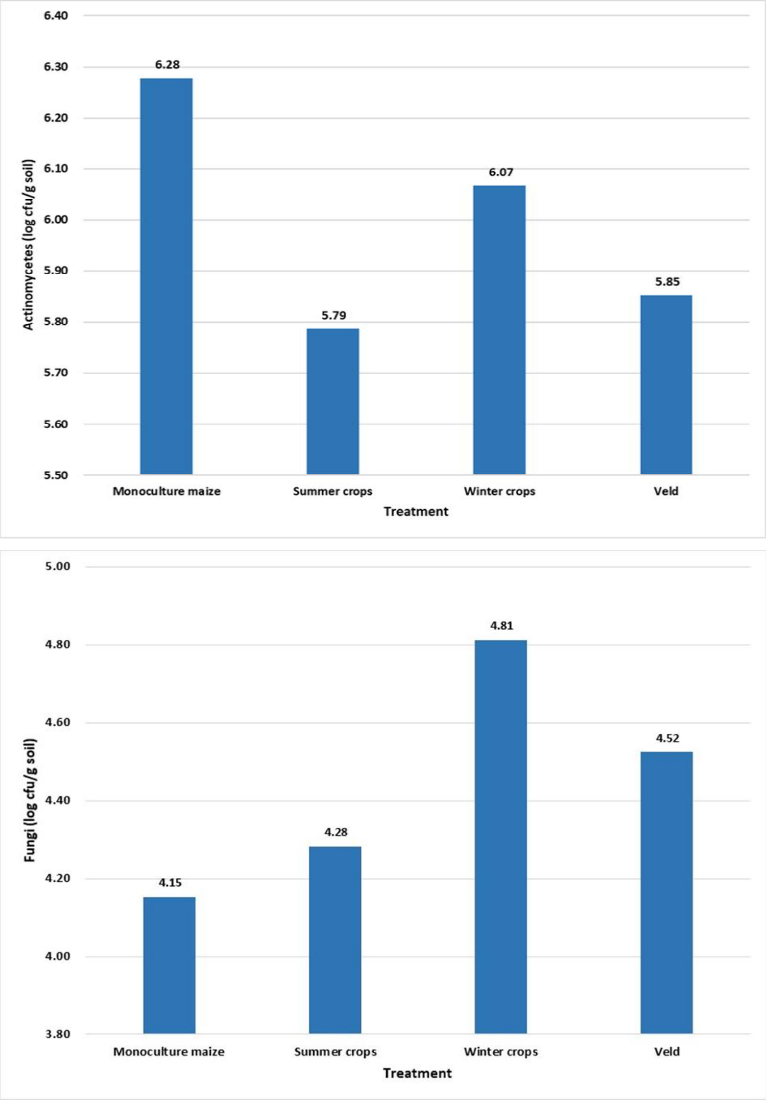
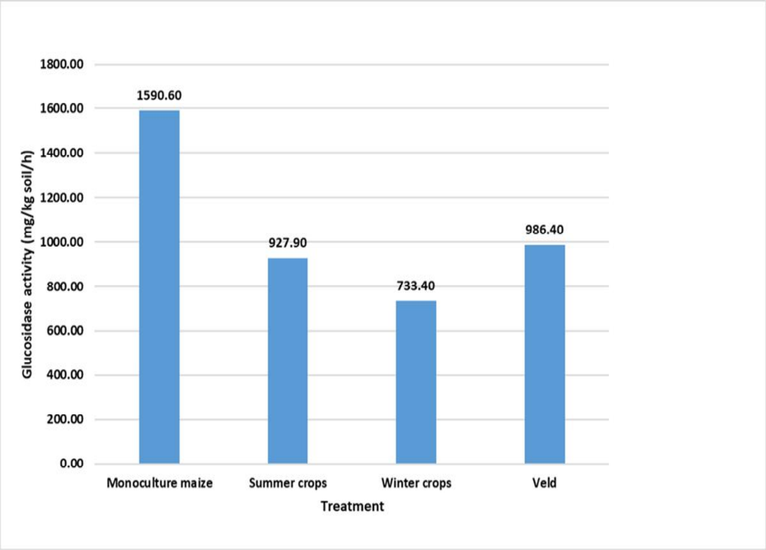


Figure 15: Cover crop effects on maize microbial groups.



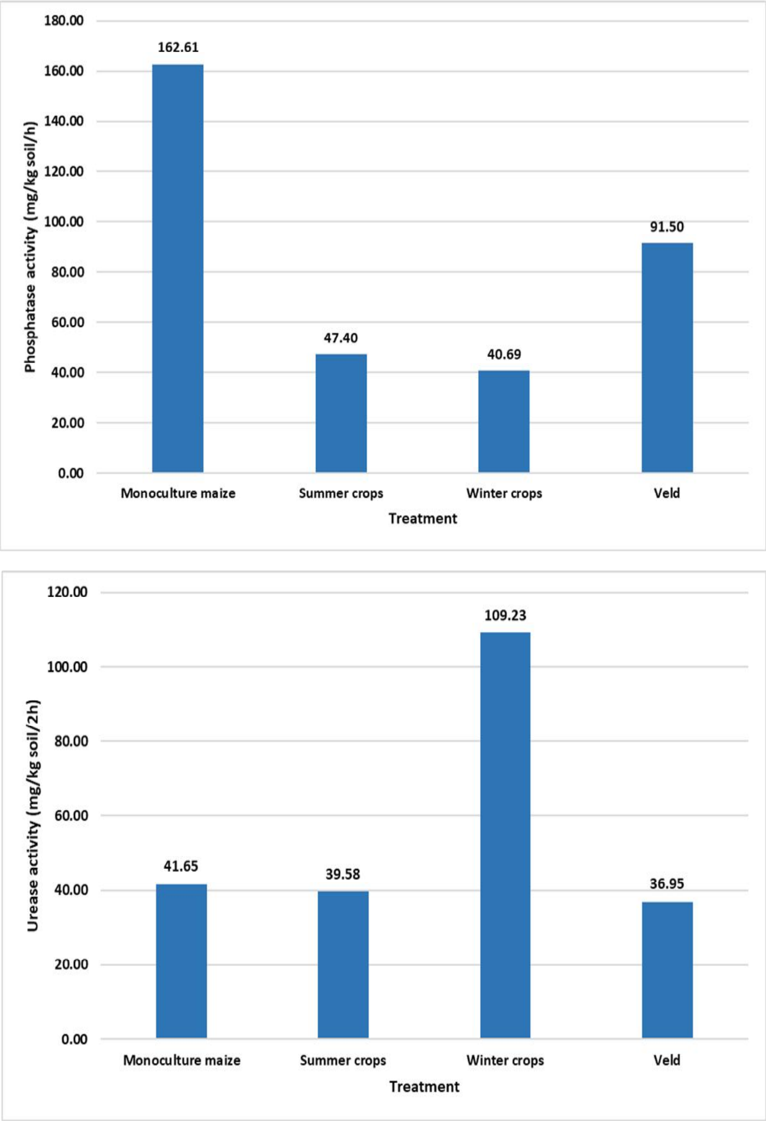


Figure 16: Cover crop effects on soil microbial enzyme activity.

4.2.9.3 Conclusion

Differences (P=0.05) could be detected among the treatments for microbial activities (enzymes and counts) in the cover crop trial. Higher numbers were observed for bacteria and actinomycete in the mono culture maize system. Filamentous fungi levels were the highest under maize following winter cover crops. Glucosidase and phosphatase enzyme activities were higher under mono culture maize soil. Urease activity was significantly higher under maize following winter cover crops.

4.3 Trials 2 and 3: Local CA, ROR and reduced tillage, stubble-mulch, cash crop rotations with maize/soybean/forage sorghum, as well as comparing the effects of tillage practices on mono culture maize cultivation

(Trial 2 at Christinasrus-Thabo van Zyl: Trial 3 at Klein Constantia-Lourens van der Linde)

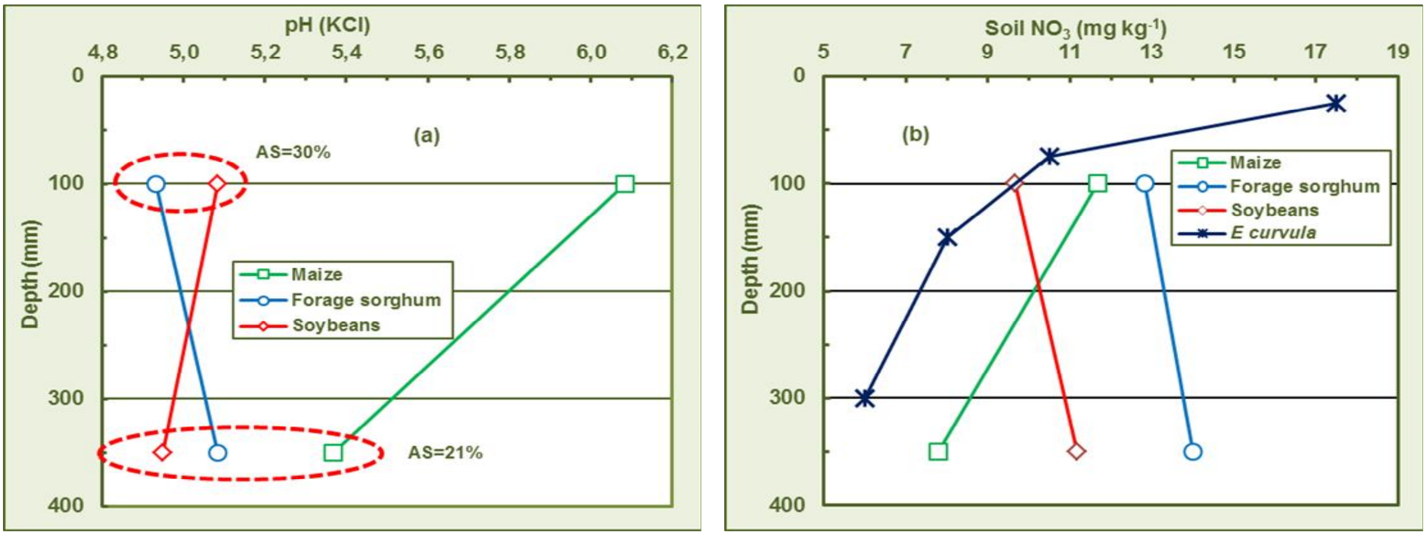
4.3.1 Soil sampling and analysis by OMNIA (Trial 2)

Some soil properties and nutrient values are displayed in Figures 17a-f. The interpretation of the values in terms of sufficient or minimum requirements for maize growth is based on norms from the FSSA (2007) and does not necessarily represent the viewpoints of OMNIA. Each data point in the graphs represents a mean of three replicates.

- Soil pH (KCl) and acid saturation (Fig 17a): Except for the top soil value under maize, pH values were relatively low, with concomitant high AS values in both the top and sub soils. It is advised that soil acidity should be ameliorated with dolomitic agricultural lime because of the sub-optimal topsoil Mg status (5th bullet).
- Inorganic N (NO_3 and NH_4) (Fig 17b-c): Low NO_3-N values, ranging from 7,8-14 mg kg^{-1} in the 0-50 cm soil layer, were measured. As a comparison, soil NO_3-N values under an *E curvula* stand are also in included in the figure to portray values under a natural grass stand. Relatively high NH_4-N values, ranging from 29.3-41.2 mg kg^{-1} in the 0-50 cm soil layer, were measured. The use of urea or NH_4-fertilizers as N carrier on these sandy soils with their very poor acid buffer capacity should be discouraged. As a comparison, soil NH_4-N values under an *E curvula* stand are also in included in the figure to portray values under a natural grass stand. Notable is the relatively high values under the grass stand (See discussion in Section 4.2.6.2).
- Phosphorus (P): In general, both top and subsoil P values are above the minimum P requirement for maize Figure 17d.
- Potassium (K): Figure 17e shows that both top and subsoil K are, in general, well-supplied (>80 mg K kg^{-1} minimum requirement for maize). The relatively low soil K under maize could be due to active uptake of K.
- Calcium (Ca) and magnesium (Mg): Both soil Ca and Mg are medium to low in both the top- and subsoil (data not shown). The low Mg values should prompt the use of dolomitic lime to ameliorate soil acidity.

- Soil organic C: Soil C is generally very low and ranged from 0.34-0.47% (Figure 18f). Maize and forge sorghum showed slightly higher values than under soybeans. The former two crops followed maize (2016/17) while the soybean plots laid fallow. As a comparison, soil organic C values under an *E curvula* stand are also in included in the figure to portray values under natural conditions.

Mean effective cation exchange capacity (ECEC) for the trial area was very low in the topsoil (2.32 $cmol_c$ kg^{-1}) and in the subsoil (2.19 $cmol_c$ kg^{-1}). Mean sand, silt and clay contents were 88%, 2.3% and 10% in the topsoil, and 86%, 1.8% and 10,7% in the subsoil, respectively. Notable is the very low silt content of the soil.



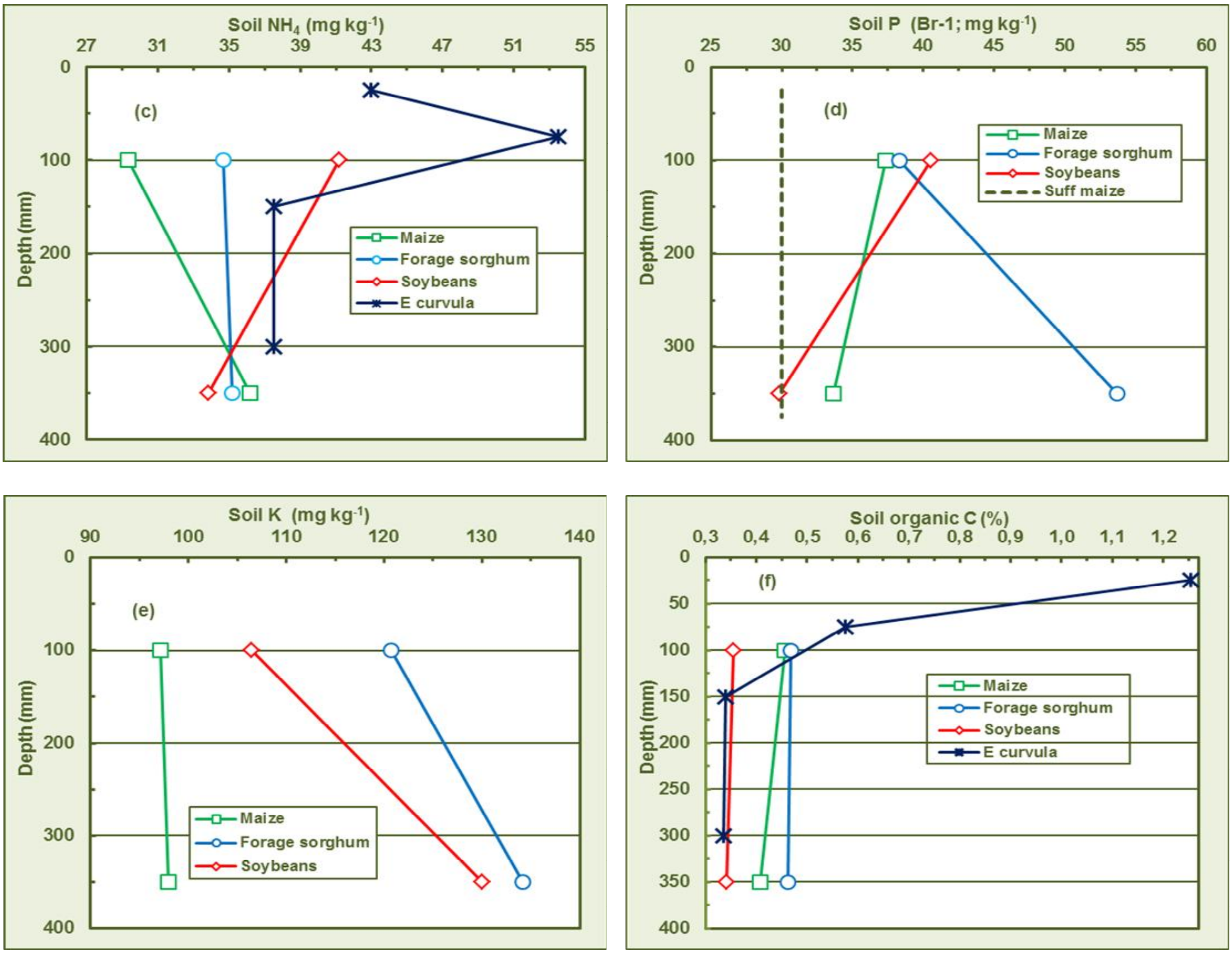


Figure 17a-f: Soil analysis values on Trial 2 (Christinasrus).

4.3.2 Root and crown rot severity study (Trial 2)

Reporting by: Dr AM Abrahams, ARC-Grain Crops, Potchefstroom

4.3.2.1 Salient results on plant biomass and on root and crown rot severity

Figures 18 to 21 show the average plant biomass, average root mass, as well as the average root and crown rot severity for the various crop rotation systems. Analysis of variance (ANOVA) indicated that there were no significant differences between root rot, crown rot and the various crop rotation systems. Across all four crop rotation systems, an average plant biomass of 1.23 kg plant^{-1} was obtained, whilst the average roots mass was 0.35 kg plant^{-1}. Average root rot severity was 143.925 and the average crown rot severity was 50.378 (index values). Although the average root and crown rot severity observed for all the plants sampled were not extremely high, some plots did have higher root and crown rot, especially the plots located in replicate three. Root rot severity varied between 116.78 and 186.11, and crown rot severity between 37.67 and 76.67 (index values). Compared to the rotation systems, root and crown rot severity was the highest under mono culture maize.

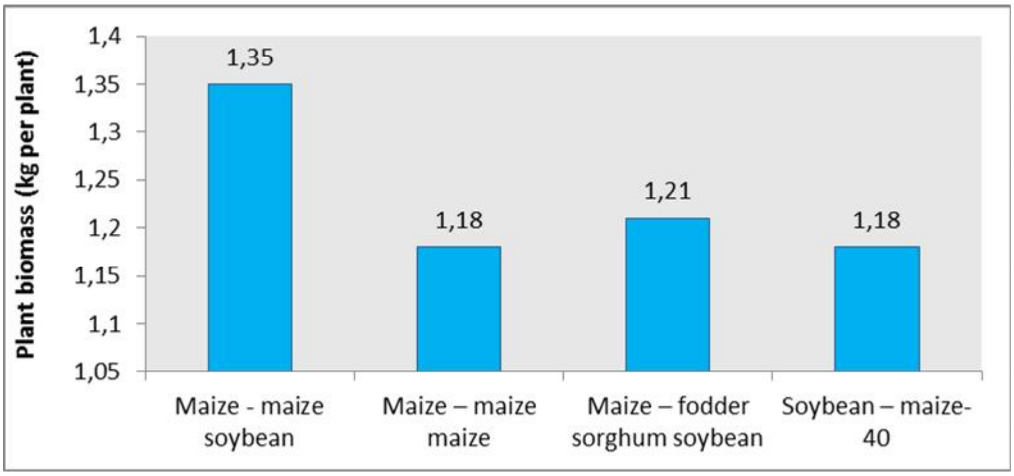


Figure 18: Average plant biomass for the four cropping systems.

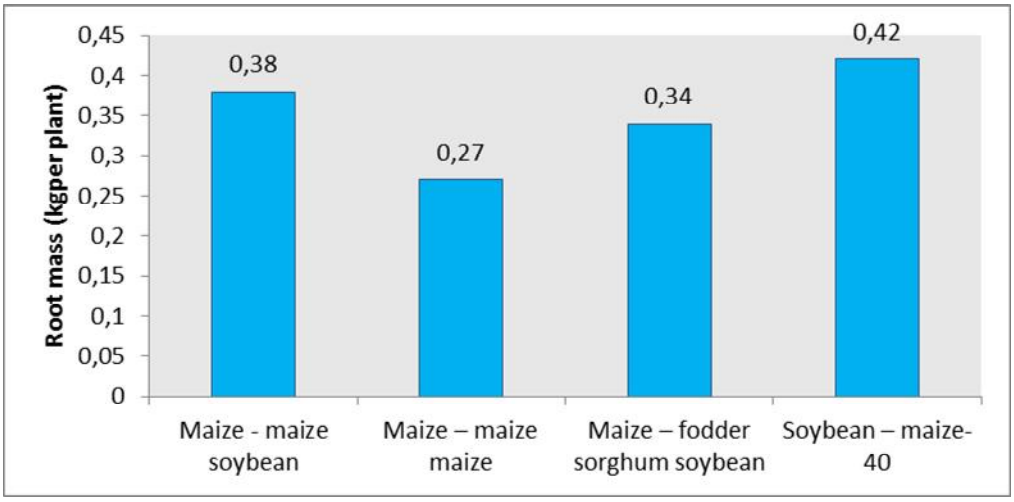


Figure 19: Average root mass for the four cropping systems.

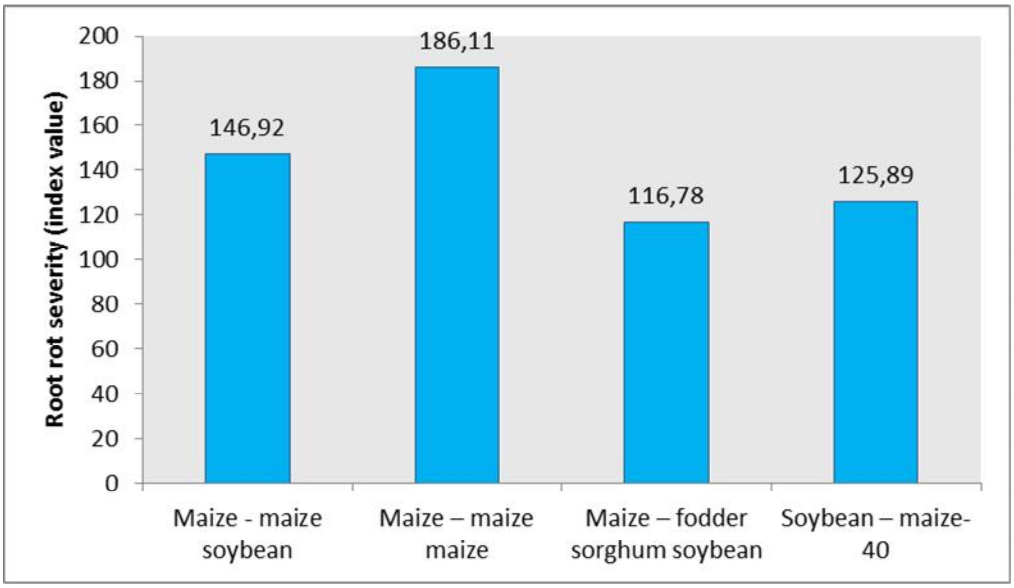


Figure 20: Average root rot severity for the four cropping systems.

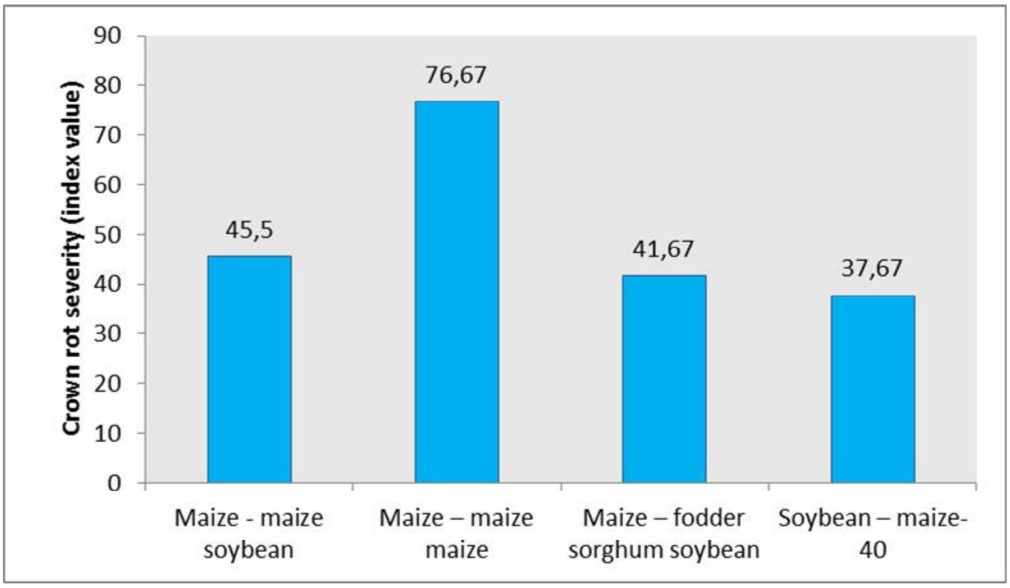


Figure 21: Average crown rot severity for the four cropping systems.

4.3.2.2 Root rot fungal pathogen identification and quantification

qPCR analyses showed that *Erioderma pedicellatum*, *Fusarium equiseti*, *F. graminearum*, *M. phaseolina, F. oxysporum, Rhizoctonia. solani* and *F. verticillioides* had a significant effect on monoculture maize and were the most prominent of the fungi tested in the current study. *Fusarium equiseti* and *F. oxysporum* were relatively prominent in maize in rotation with soybean. Maize in rotation with fodder sorghum, as well as soybean in rotation with maize$_{-40}$ (where the maize was fertilized with 40 kg ha^{-1} less nitrogen), it was observed that the root rot fungal pathogens were drastically reduced. The current study demonstrated that multiple seasonal data are required in order to obtain better insights into the effect of cultivation practice and crop rotation crop on soil borne pathogens and their resultant impact on root and crown rot development and eventual grain yield and quality. This would also assist with pointing out a viable management strategy for the fungi analysed.

4.3.3 Plant parasitic nematode study (Trial 2)

Reporting by: Dr S Steenkamp, ARC-Grain Crops, Potchefstroom

4.3.3.1 Treatments sampled

Treatments for the crop rotation trial at Christinasrus (real implementation in bold):

10. Maize – Maize (MMM): **Maize 2016/17; Maize 2017/18**
11. Maize – Maize - Forage sorghum (MMK1): **Maize 2016/17; Maize 2017/18**
12. Maize – Maize –Soybeans (MMK2): **Maize 2016/17; Soybeans 2017/18**
13. Wheat – Maize – Maize (MMK3): **Fallow 2016/17; Maize 2017/18**
14. Wheat – Maize – Maize – Wheat (MMK4): **Fallow 2016/17; Maize 2017/18**
15. Maize – Wheat – Soybean (MKS1): **Maize 2016/17; Forage sorghum 2017/18**
16. Wheat – Soybean – Maize (MKS2): **Fallow 2016/17; Soybeans 2017/18**
17. Wheat – Soybean – Maize - Wheat (MKS3): **Fallow 2016/17; Soybeans 2017/18**
18. Soybean – Maize - Wheat (MKS4): **Soybeans 2016/17; Maize 2017/18**

4.3.3.2 Nematodes in the soil

The feeding type composite and the C-p and P-p classes of the nematode assemblage present in soil samples over the 2016/17 and 2017/18 summer growing seasons, are provided in Tables 13 and 14, respectively.

Table 13: Nematode feeding types and their C-p (non-parasitic) / P-p (plant-parasitic) classes present in soil samples (2016/17 growing season).

Feeding type	Nematode genus	C-p class	P-p class
Herbivore ectoparasite	Belonolaimidae	0	3
	Criconematidae	0	3
	Longidorus	0	5
	Paratylenchus	0	2
	Trichodoridae	0	4
Herbivore epidermal/root hair feeders	*Neothada*	0	2
	Tylenchidae	0	2
Herbivore semi endoparasites	*Helicotylenchus*	0	3
Herbivore migratory endoparasites	*Pratylenchus*	0	3
Herbivore sedentary endoparasites	*Meloidogyne*	0	3
	Rotylenchulus	0	3
Herbivore algal/lichen/moss feeders	*Tylenchus*	0	2
Fungivores	*Aphelenchoides*	2	0
	Aphelenchus	2	0
	Ditylenchus	2	0
	Nothotylenchus	2	0
Bacterivores	*Acrobeles*	2	0
	Acrobeloides	2	0
	Cephalobidae	2	0
	Cervidellus	2	0
	Diplogasteridae	1	0
	Eucephalobus	2	0
	Mesorhabditis	1	0
	Monohystera	2	0
	Panagrolaimus	1	0
	Plectus	2	0
	Rhabditis	1	0
	Zeldia	2	0
Omnivores	Dorylaimidae	4	0

Table 14: Nematode feeding types and their C-p (non-parasitic) / P-p (plant-parasitic) classes present in soil samples (2017/18 growing season).

Feeding type	Nematode genus	C-p class	P-p class
Herbivore ectoparasite	Belonolaimidae	0	3
	Criconematidae	0	3
	Longidorus	0	5
	Paratylenchus	0	2
	Trichodoridae	0	4
Herbivore epidermal/root hair feeders	*Neothada*	0	2
	Tylenchidae	0	2
Herbivore semi endoparasites	*Helicotylenchus*	0	3
Herbivore migratory endoparasites	*Pratylenchus*	0	3
Herbivore sedentary endoparasites	*Meloidogyne*	0	3
	Rotylenchus	0	3
Herbivore algal/lichen/moss feeders	*Tylenchus*	0	2
Fungivores	*Aphelenchoides*	2	0
	Aphelenchus	2	0
	Ditylenchus	2	0
	Nothotylenchus	2	0
Bacterivores	*Acrobeles*	2	0
	Acrobeloides	2	0
	Cephalobidae	2	0
	Cervidellus	2	0
	Diplogasteridae	1	0
	Eucephalobus	2	0
	Mesorhabditis	1	0
	Monohystera	2	0
	Panagrolaimus	1	0
	Plectus	2	0
	Rhabditis	1	0
	Zeldia	2	0
Omnivores	Dorylaimidae	4	0

The percentage feeding type composition of the nematode assemblages present in soil samples collected at the crop rotation trial during the 2016/2017 and 2017/2018 summer growing seasons is represented in Table 15. During both seasons the nematode assemblages consisted of herbivores, fungivores, bacterivores and omnivores. Predators additionally appeared during 2018 in most of the treatments (Table 15).

The nematode assemblages in all of the treatments during 2017 were dominated by low C-p class bacterivores (Table 14). However, during 2018, the bacterivores decreased in all of the treatments, while the herbivore percentage increased so much that this feeding type started to dominate (Table 15).

Table 15: Percentage feeding type composition of nematode assemblages in the soil during 2017 and 2018.

Treatments	Herbivores		Fungivores		Bacterivores		Predators		Omnivores	
	2017	**2018**	2017	**2018**	2017	**2018**	2017	**2018**	2017	**2018**
1	5.6	**57.3**	31.6	**2.3**	60.5	**34.0**	0	**1.1**	2.3	**5.4**
2	6.7	**42.2**	8.8	**5.4**	81.8	**44.3**	0	**0.1**	2.7	**8**
3	17.3	**54.9**	16.8	**0.3**	54.8	**37.8**	0	**0.1**	11.1	**6.9**
4	6.1	**60.3**	4.2	**2.1**	77.5	**31.1**	0	**0.2**	12.2	**6.4**
5	11.9	**31.6**	3.6	**1.3**	80.5	**61.2**	0	**0**	4.0	**5.8**
6	15.6	**55.5**	4.9	**1.2**	77.3	**35.7**	0	**0.1**	2.2	**7.6**
7	15.0	**42.4**	0	**0.4**	80.2	**51.7**	0	**0.4**	4.8	**5.1**
8	0.8	**42.9**	10.6	**0**	67.8	**47.9**	0	**1.4**	20.8	**7.8**
9	12.6	**51.1**	6.1	**2.3**	75.4	**40.4**	0	**0**	6.6	**6.1**

The herbivore population composition in the soil of the crop rotation trial over both growing seasons is provided in Table 16. During 2017 the soil from treatments 1, 2, 5 and 8 contained only ectoparasites (Belonolaimidae, Criconematidae, *Longidorus* spp., *Paratylenchus* spp. and Trichodoridae; Table 14) while treatment 4 contained only migratory endoparasites (*Pratylenchus* spp.; Table 14) (Table 16). Treatment 3 maintained ectoparasites, semi endoparasites (*Helicotylenchus* spp.; Table 14) and migratory endoparasites while treatments 6, 7 and 9 maintained ectoparasites and migratory endoparasites (Table 16). During 2018 the sedentary endoparasites (*Meloidogyne* spp.; Table 14) increased in all of the treatments, the migratory endoparasites in all but treatments 3, 4, 7 and 9 and the semi endoparasites in all but treatment 3 (Table 16).

Table 16: Percentage composition of herbivore population in the soil during 2017 and 2018.

Herbivore	Treatment 1		Treatment 2		Treatment 3		Treatment 4		Treatment 5	
	2017	**2018**	2017	**2018**	2017	**2018**	2017	**2018**	2017	**2018**
Ectoparasites	100	**63.0**	100	**19.9**	30.5	**34.4**	0	**37.8**	100	**61.0**
Epidermal/root feed	0	**0**	0	**0**	0	**0**	0	**0**	0	**0**
Semi endoparasite	0	**0.7**	0	**0.9**	9.6	**2.6**	0	**6.3**	0	**1.1**
Migrator. endoparasites	0	**23.7**	0	**66.7**	59.9	**50.3**	100	**36.8**	0	**20.2**
Sedentar. endoparasites	0	**12.4**	0	**9.9**	0	**11.5**	0	**17.6**	0	**17.3**
Algal/lichen/moss feed	0	**0.3**	0	**2.6**	0	**1.3**	0	**1.5**	0	**0.4**

Herbivore	Treatment 6		Treatment 7		Treatment 8		Treatment 9	
	2017	**2018**	2017	**2018**	2017	**2018**	2017	**2018**
Ectoparasites	48.0	**24.6**	33.3	**33.6**	100	**14.3**	73.5	**51.1**
Epidermal/root feed	0	**0**	0	**0**	0	**0**	0	**0**
Semi endoparasite	0	**0.5**	0	**6.0**	0	**12.5**	0	**2.4**
Migrator. endoparasites	52.0	**62.8**	66.7	**47.2**	0	**60.9**	26.5	**32.6**
Sedentar. endoparasites	0	**11.9**	0	**12.6**	0	**12.3**	0	**13.6**
Algal/lichen/moss feed	0	**0.1**	0	**0**	0	**0**	0	**0.2**

The life strategy structure of the herbivore feeding type maintained in the soil from the crop rotation trial at Christinasrus during 2016/17 and 2017/18 is provided in Table 17. Most of the herbivore population consist of P-p3 nematodes, which was the case for both growing seasons

(Table 17). The P-p2 % of nematodes increased in all of the treatments except in treatment 3, 8 and 9 and the P-p4 increased in all treatments except in treatment 5 (Table 17). P-p5 nematodes (*Longidorus* spp.; Table 14) appeared in treatments 3 and 9 during the 2018 season (Table 17).

Table 17: Life strategy structure (%) of herbivores (plant-parasitic) nematode assemblage in the soil during 2017 and 2018.

Treatments	P-p1 (%)		P-p2 (%)		P-p3 (%)		P-p4 (%)		P-p5 (%)	
	2017	**2018**	2017	**2018**	2017	**2018**	2017	**2018**	2017	**2018**
1	0	0	0	**0.3**	100	**95.0**	0	**4.6**	0	0
2	0	0	0	**2.6**	100	**90.4**	0	**7.0**	0	0
3	0	0	9.6	**1.3**	90.4	**94.5**	0	**2.7**	0	**1.4**
4	0	0	0	**1.5**	100	**97.9**	0	**0.5**	0	0
5	0	0	0	**0.4**	66.1	**97.4**	33.9	**2.2**	0	0
6	0	0	0	**0.1**	100	**98.2**	0	**1.7**	0	0
7	0	0	0	**0.6**	100	**89.5**	0	**9.9**	0	0
8	0	0	0	**0**	100	**97.1**	0	**2.9**	0	0
9	0	0	47.1	**0.2**	52.9	**92.6**	0	**4.6**	0	**2.5**

The coloniser-persister structure of the free-living nematode assemblage in soil samples collected during 2017 and 2018 is provided in Table 18. Although C-p2 nematodes dominated the nematode assemblage during 2017 and 2018, they did decrease during 2018 in all treatments except for treatment 8 (Table 18). C-p4 nematodes increased during 2018 in all treatments except for treatment 8 and C-p5 nematodes increased in all but 5, 8 and 9 (Table 18).

Table 18: Coloniser-persister structure (%) of free-living nematode assemblage in the soil during 2017 and 2018.

Treatments	C-p 1 (%)		C-p 2 (%)		C-p 3 (%)		C-p 4 (%)		C-p 5 (%)	
	2017	**2018**	2017	**2018**	2017	**2018**	2017	**2018**	2017	**2018**
1	2.4	**7.7**	95.2	**73.3**	0	0	2.5	**17.7**	0	**1.4**
2	0	**1.2**	97.1	**80.3**	0	0	2.9	**18.3**	0	**0.2**
3	0	**0.5**	86.6	**83.2**	0	0	13.4	**16.1**	0	**0.2**
4	4.1	**4.1**	82.9	**74.2**	0	0	13.0	**21.3**	0	**0.5**
5	0	**1.2**	95.4	**88.7**	0	0	4.6	**10.1**	0	**0**
6	2.5	**3.5**	95.0	**76.6**	0	0	2.6	**19.7**	0	**0.2**
7	0	**0.9**	94.4	**88.9**	0	0	5.6	**9.9**	0	**0.3**
8	0	**1.0**	79.0	**82.9**	0	0	21.0	**16.1**	0	**0**
9	0	**4.1**	92.5	**78.7**	0	0	7.5	**17.2**	0	**0**

4.3.3.3 Nematodes in the roots

The number of sedentary and migratory endoparasites present in root samples from the crop rotation trial at Christinasrus during 2017 and 2018 are provided in Table 19. The sedentary endoparasite *Meloidogyne* spp. mostly dominated in the roots during both seasons and increased during 2018 in all of the treatments except for treatments 2 and 3 (Table 19).

Table 19: Nematode numbers in root samples during 2017 and 2018.

Treatments	[1]*Meloidogye* / 50g roots		*Meloidogyne* / 5g roots		[2]*Pratylenchus* / 5g roots	
	2017	**2018**	2017	**2018**	2017	**2018**
1	228	**274**	93	**23**	6	**193**
2	604	**257**	76	**23**	12	**368**
3	778	**677**	99	**6**	18	**1 698**
4	No roots	**263**	No roots	**6**	No roots	**286**
5	No roots	**134**	No roots	**8**	No roots	**112**
6	298	**1 670**	41	**35**	0	**502**
7	No roots	**1 219**	No roots	**47**	No roots	**332**
8	No roots	**618**	No roots	**76**	No roots	**257**
9	140	**1 096**	14	**41**	0	**455**

[1]Root-knot nematodes [2]Lesion nematodes

4.3.3.4 Foodweb analysis

The analysis of the foodweb in the crop rotation trial during 2017 and 2018 is presented in Figures 22 and 23, respectively. All treatments occurred in the lower, left hand square during 2017 (Figure 22). During 2018 however, all of the treatments started to move towards the lower, right hand square (Figure 23).

4.3.3.5 Conclusions for the crop rotation trial at Christinasrus

The soil in the crop rotation trial at Christinasrus shows a slight improvement in soil health, which is supported by the increase of C-p4 and C-p5 nematodes from 2017 to 2018. There is a significant increase in the herbivore population too, however. This indicates that although the soil may be healthy, the plant-parasitic nematode numbers will still increase and will remain a problem. The only solution will be to include nematode-resistant cultivars into these treatments.

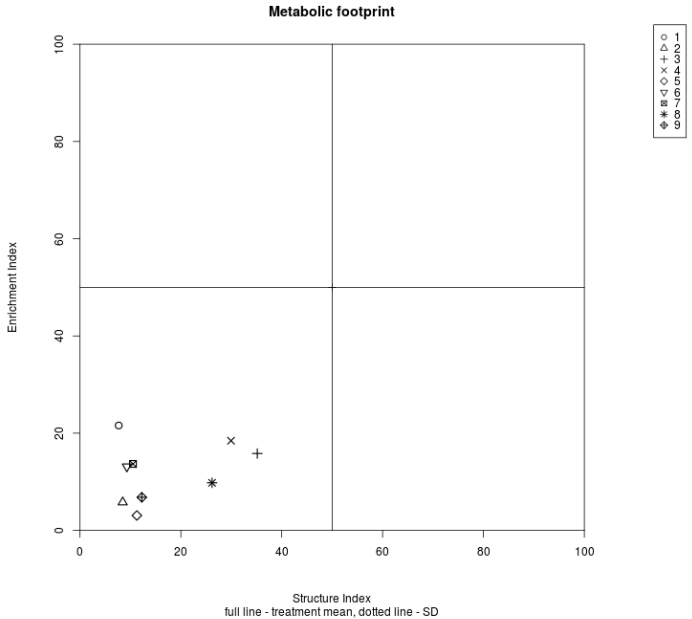


Figure 22: Metabolic footprint (foodweb analysis) for the crop rotation trial (2017).

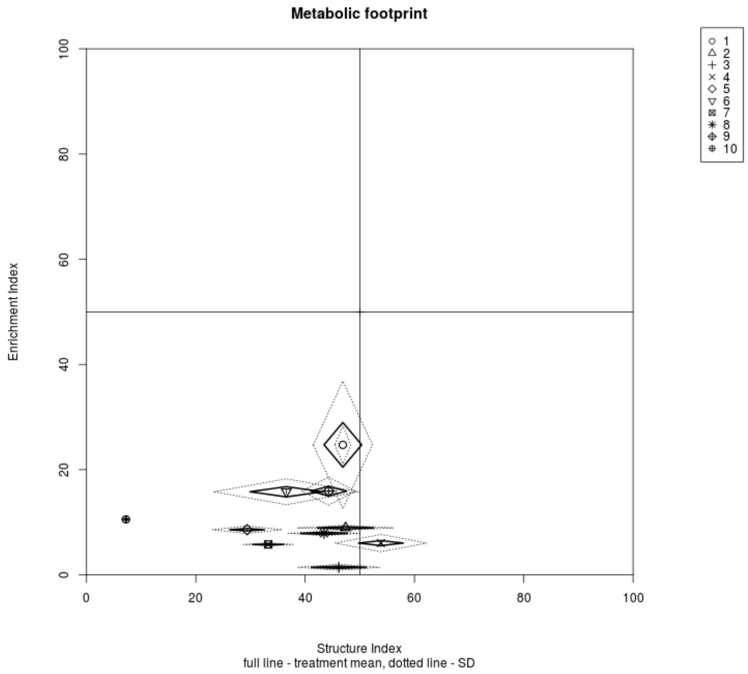


Figure 23: Metabolic footprint (foodweb analysis) for the crop rotation trial (2018).

4.3.5 Soil microbiological study (Trial 2)

Reporting by: Mr OHJ Rhode, ARC-Grain Crops, Potchefstroom

4.3.5.1 Microbial groups

The monoculture maize cropping system in comparison with crop rotations of maize/soybean and maize/forage sorghum had a significant effect (Table 20: F ratio *p* =2.84 (0.047) 2.51 (0.069)) on bacterial and actinomycetes activity. Bacteria and actinomycetes counts were higher under monoculture maize compared to maize/soybean and maize/forage sorghum cropping system (Table 20; Fig. 24). Although not significant, fungal counts were higher under maize/forage sorghum compared to mono culture maize, while fungal activity under natural grass was the highest of all treatments (Table 18; Fig. 24).

4.3.5.2 Enzyme activity

For the crop rotation trial, the natural grass stand soils had a significant effect (Table 21: F ratio *p* = 13.01 (0.038) 16.64 (0.001)) on phosphatase and urease activity (Fig 26). Activity for glucosidase was the highest under forage sorghum (Table 21, Fig 25).

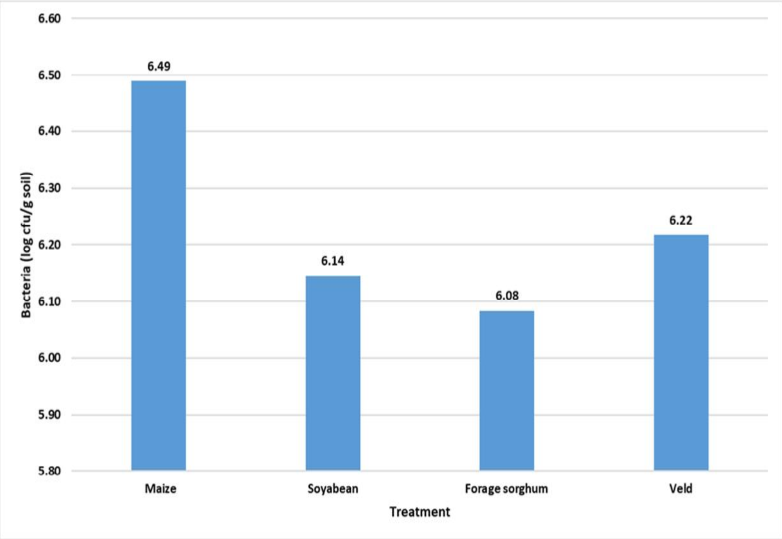
Table 20: Statistical parameters for microbial counts.

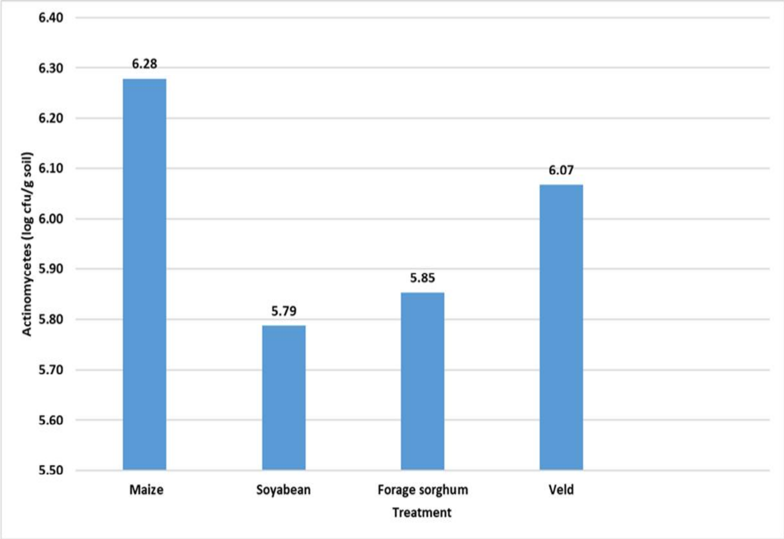
Source of variation	**F ratio (probability)**		
	Property		
	Bacteria	**Actinomycetes**	**Fungi**
Crop	2.84 (0.047)	2.51 (0.069)	0.39 (0.762)
Practice	**Treatment means**		
	(cfu g soil^{-1})	**(cfu g soil^{-1})**	**(cfu g soil^{-1})**
Monoculture maize	6.49a	6.28a	4.15a

Soybeans	6.14b	5.79a	4.28a
Forage sorghum	6.08b	5.85a	4.52a
Natural grass stand	6.22ab	6.07a	4.81a
LSD(0.05)			

Table 21: Statistical parameters for enzymatic activity.

Source of variation	**F ratio (probability)**		
	Property		
	Glucosidase	**Phosphatase**	**Urease**
Crop	1.60 (0.201)	3.01 (0.038)	16.64 (0.001)
Practice	**Treatment means**		
	(mg kg $^{-1}$ hr^{-1})	**(mg kg $^{-1}$ hr^{-1})**	**(mg kg $^{-1}$ 2hr^{-1})**
Monoculture maize	1108.70ab	1446.90b	27.90b
Soyabean	835.50b	1002.60b	25.35b
Forage sorghum	1467.80a	1209.20b	31.92b
Natural grass stand	1253.10ab	3695.90a	109.86a
LSD(0.05)			





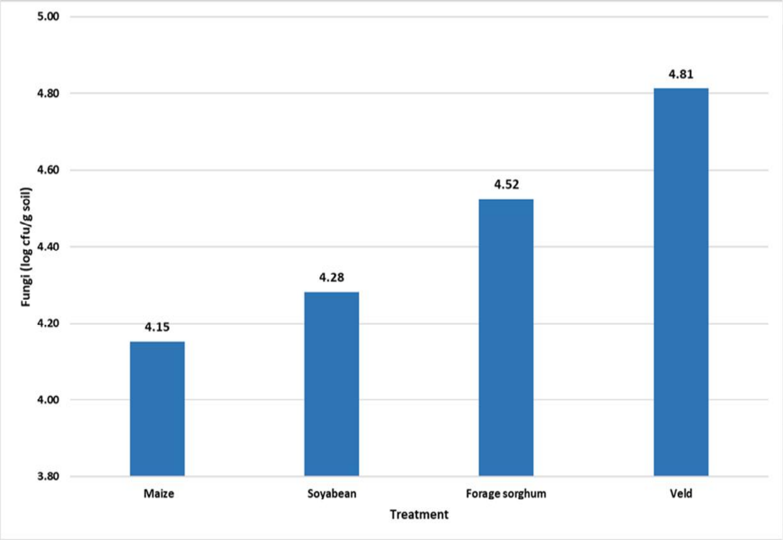
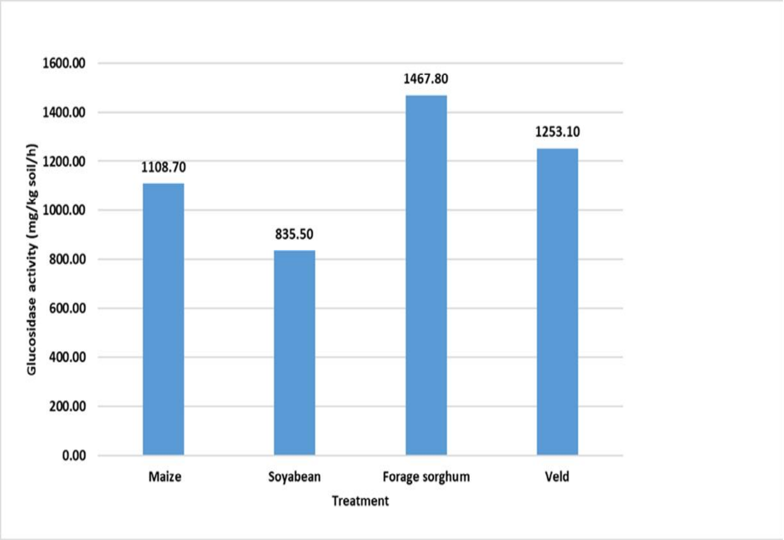
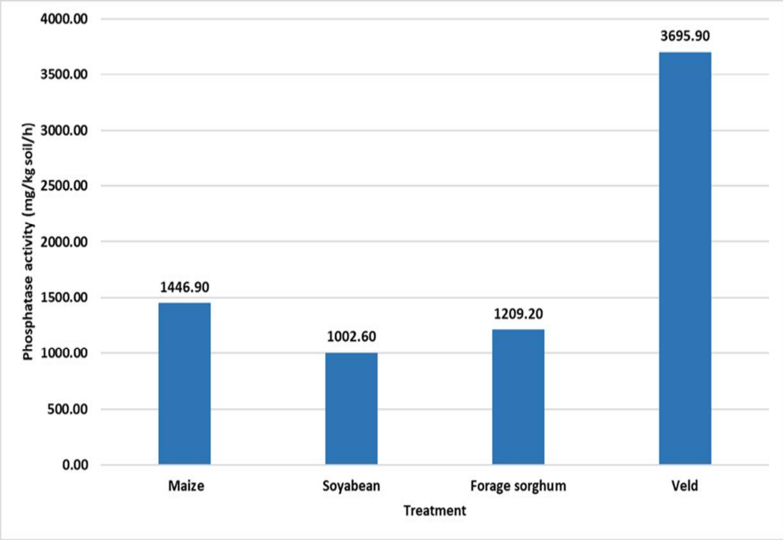


Figure 24: Cropping effects on maize microbial groups.





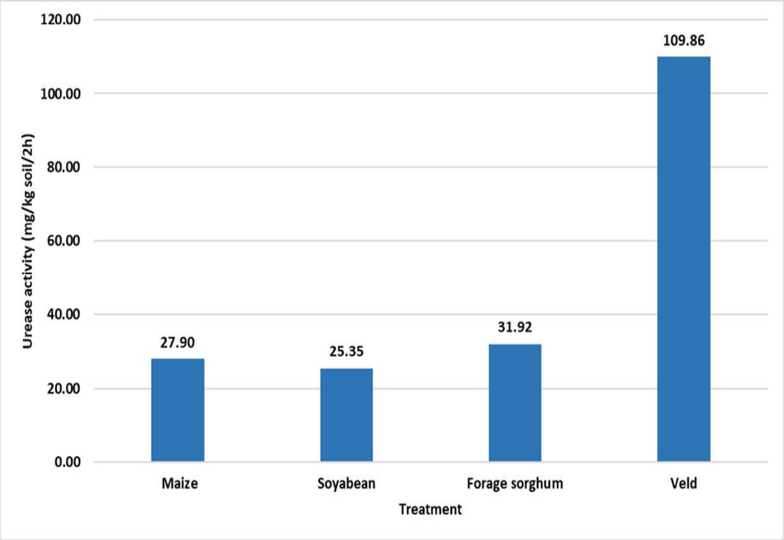


Figure 25: Cropping effects on soil microbial enzyme activity.

4.3.5.3 Conclusion

In the crop rotation trial the highest bacterial and actinomycetes counts were mono culture maize. Although not significant, fungal counts were higher under maize/forage sorghum compared to mono culture maize, while fungal activity under natural grass was the highest of all treatments. Enzymes exhibited no significant difference among rotations, although the highest glucosidase activity was measured under forage sorghum. Under the natural grass stand, significantly higher phosphatase and urease activities were measured. Findings obtained for the second season are still inconclusive and exhibit opposing results compared to the previous season.

4.3.6 Agronomic observations and measurements (Trial 2)

(Dr AA Nel)

4.3.6.1 Maize in rotation with soybean and forage sorghum at Christinasrus

As 2016/17 was the first season of this trial, no agronomic measurements were made apart from the yields of the different crops. Maize yield ranged from 2.89 to 9.68 t ha^{-1} with a mean yield of 7.71 t ha^{-1}. The large yield range is due to 3 plots where the application of fertilizer was most likely limited. Soybean yields ranged from 2.02 to 2.31 t ha^{-1} with a mean yield of 2.21 t ha^{-1}. Both maize and soybean yields were high and it can be assumed that a rotational effect was created which might have had an effect the crops in the 2017/18 season.

Although differences among mean maize yields of the rotation systems were in some cases more than 1 t ha^{-1}, the statistical analysis indicated that yields were unaffected by the previous crop (or fallow) in 2017/18 (Table 22). The coefficient of variation was relatively high at 20%, which can be an indication of soil variability of the trial area.

Like maize, the yield of soybean was not affected by the crop rotation system in 2017/18 as shown in Table 23.

Table 22: The yield of maize as affected by crop rotation system in 2017/18.

Crop system and previous crop				
MMS Fallow	MMS Soybean	MS Soybean	MM Maize	MVS Soybean
5.21	4.35	5.57	4.51	4.63
F-ratio	Probability	LSD (t ha^{-1})	CV (%)	

1.72	0.24	3.63	20

Table 23: The yield of soybean as affected by crop rotation system in 2017/18.

Crop system and previous crop		
MMS Maize	MS Maize	MVS Fallow
1.29	1.40	1.20
Probability	LSD (t ha^{-1})	CV (%)
0.19	0.50	62

Plate 13: Discussing the forage sorghum stand at Christinasrus on 4 Jan 2018.

4.3.7 Agronomic observations and measurements (Trial 3)

(Dr AA Nel)

4.3.7.1 Effects of tillage practices on mono culture maize cultivation at Klein Constantia

Analyses of the 2016/17 and 2017/18 yields showed a similar and significant yield gradient across the trial area (Fig. 26) despite the tillage system. Accordingly, measured yields were adjusted to a zero gradient.

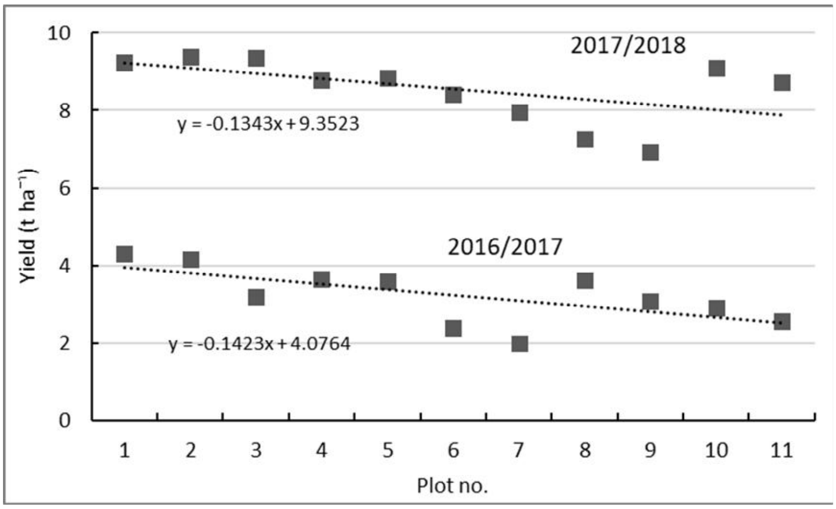


Figure 26: The yield of maize across the plot area in 2016/17 and 2017/18.

In 2016/17, wind and water logging at some stage, damaged the crop. As a result, yields were very low and similar for all tillage systems (Fig 27). Tillage systems were rip-on-row (11), no-till (0) and rip-between-rows (010). Yields were relatively high in 2017/18 and are shown in Figure 28. The mean yield of the three rip-on-row tillage treatment is 1.19 t ha^{-1} higher than the mean no-till yields. This is most likely a significant difference as the least significant difference between treatments of maize trials are often about 0.5 t ha^{-1}. These results also agree with results found on the farm Leeukuil near Odendaalsrus, on a similar sandy soil in a trial done during 2012/13 and 2013/14 under the agreement between Grain SA and INTA from Argentina.

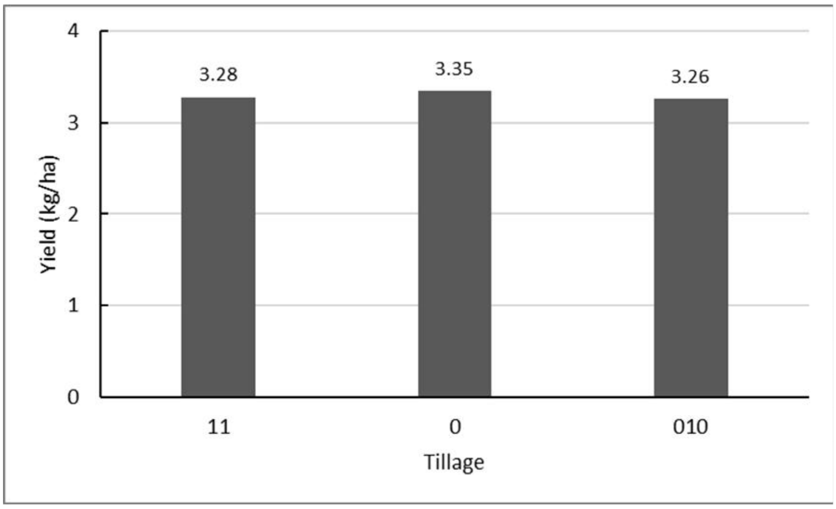


Figure 27: The yield of maize as affected by tillage system at Klein Constantia (2016/17).

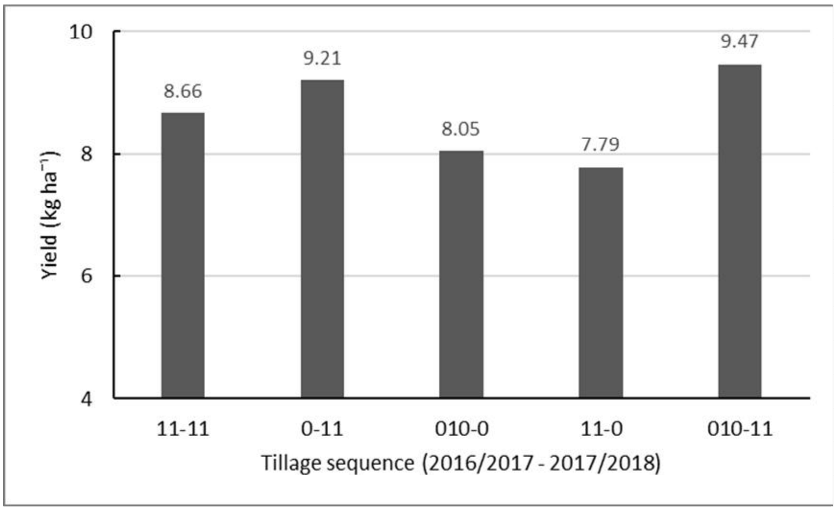


Figure 28: The yield of maize as affected by tillage system at Klein Constantia (2017/18).

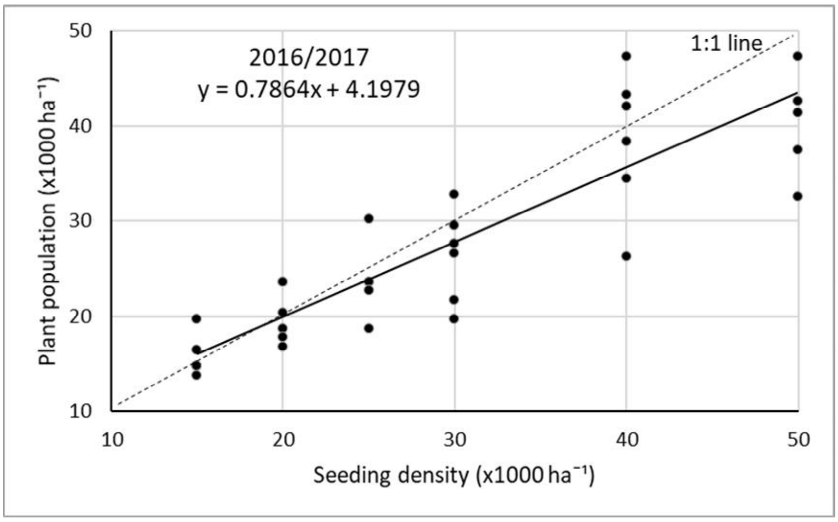
Plate 14: Discussing the maize stand at Klein Constantia on 4 Jan 2018.

4.4 Trials 4 and 5: Interactions of plant row width, population density and cultivar as component to the sustainable cultivation of monoculture maize on sandy soils.

(Trial 4 at Doornbult, Thabo van Zyl; Trial 5 at Vlakvley, Danie Minnaar)

4.4.1 The effect of plant population and row width on the yield of maize *(Trial 4)*

The plant population density as related to the seeding density is shown in Fig. 29. The plant population deviates linearly from the seeding density with increasing seeding rates in both seasons although to a lesser extend in 2017/18 than in 2016/17.



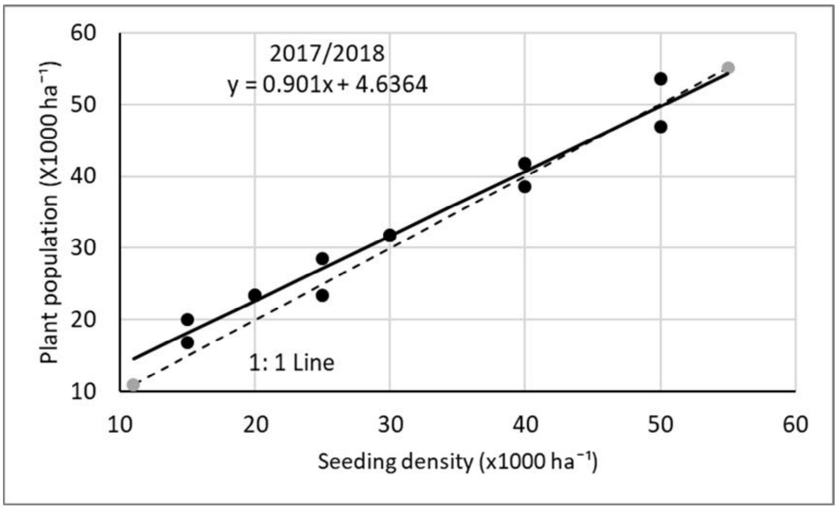


Figure 29: Plant population density as a function of seeding density at Doornbult 2016/17 and 2017/18.

Plant density had no effect on the formation of tillers in 2016/17 (Table 24). Row width however, had a significant effect on tiller formation. Maize plants in 1.524 m rows had 2.5 times the number of tillers than maize plants in the 1.016 m spaced rows. This indicates that intra-row competition between plants had a strong effect on tiller development with higher competition resulting in less tillers.

Table 24: The effect of plant population density and row width on number of tillers ha^{-1} at Doornbult in 2016/17.

Row width	Plant population density (x 1000 ha^{-1})						Mean
(m)	16.0	19.9	23.9	27.8	35.7	43.5	
1.016	20	20	17	25	17	11	18
1.524	12	12	9	5	3	5	8
Mean	16	16	13	15	10	8	

Significance	F-ratio	Probability	LSD
Row width	24.2	<0.01	4.6
Plant density	1.61	0.21	8.1

In 2017/18, tillers developed late in the growing season. As in 2016/17, plant population density again had no effect on the number of tillers that developed (Fig. 30).

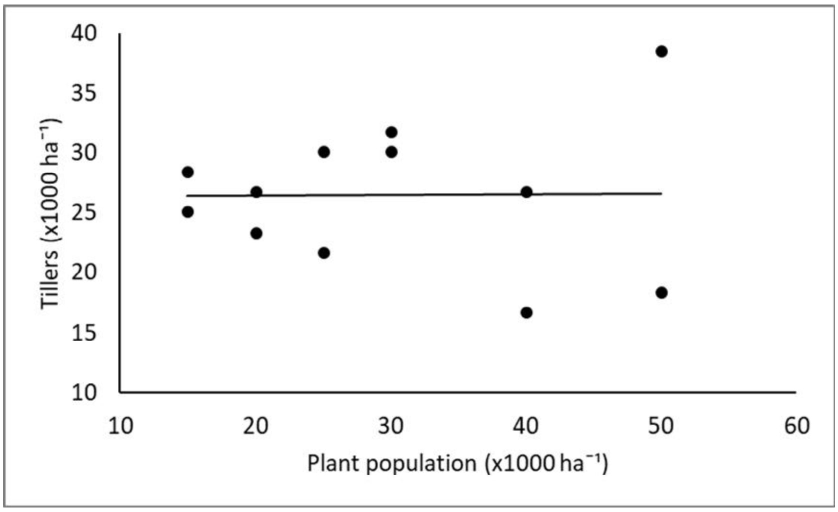


Figure 30: Number of tillers as a function of plant population density in 2017/18 at Doornbult.

Plate 15: Crop residues on the plant density trial on 27 March 2018 at Doornbult.

Grain yield was affected by both plant population density and row width in 2016/17 (Table 25). The mean yield of the 1.016 rows was 1.37 t ha^{-1} higher than the yield of the 1.524 m rows. However, it should be taken into account that the fertilizer application during planting was band placed 1.016 m apart and that the 1.524 m rows received half of its fertilizer next to the plant row and the other half in between the rows. This most likely played a role in the yield difference between rows. The results are also graphically displayed in Fig. 31 with regression curves fitted to the data. The upper curve in the figure represents the 1.016 m and the lower curve the 1.524 m row spacing.

In 2017/18, grain yield was affected by plant population density. A significant yield difference of 2.05 t ha^{-1}, between the two replicates, was also present Table 25. Yield as a function of seeding density for the two replicates are shown in Fig. 32.

Table 25: Maize yield in t ha^{-1} as affected by plant population density and row width 2016/17 and by plant population density in two replicates in 2017/18.

	2016/2017						
Row width	Plant population density (x 1000 ha^{-1})						Mean
(m)	16.0	19.9	23.9	27.8	35.7	43.5	
1.016	6.11	6.84	7.44	7.96	7.88	8.55	7.46
1.524	5.15	5.43	6.40	6.16	6.61	6.77	6.09
Mean	5.63	6.14	6.92	7.06	7.25	7.66	
Significance		F-ratio	Probability		LSD		
Row width		205.7	<0.01		0.20		
Plant density		41.0	<0.01		0.35		
	2017/2018						
Replicate	Plant population density (x 1000 ha^{-1})						Mean
(m)	18.4	23.4	25.9	31.8	40.2	50.2	
1	7.70	8.35	8.62	9.18	9.46	9.74	8.84
2	6.10	6.56	6.89	6.92	6.96	7.05	6.75
Mean	6.90	7.46	7.76	8.05	8.21	8.39	
Significance		F-ratio	Probability		LSD		
Plant density		6.2	<0.01		0.66		
Replicate		135.4	<0.01		0.38		

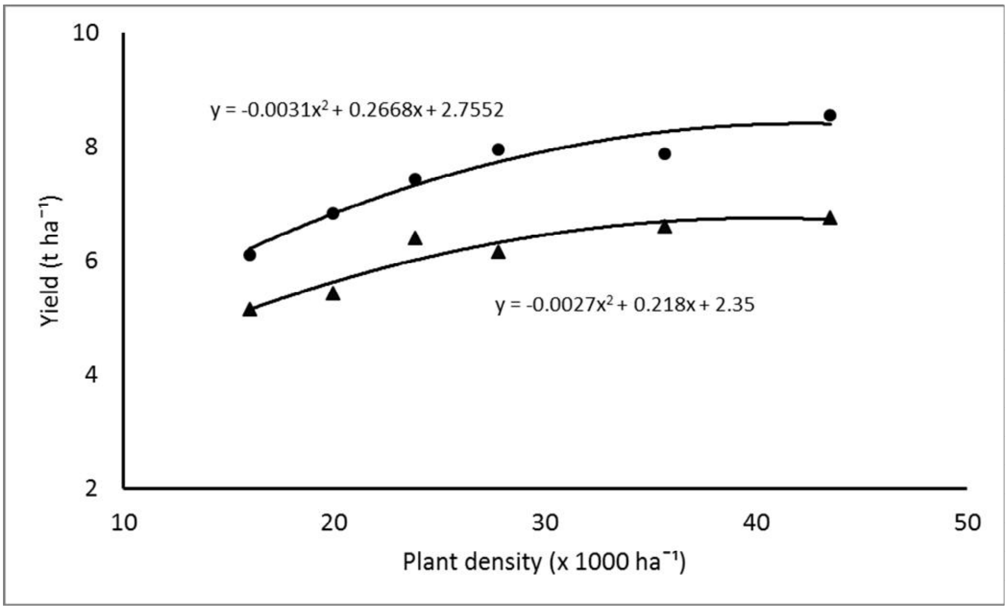


Figure 31: Grain yield as related to plant population density in 2016/17 at Doornbult.

The two relationships are both curvi-linear and thus suitable for calculation of optimum planting densities. Assuming a seed price of R3 260 per 60 000 seeds and a grain price of R1 650 t^{-1}, the optimum plant densities are 37 800 and 34 300 ha^{-1} for the 1.016 and 1.524 row spacings, respectively.

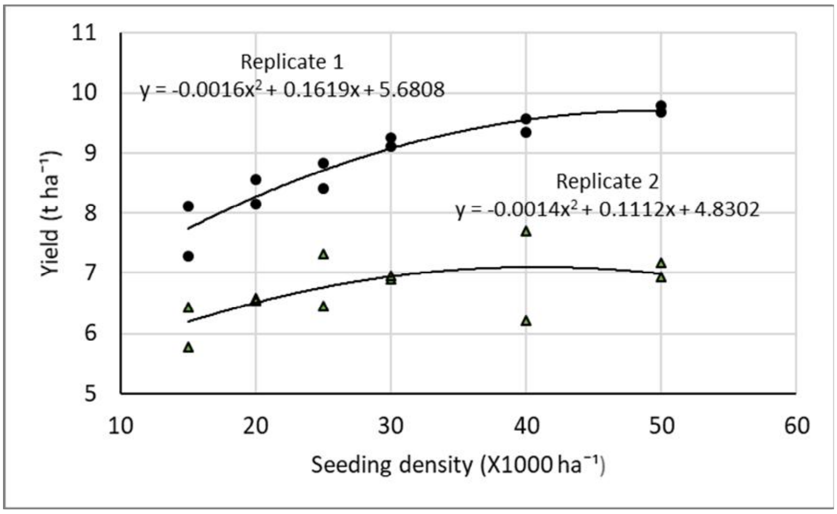


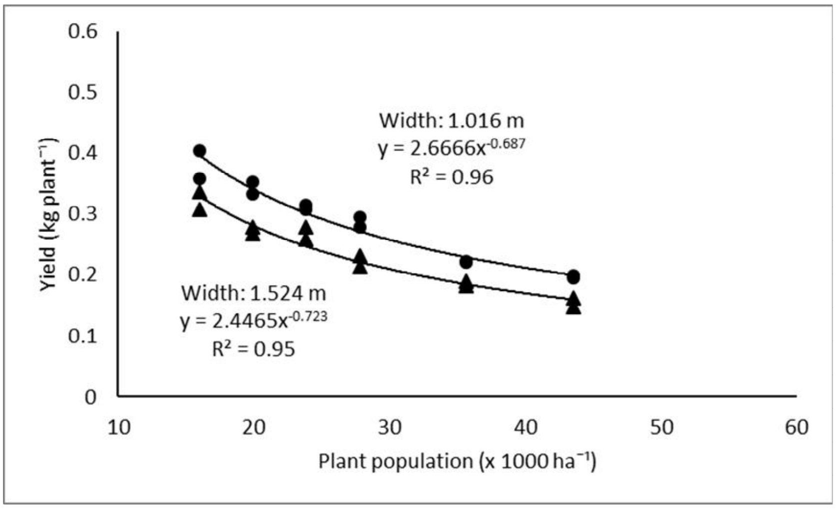
Figure 32: Grain yield as related to plant population density in 2017/18 at Doornbult.

The yield to density relationships found in both seasons are curvilinear and had different maximum yields. These relationships are thus suitable for calculation of optimal seeding density for a series of grain and seed prices. The optimal density is the point of the curve where the last one Rand spend on seed will have return of one Rand in yield. Optimal densities are shown in Table 26. Optimal seeding rates increase with an increase in yield potential, an increase in grain price and a decrease in seed price.

Table 26: Optimal seeding densities derived from the relationships found for a row width of 1.016 m in 2016/17 and 2017/18.

Seed price		Grain price (R t^{-1})			
(R per 80K)	1500	1800	2100	2400	2700
		Yield potential = 7 t ha^{-1}			
1500	35.3	36.0	36.5	36.9	37.2
2500	32.3	33.5	34.4	35.1	35.6
3500	29.3	31.0	32.3	33.2	33.9
4500	26.3	28.6	30.1	31.3	32.3
5500	23.3	26.1	28.0	29.5	30.6
		Yield potential = 8.5 t ha^{-1}			
1500	41.0	41.4	41.6	41.8	41.9
2500	39.7	40.2	40.6	40.9	41.2
3500	38.3	39.1	39.7	40.1	40.4
4500	37.0	38.0	38.7	39.3	39.7
5500	35.6	36.9	37.8	38.4	38.9
		Yield potential = 9.8 t ha^{-1}			
1500	46.7	47.3	47.8	48.2	48.4
2500	44.1	45.2	45.9	46.5	47.0
3500	41.5	43.0	44.1	44.9	45.5
4500	38.9	40.8	42.2	43.3	44.1
5500	36.3	38.7	40.4	41.6	42.6

Mean yield per plant as related to plant population and row width is shown in Fig. 33 for both 2016/17 and 2017/18. As in the case of yield ha^{-1}, two distinct curvilinear relationships were found for the two row widths used in 2016/17 as well as the two yield potentials of the two replicates in 2017/18. It is surprising that these relationships are not linear as expected. Its curvi-linearity indicates that these cultivars display tolerance to stress caused by increasing plant densities and that the efficiency per plant probably increases.



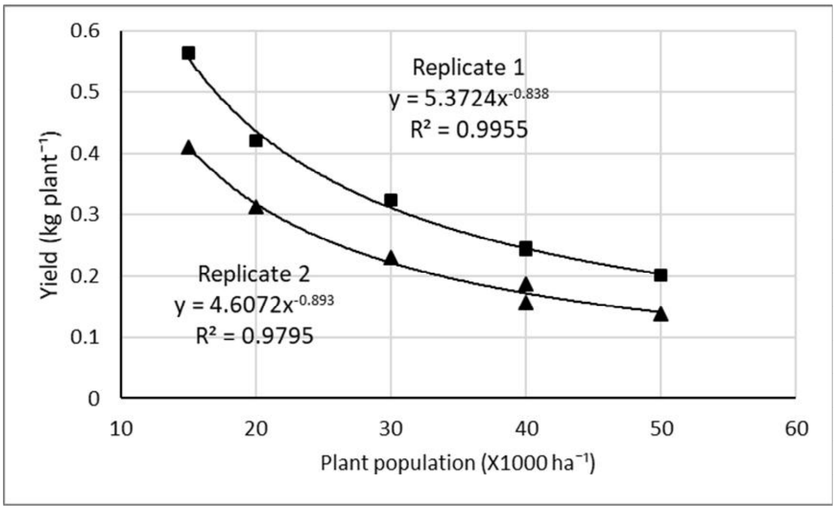


Figure 33: Yield per plant as related to plant population density in 2016/17 at Doornbult.

4.4.2 The effect of plant population on the yield of maize (Trial 5)

As at Doornbult (Trial 4), the plant population density in Trial 5 deviated from the seeding density in a linear way in both 2016/17 (Vlakvley) and 2017/18 (Hamiltonsrus) (Fig. 34). In 2017/18, however, the deviation was much smaller than in 2016/17.

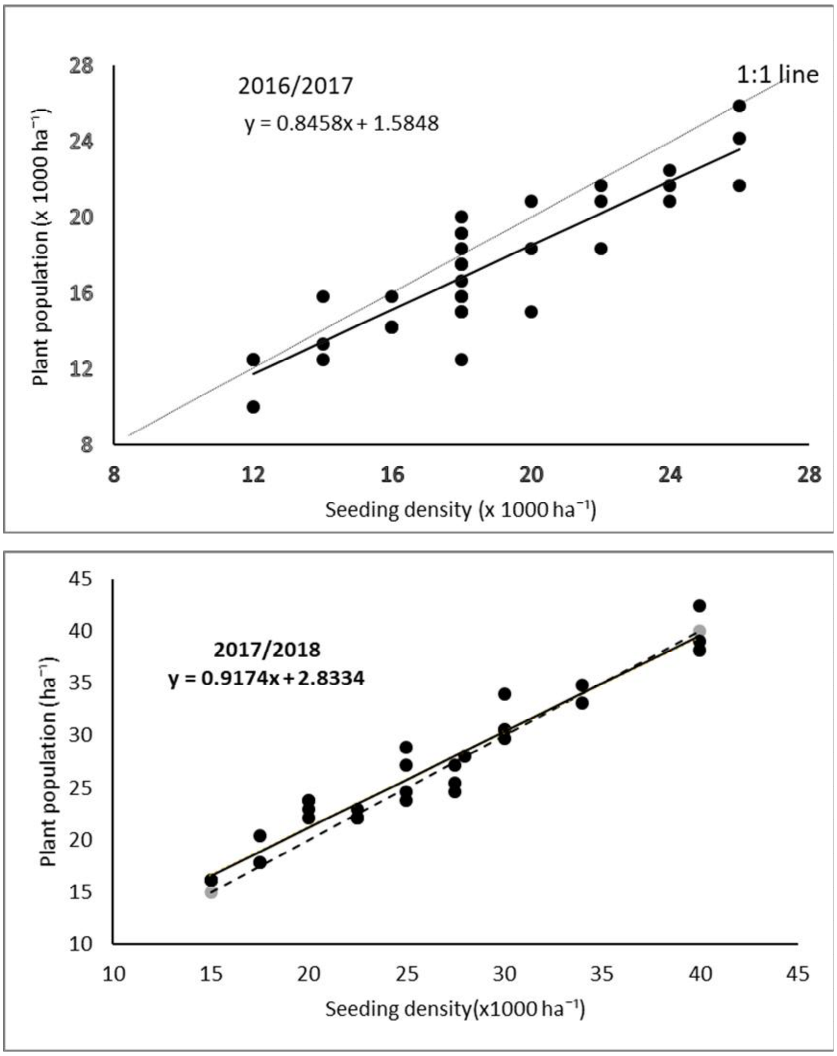


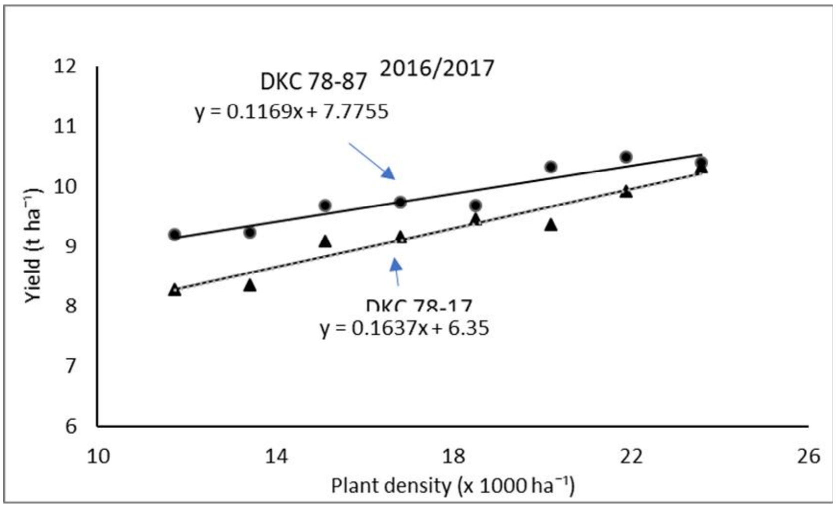
Figure 34: Plant population density as a function of seeding density at Vlakvley (2016/17) and Hamiltonsrus (2017/18).

Plate 16: Viewing the maize stand on the plant density trial at Hamiltonsrus on 24 Jan 2018.

The number of tillers that developed in 2016/17 and in 2017/18 had no significant relationship with plant population density. The number of tillers varied from 18 000 to 49 000 ha^{-1} with an overall mean 33 000 ha^{-1} in 2016/17 and from 25 000 to 54 000 in 2017/18.

The grain yield of each cultivar in 2016/17 showed a distinct relationship with plant population density (Fig. 35). At a density of 12 000 plant ha^{-1} the yield difference between the two cultivars was 0.86 t ha^{-1} while at 23 000 plants ha^{-1}, the difference was only 0.35 t ha^{-1}. As the two relationships are not curvilinear no optimum plant population densities could be derived. It is, however, obvious that the optimum density is higher than 23 000 plants ha^{-1}.

In 2017/2018 a curvilinear relationship between the plant population density and yield was found (Fig. 36). Using this relationship, optimal densities were calculated for a series of possible seed and grain prices and are shown in Table 27 for a yield potential of 8.8 t ha^{-1}. The optimal density increases with a grain price increase and or a seed price decrease.



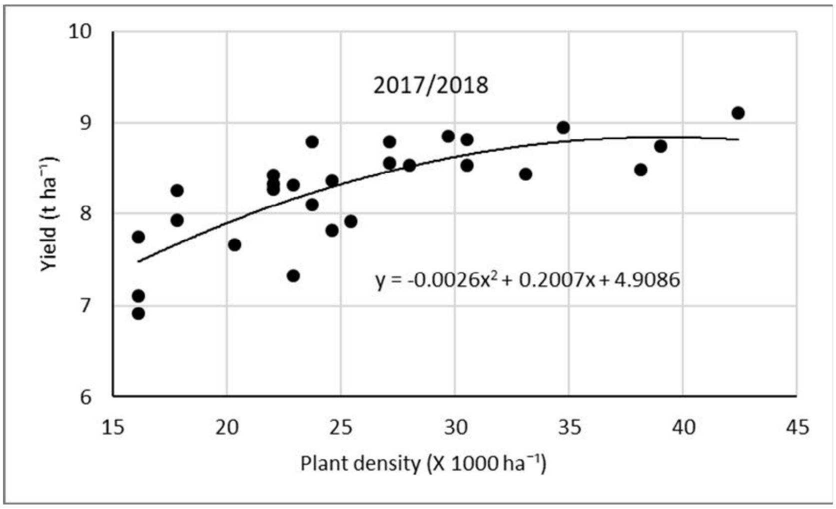


Figure 35: Grain yield of DKC 78-87 and DKC 78-17 as related to plant population density at Vlakvley (2016/17) and of DKC 75-65BR at Hamiltonsrus (2017/18).

Table 27: Optimal seeding densities derived from the relationship found for a row width of 1.5 m at Hamiltonsrus in 2017/18 for a yield potential (maximum yield) of 8.8 t ha^{-1}

Seed price (R per 80K)	Grain price (R t^{-1}) 1500	1800	2100	2400	2700
	Yield potential = 8.8 t ha^{-1}				
1500	34.4	35.0	35.4	35.7	35.9
2500	32.3	33.2	33.8	34.3	34.7
3500	30.2	31.4	32.3	33.0	33.5
4500	28.0	29.6	30.8	31.6	32.3
5500	25.9	27.9	29.3	30.3	31.1

Combined results for the two cultivars (DKC 78-87 and DKC 78-17), in terms of tiller and main stem yields, show a linear but negative relationship (Fig. 36) in 2016/17. The yield of tillers is thus not independent from the yield of the main stem. Tiller yield declined as the yield of the main stem increased.

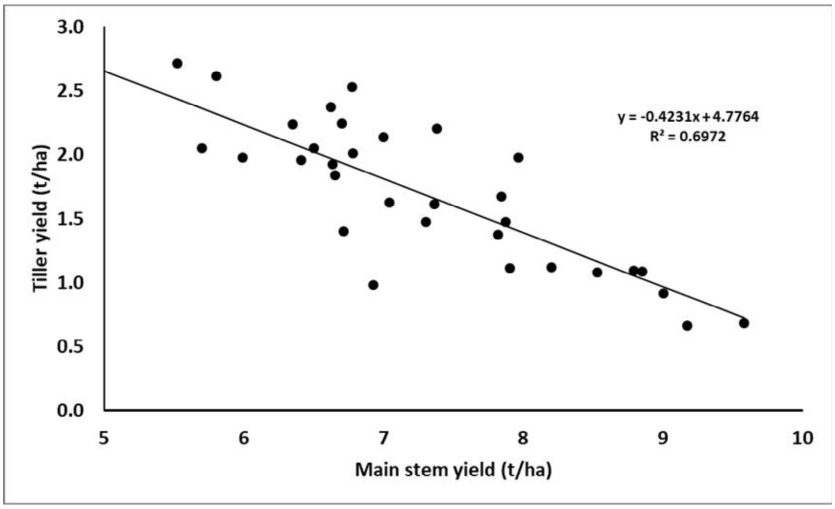


Figure 36: Tiller yield as related to main stem yield at Vlakvley in 2016/17.

Grain yield per plant, in both seasons, had a curvilinear relation to plant population density (Fig. 37). These relationships indicate tolerance to stress caused by increasing plant densities and is similar to what was found at Doornbult (Trial 4). The plants most likely get more efficient at higher densities, possibly, due to a change of the grain to biomass ratio. This should however, be confirmed.

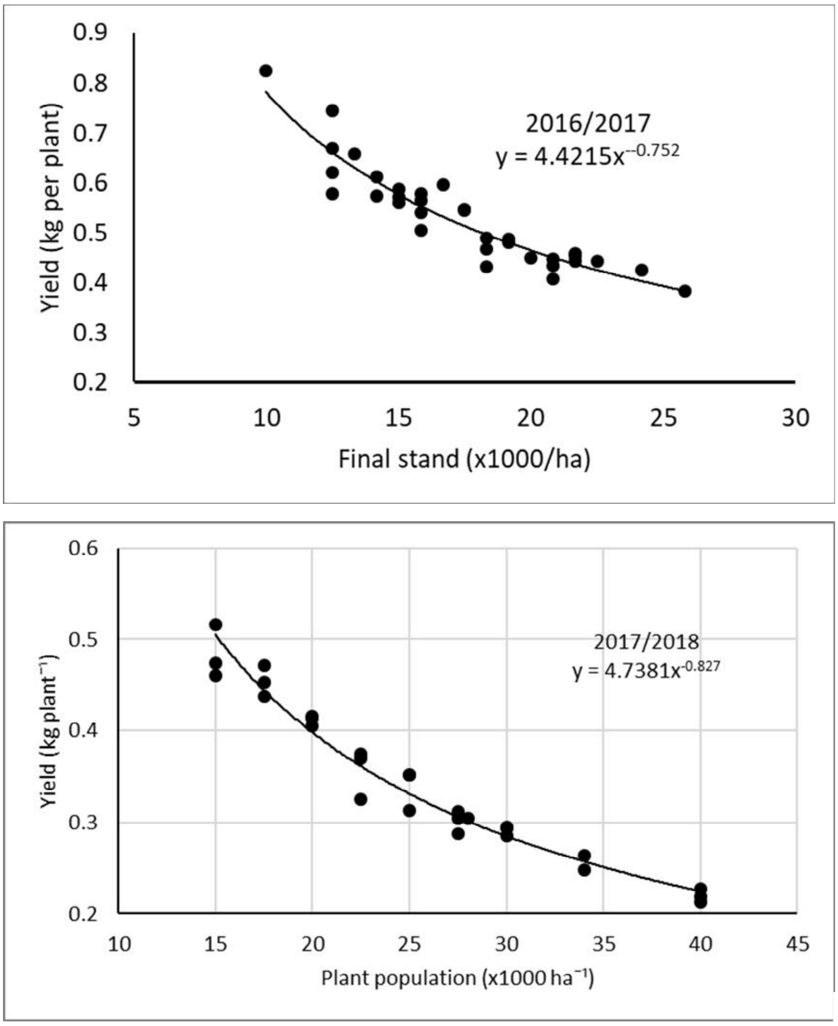


Figure 37: Yield per plant as related to plant population density at Vlakvley (2016/17) and at Hamiltonsrus (2017/18).

4.5 Trial 6: The optimum depth of ripping for the sustainable cultivation of monoculture maize on sandy soils.

(Doornbult-Thabo van Zyl)

Diesel consumption increased curvi-linearly with increasing ripping depths (Fig. 38) in 2016/17. Increasing the ripping depth from 45 to 60 cm, increased diesel consumption by 2.13 L ha^{-1}, while increasing the ripping depth from 75 to 90 cm, led to an increased consumption of 7.26 L ha^{-1}.

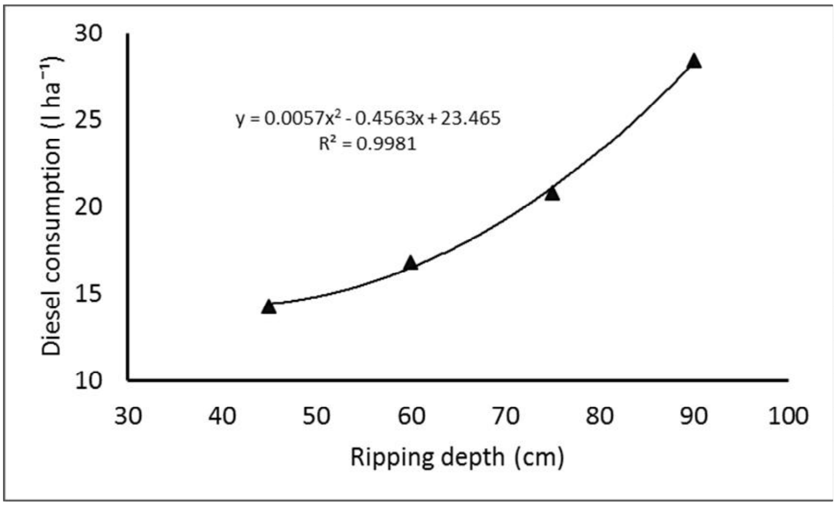


Figure 38: Diesel consumption as related to ripping depth at Doornbult (2016/17).

Ripping depth had no significant effect on plant height ($p = 0.24$). The height varied from 0.9 to 1.79 m with an overall mean of 1.425.

Ripping depth had a highly significant effect on grain yield in 2016/2017 (Table 28). The results are also graphically displayed in Fig. 39. In contrast, ripping depth had no effect on grain yield in 2017/2018 (Table 28), most likely due to adequate rain during the grain filling period as indicated by the high grain yields.

Table 28: Maize yield in t ha^{-1} as affected by ripping depth at Doornbult in 2016/17 and 2017/18.

Season	Ripping depth (cm)				F-ratio	Probability	LSD
	45	60	75	90			(t ha^{-1})
2016/2017	4.27	5.66	6.87	7.00	160	<0.01	1.00
2017/2018	8.27	8.19	8.48	8.64	2.3	ns	1.4

In 2016/17, grain yield increased linearly with ripping depths from 45 to 75 cm at a rate of 0.87 t ha^{-1} per 100 mm increase in depth. Increasing the depth from 75 to 90 cm resulted in no significant increase in yield. Accordingly, there is no advantage to rip deeper than 75 cm.

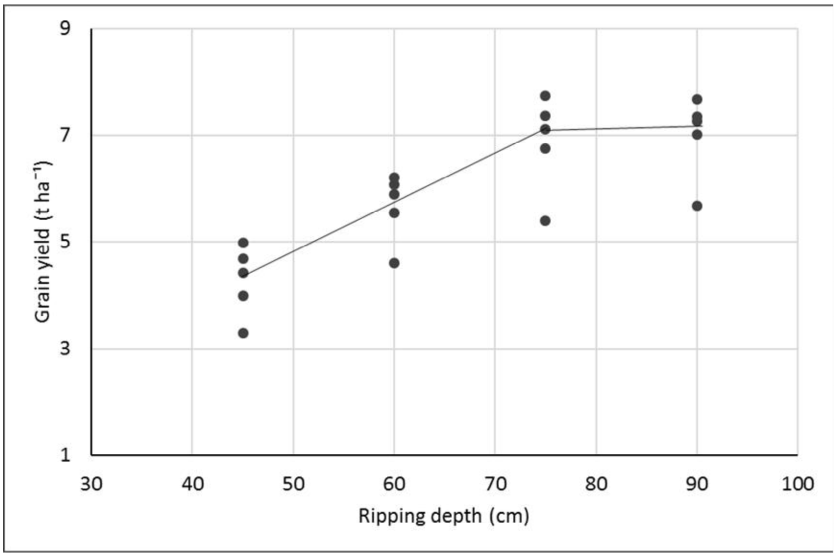


Figure 39: Grain yield as related to ripping depth at Doornbult (2016/17).

Plate 17: Maize stand on 90 cm ripping depth at Doornbult on 27 March 2018.

4.6 Trial 7: Effects of N fertilizer application on soybean growth and yield.

(Thabo van Zyl, Ancona).

An exceptionally high mean soybean yield of 4.19 t ha^{-1} was recorded. Nitrogen fertilization at any rate had no effect on the yield as can be seen in Fig. 40. Accordingly, the application of N had, in this case, no financial benefit.

Soybean contains about 65 kg N t $grain^{-1}$. About 272 kg of N ha^{-1} was, accordingly, removed from the land. The added N had no effect on the yield as the residual N plus the N fixed by *Rhizobium* bacteria satisfied the demand of the crop.

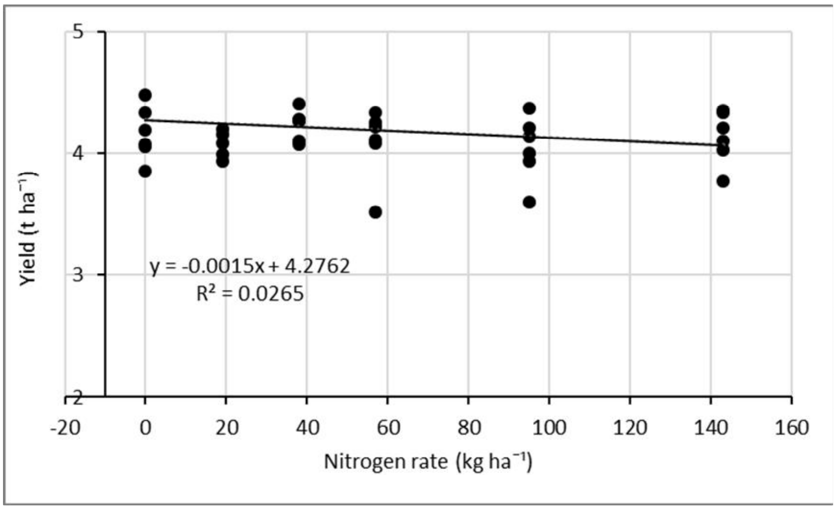


Figure 40: Yield response of soybean to nitrogen fertilization at Ancona (2017/18).

Plate 18: Discussing the exceptional soybean stand at Ancona on 27 March 2018.

4.7 Enterprise financial analyses

In the analyses, a farm gate price of R1 800 t^{-1} for maize was used for all farmer co-workers in order to eliminate the advantage of own marketing. The same price for diesel price at R13 L^{-1} was used for all farmer co-workers.

4.7.1 Trial 1: Regenerative CA crop-livestock integrated system with rotations of maize/summer/winter diverse ley crops

(Deelpan, Danie Crous)

Mono culture maize yielded only 10kg ha^{-1} more than maize following summer cover crops. However, the margin for the latter was R63 ha^{-1} higher. The margin under maize following winter cover crops was R576 ha^{-1} lower than under maize following summer cover crops. The poorer margin could be due to lower plant available because of water uptake by the winter cover crops (Appendix 1).

4.7.2 Trial 2: Reduced tillage, stubble-mulch, cash crop rotations with maize/soybean/ forage sorghum

(Thabo van Zyl, Christinasrus)

Maize (additional 40 kg N ha^{-1}) after fallow realized the highest yield of 5.57 t ha^{-1}, as well as the best margin of R2 395 ha^{-1}. The second best yield and margin was obtained under maize after fallow with a yield of 5.21 t ha^{-1} and a difference in margin of R453, compared to the best margin. Soybean following maize or fallow realized in both cases negative margins. In the case of forage sorghum, biomass should be determined in order to calculate a monetary value (Appendix 2).

4.7.3 Maize/soybean rotation system at Klein Constantia (Trial 3)

(Klein Constantia, Lourens van der Linde)

In the case of mono culture maize, the highest yields were realized under ROR in 2017/18-season. Compared to No-Till, the mean yield was 935 kg grain ha^{-1} higher under ROR tillage, realizing a higher margin of R1 460 ha^{-1}. It should be mentioned that the best margins were achieved in 2016/17 under No-Till, while the best margin in 2017/18 was achieved under ROR tillage (Appendix 3).

For maize following soybean, the highest yields were realized under ROR tillage in 2017/18. Maize grain yield under ROR was 1 806 kg ha^{-1} higher than under No-Till, realizing a mean margin difference of R2 807 ha^{-1}. It should be mentioned that the best margin of R10 593 ha^{-1} was achieved under ROR tillage in 2017/18, following No-Till in 2016/17. The second best margin was R664 ha^{-1} lower than the best margin (Appendix 3).

4.7.4 The effect of plant population on the yield of maize (Trial 4)

(Doornbult, Thabo van Zyl)

Replication 1: The 50 000 plants ha^{-1} stand gave the highest grain yield that was 283 kg ha^{-1} higher than the 40 000 plants ha^{-1}, the latter giving the best margin of R8 391 ha^{-1}. The second best margin of R8 386 is achieved by 30 000 plants ha^{-1}. The reason for the similar margins for the mentioned three population densities can be ascribed to the low commodity price for maize (Appendix 4).

Replication 2: The 25 000 plants ha^{-1} stand gave the highest margin of R4 743 ha^{-1}, with the second best margin of R4 532 ha^{-1} realized by a 30 000 plants ha^{-1} stand (Appendix 4).

Replications 1 and 2 combined: The 50 000 plants ha^{-1} stand gave 341 kg ha^{-1} more grain than the 30 000 plants ha^{-1} stand. The best margin was realized by a 30 000 plant ha^{-1} stand at R6 459 ha^{-1} Comparable second best margins were achieved by stands of 25 000 and 40 000 plants ha^{-1} at margins of R6 224 and R6 228 ha^{-1}, respectively. The reason for the similar margins can again be ascribed to the low commodity price for maize (Appendix 4).

4.7.5 The effect of plant population on the yield of maize (Trial 5)

(Hamiltonsrus, Danie Minnaar)

Planting date 14 Dec 2017: A population density of 30 000 plants ha^{-1} realized a higher margin at R9 230 ha-1 than 40 000 plants ha^{-1} at R8 721. The latter population density gave the same grain yield but at a higher seed cost of R515 ha^{-1} the recommended population will be 30 000 plants ha^{-1}. The 20 000 and 34 000 plant ha^{-1} populations gave similar margins at R8 869 and R8 874, respectively. The population density of 25 000 plants ha^{-1} realized the second highest margin at R9 006 ha^{-1}
(Appendix 5).

Planting date 28 Dec 2017: A population density of 20 000 plants ha^{-1} realized a higher margin at R8 031 ha^{-1} than 30 000 plants ha^{-1} at R7 607. The latter population density gave a slightly higher yield, but at a higher seed cost of R515 ha^{-1} it does not make sense to increase the population to 30 000 plants ha^{-1}. A population density of 20 000 plants ha^{-1} gave a higher margin difference at R424 ha^{-1} compared to 30 000 plants ha^{-1}(Appendix 5).

4.7.6 The optimum depth of ripping for the sustainable cultivation of monoculture maize on sandy soils (Trial 6)

(Doornbult, Thabo van Zyl)

The best margin was realized with a 90 cm deep ripping at R 7 355 ha^{-1}, compared to a margin of R7 231 ha^{-1} for a 75 cm ripping depth. In this comparison the additional capital cost to rip deeper was not taken into account, thereby probably eliminating the advantage of a 90 cm ripping depth. On the basis of the achieved margins, the recommendation would be not to rip shallower than 75 cm (Appendix 6).

4.8 Soil water content measurements with capacitance probes

Reporting by Petrus van Staden, Senwes

4.8.1 The effect of plant population on the yield of maize (Trial 4)

(Doornbult – Thabo van Zyl)

The DFM probe data are expressed as gravimetrical SWC. The changes in SWC are presented in Figures 41 to 44. In general, the figures indicate two rain events that changed SWC in all six layers measured.

The original probe in the R1P1 treatment was damaged by a porcupine and there was no replacement available. By the time it was repaired and installed again, it missed the rain event of 15 March. Therefore, the R2P1 data presented in Figure 41 is for the 15 000 plants ha^{-1} treatment. Figure 42 presents SWC data for the 50 000 plants ha^{-1} treatment.

Figure 42 shows that the rain event on 10 February caused a 5% increase in SWC of five layers. These layers indicate water extraction until the next big rain event at 15 March. The latter event caused an increase in SWC of the 100-120 cm layer. Comparing Figs 41 and 42, it can be concluded that the 50 000 plants ha^{-1} treatment (Fig 42) extracted more water.

Changes in SWC on a 25 000 plants ha^{-1} plot are shown in Fig 43.

Figure 44 presents SWC data for another 25 000 plants ha^{-1} plot. Comparing Figs 43 and 44, it appears that less water was extracted from the 60-120 cm layer from the end of March until the end on the 25 000 plants ha^{-1} plot depicted in Fig 44. During the same period, the decrease in SWC in the 20-60 cm layer was higher in the 25 000 plants ha^{-1} plot (Fig 44) than in the 25 000 plants ha^{-1} plot in Fig 43.

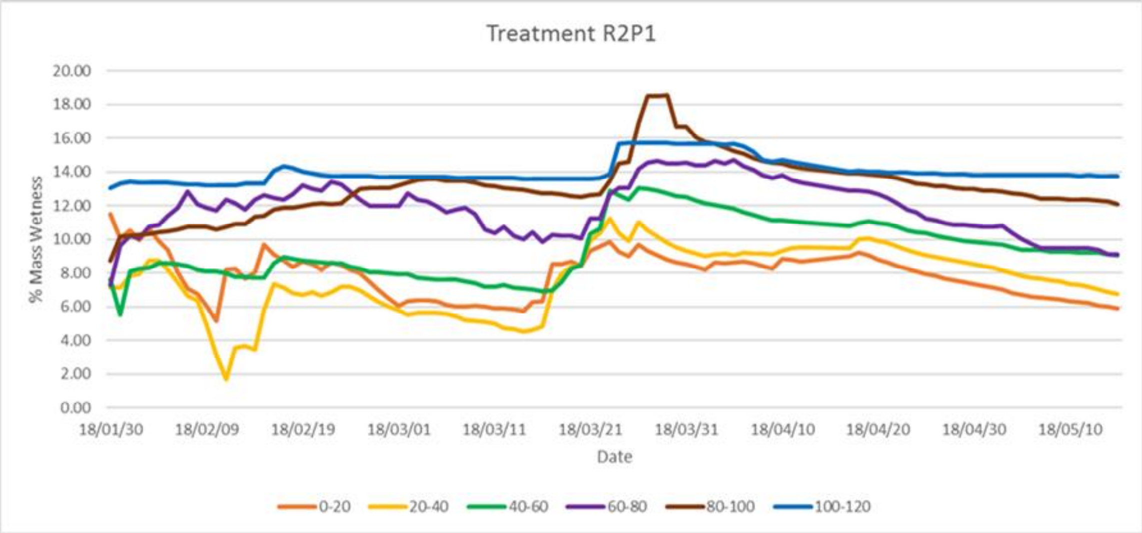


Figure 41: Change in SWC on a 15 000 plants ha^{-1} plot.

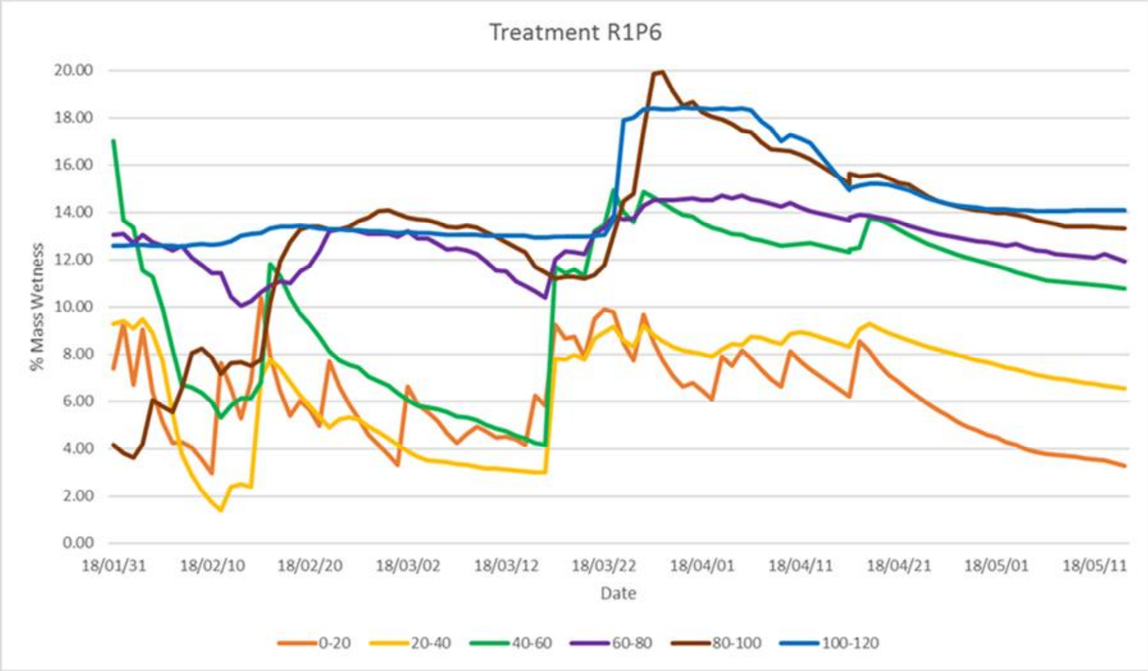


Figure 42: Changes in SWC on a 50 000 plants ha^{-1} (R1P6) plot.

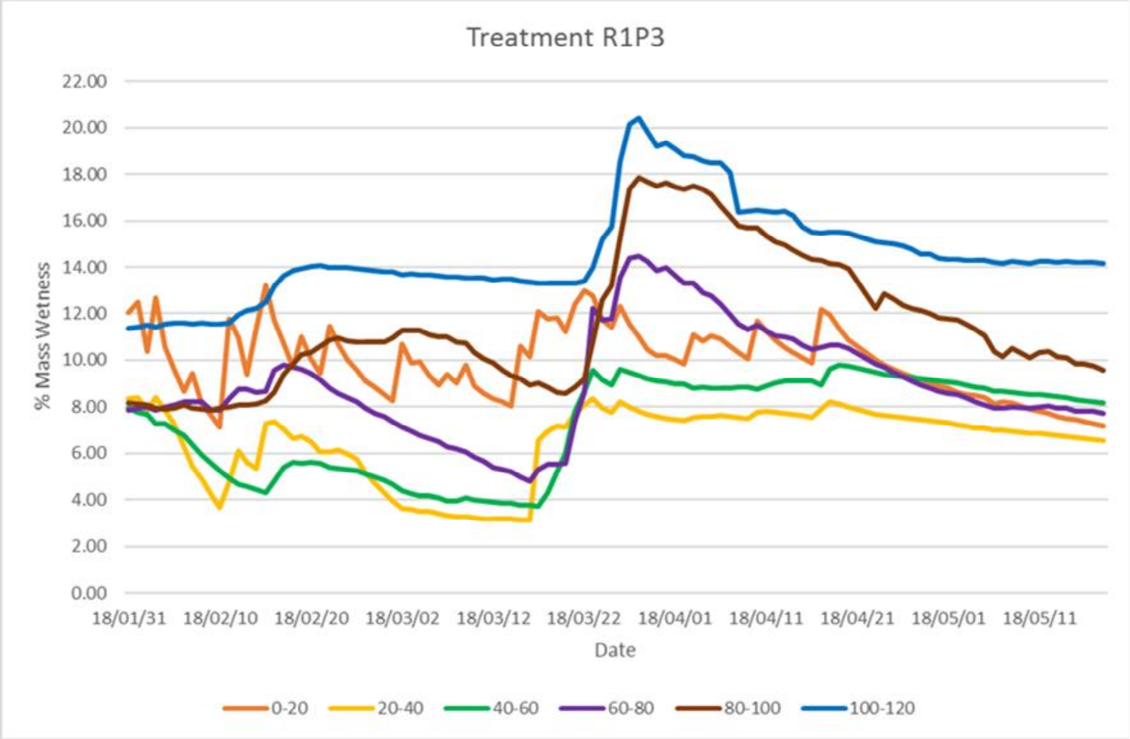


Figure 43: Changes in SWC in a 25 000 plants ha^{-1} plot.

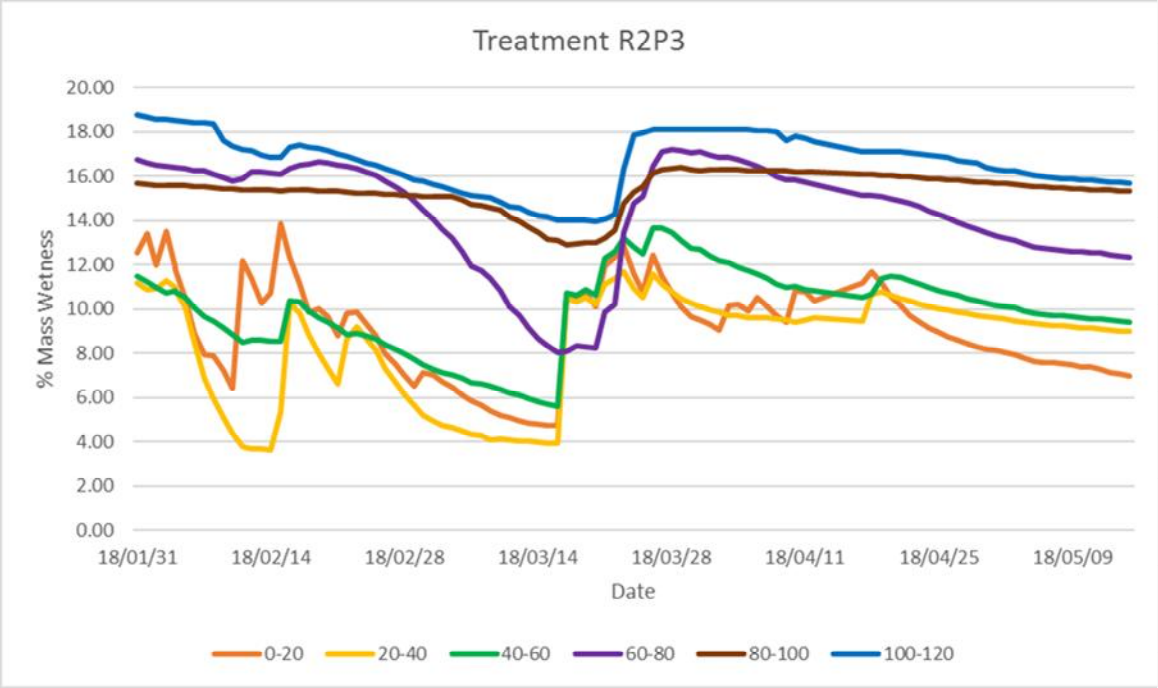


Figure 44: Changes in SWC in a 25 000 plants ha^{-1} plot.

4.8.1.1 Conclusions on the effects of plant population density on SWC

- Plant population determines the effective use of water in the soil profile.
- The 2017-18 data showed more water extraction throughout the whole profile compared to the 2016-17 data.

4.8.2 *The optimum depth of ripping for the sustainable cultivation of monoculture maize on sandy soils (Trial 6)*

(Doornbult – Thabo van Zyl)

The changes in SWC as a function of two ripping depths, *viz* 45 and 90 cm, are presented in Figures 45 and 46.

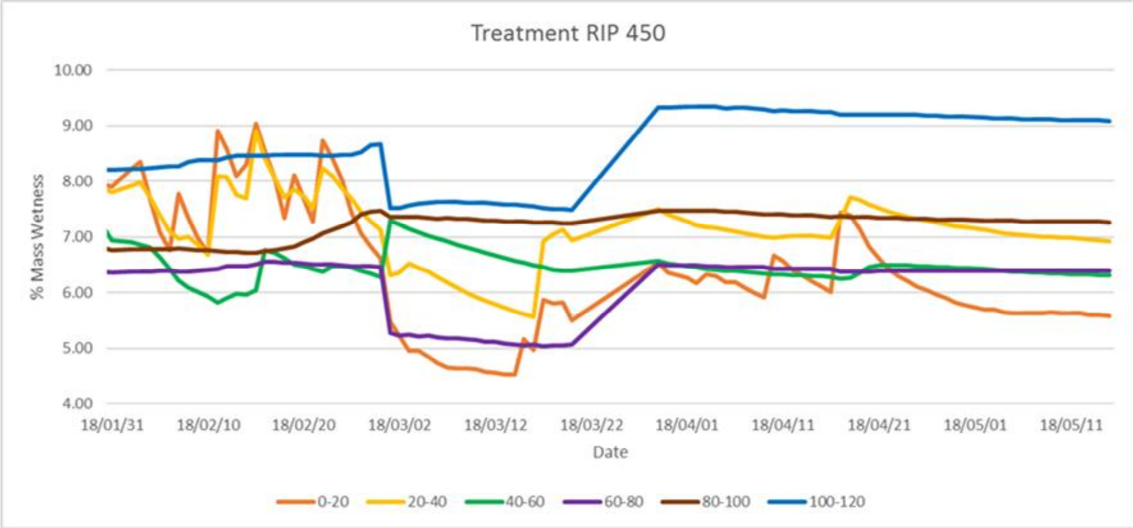


Figure 45: Changes in SWC in a 45 cm ripping depth plot.

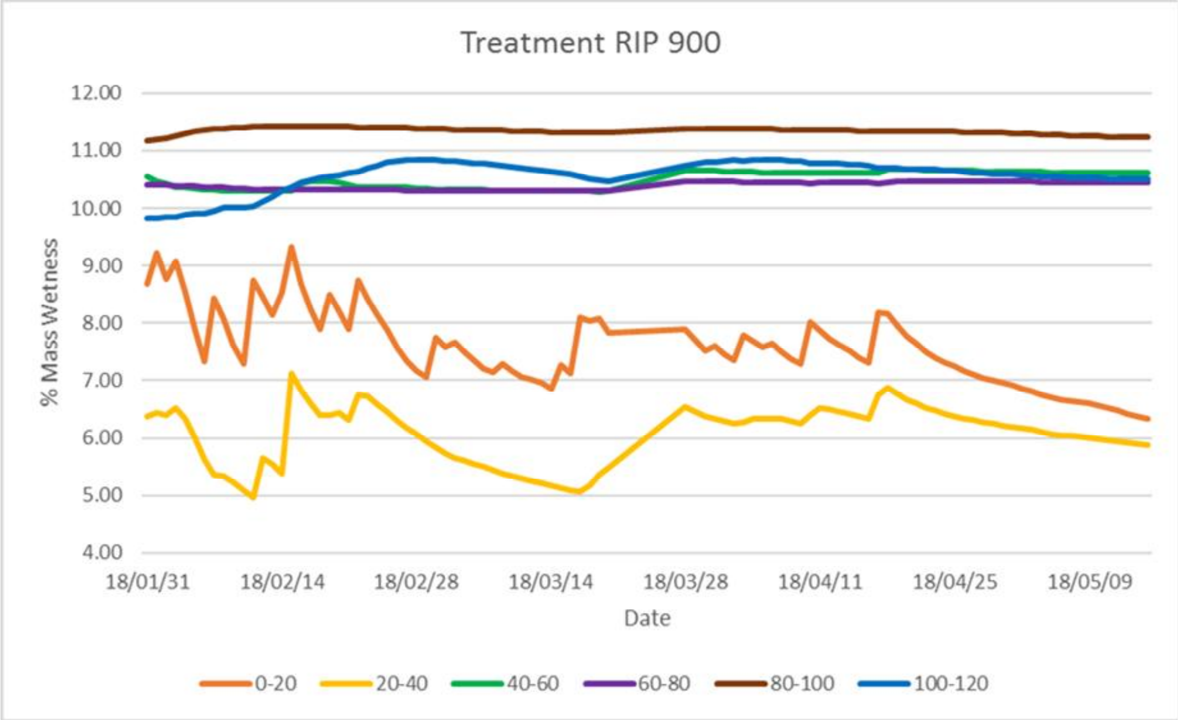


Figure 46: Changes in SWC in a 90 cm ripping depth plot.

4.8.2.1 Conclusions on the effects of ripping depth on SWC

- Comparing the figures, it is clear that the depth of ripping had an effect on the total water regime in the soil profile.
- The depth of ripping did not show a similar response on water infiltration or extraction compared to the 2016/17 season.

4.8.3 Recommendations

- The project was successful and needs to be repeated as per project plan in order to confirm the results to date.
- During installation of the probes in 2016/17 and 2017/18 seasons, it was observed that the soil was very unstable in the 40 to 80 cm layer. This is probably due to ripping. This phenomenon needs to be investigated as it appears to have negative effects on the regression between probe reading and gravimetrical SWC. The graphs of the data also reveal some discrepancies.

5 ANY PROBLEMS THAT HAVE BEEN ENCOUNTERED WITH THE PROJECT

5.1 Cover crop trial at Deelpan

Although noted problems can be regarded as minor, they can have serious effects on these sandy soils, such as compaction and therefore should to be mentioned:

- A small seed planter was not available and planting was done using a fertilizer spreader, which is basically impossible to calibrate. This meant that the seeding rate was almost double for the small area.
- The availability of a no-till maize planter remains a problem and at this stage seems unattainable.

5.2 Measuring SWC with capacitance probes

Capacitance probe installations on the population density and ripping depth trials on Doornbult experienced damage to instruments that impacted negatively on data availability (Plate19). Other problems that were encountered were the quality of batteries and motherboards supplied by the service provider.

Plate 19: Damage by porcupines (left) and malicious damage to transmitter (right).

6 MILESTONES THAT HAVE NOT BEEN ACHIEVED AND REASONS FOR THAT

For the cover crop trial at Deelpan, some treatments were changed due to the unavailability of a no-till planter.

7 AN ASSESSMENT OF THE ADEQUACY OF FUNDING TO COMPLETE THE EXECUTION OF THE PROJECT

See the appended copies of bank statements for the periods 1 Oct 2017 to 22 March 2018 and 1 June to 10 Sept 2018, respectively. The balance on 2018-09-10 was R1 120 785.92. An approximate balance by 31 Oct 2018 will be R1 120 786- R51 741 - R302 841 - R140 000 = R626 204.

It should be noted that several claims (in total about R495 000.00) total are still outstanding. In the case of the project team members from the ARC this state of affairs is due to bureaucracy and impractical financial procedures of the ARC. For example:

- Mr G Trytsman from ARC-Irene could only invoice expenses of R4 059.19, while his approved budgeted amount for materials, travel, accommodation and professional time amounts to R55 800.00, leaving R51 741 still due to Mr Trytsman.
- Project team members from ARC-GC (Drr S Steenkamp, AM Abrahams, Mr OHJ Rhode) have been unable to submit any invoices for their approved budgeted amount of R302 841.

Outstanding claims due to administrative and logistical reasons for Drr DJ Beukes and AA Nel amount to about R140 000.00.

An attempt will be made in October to submit all outstanding claims.

8 THE ESTIMATED DURATION OF THE PROJECT UNTIL COMPLETION

Five (5) years. The current report contains project results on the second experimental year, namely the 2017/18-growing season. The evaluation of regenerative and locally adapted CA systems, with the emphasis on promoting CA principles and soil health to contribute to sustainable maize production systems on semi-arid sandy soils with water tables, need to be investigated over a number of years for various reasons. To name three:

- The beneficial effects of CA on certain soil properties, like soil microbiology and soil organic C, will only be manifested after three to five years, but might take longer on these semi-arid sandy soils.
- Soil compaction is a recurring phenomenon, even under deep ripping (e.g. ROR). The search must go on comparing mechanical or biological tillage practices that economically alleviates soil compaction over the long term.
- The effects of CA and soil health on nematode infestation and the occurrence of crown and root rot will only be manifested after about five years.

A report back and planning meeting, attended by a number of role players, on the 2017/18-season, was held on 11 September 2018 (Appendix 10: Programme). The reporting back on the results and activities of previous provided valuable guide lines and suggestions for the planning of the 2018/19-season. It was decided to submit an application for financial assistance for the continuation of the present project in 2018/19. This submission will be made to the Maize Trust on 30 September 2018.

9 MANNER IN WHICH RESULTS WILL BE PUBLISHED

9.1 Farmers Day at Springboklaagte

A Farmers Day was held on 22 February 2018 on the farm, Springboklaagte, of Danie Minnaar to view and discuss field trials on planting density, root development as function of tillage in crop rotation trials and on subsurface irrigation (See Appendix 11: Programme). The farmer co-workers reported back on progress of their field trials in terms of sustainable crop production on sandy soils, prompting lively interaction and discussion by the delegates. An Information Session by Region 22 of Grain SA was also included in the programme. The Day was attended by 78 farmers, input supply personnel, persons from organized agriculture and research personnel. The Day was concluded with a pleasant lunch.

Plate 20: Viewing population density trial.

Plate 21: Viewing root development as function of tillage.

9.2 Printed media and farmers days

It is foreseen that project results will be made available through articles in agricultural periodicals (e.g. Landbouweekblad, Farmers Weekly), publication in SA Grain Journal, oral presentations at farmers days and farmer study groups.

Articles on the Farmers Day of 22 Feb 2018 appeared in the Landbouweekblad of 23 March 2018 (Appendix 12) and in the April edition of the SA Grain journal (Appendix 13).

The present project follows and builds on a completed project funded by the Maize Trust. In the latter project a base was laid for the present project by testing the effects of tillage and crop rotation on soil chemical, physical and biological properties to contribute to sustainable maize production on the sandy soils with water tables in the north western Free State. Four articles from the previous project were published in the August 2017 and October 2017 editions of the SA Grain journal.

10 REFERENCES

Allison LE, 1965. Organic Carbon. In*:* CA Black (ed). *Methods of Soil Analysis. Part 2. Chemical and Microbiological Methods. Agronomy Series No.9*, Madison, Wisconsin, USA. pp 1367-1378.

Bongers T. 1990. The maturity index: an ecological measure of environmental disturbance based on nematode species composition. *Oecologia* 83:14-19.

Bongers T. 1995. Proposed changes of c-p classification for nematodes. *Russian Journal of Nematology* 3(1):61-62.

Botha ADP.1963. Die invloed van gras (*Eragrostis curvula*) op die ammonium- en nitraatstikstof in 'n swart kleigrond. *S Afr Tydskr Landbouwet* 6: 3-20.

Caveness FE, Jensen HE. 1955. Modification of the centrifugal-flotation technique for the isolation and concentration of nematodes and their eggs in soil. *Proceedings of the Helminthological Society of Washington* 22:87-89.

Cobb NA. 1918. Estimating the mean population of the soil. *Agric. Tech. Circ. Bur. Pl. Ind. US. Dep. Agric. No1*. 48pp.

De Waele E, De Waele D, Wilken R. 1987. Effect of root mass on the efficacy of methods for extracting root-lesion nematodes from maize roots. *Phytophylactica* 19:473-474.

Ferris H. 2010. Form and function: Metabolic footprints of nematodes in the soil food web. *European Journal of Soil Biology* 46(2):14-19.

FSSA. 2007. Fertilizer Handbook. The Fertilizer Society of South Africa. Sixth revised edition. Pretoria, South Africa. 298pp.

Genstat for Windows. 2009. 12th Edition. VSN International, Hemel Hempstead, UK.

Gomez KA, Gomez AA. 1984. Regression and correlation analysis. In: Gomez KA Gomez AA (eds). *Statistical Procedures for Agricultural Research*. Second Edition, John Wiley & Sons, New York, USA. pp 357-423.

Hanks RJ, Ashcroft GL. 1980. Soil Heat Flow and Temperature. In: Hanks RJ, Ashcroft (eds). *Applied Soil Physics*. Springer-Verlag, New York, USA. pp125-144.

Henning JAG. 1991. Die invloed van variërende vrywatervlakke in grond van die noordwestelike OVS op verbouing van gewasse (veral mielies). PhD Proefskrif, Potchefstroomse Universiteit vir Christelike Hoër Onderwys, Potchefstroom. 125pp.

Riekert HF. 1995. An adapted method for extraction of root-knot nematode eggs from maize root samples. *African Plant Protection* 1:41-43.

Subbarao GV, Rondon M, Osamu I, Berry WL. 2007. Biological nitrification inhibition (BNI) – Is it a widespread phenomenon? *Plant and Soil* 294 (1): 5-18.

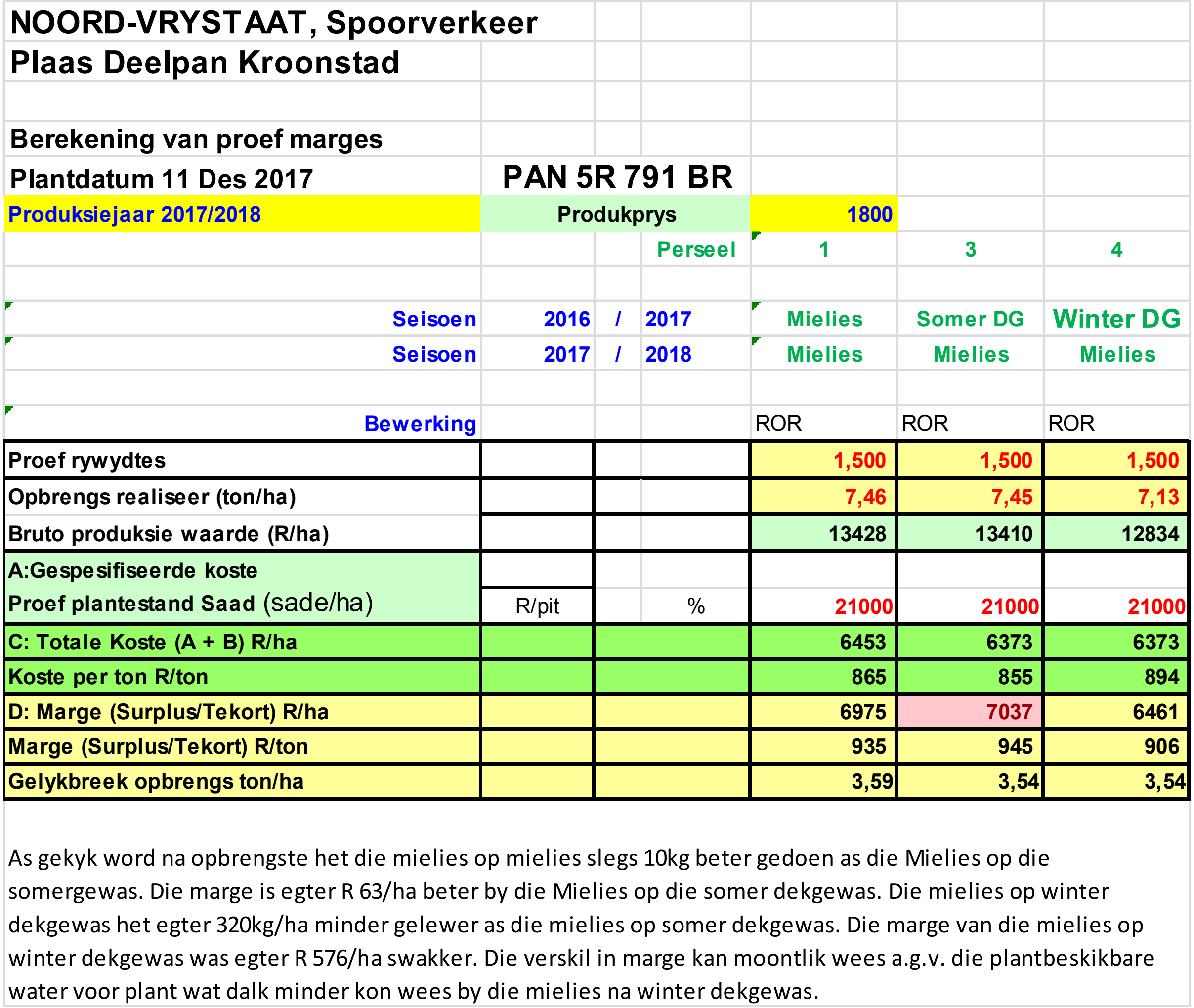
Tabatabai, MA. 1982. Soil enzymes In: A.L. Page, R.H. Miller & D.R. Keeney (eds.) *Methods of soil analysis, part 2 Chemical and Microbiological Properties* 2nd ed., Madison, Wisconsin USA.

Tabatabai, MA. 1994. Soil enzymes. In: Weaver RW, Angle JS, Bottomley PS (eds) *Methods of soil analysis, part 2. Microbiological and biochemical properties.* SSSA Book Series No. 5. Soil Sci. Soc. Am. Madison, Wis., pp. 775-833.

Theron JJ. 1951. The influence of plants on the mineralization of nitrogen and the maintenance of organic matter in the soil. *J Agric Sci* 41: 289-296.

11 APPENDICES

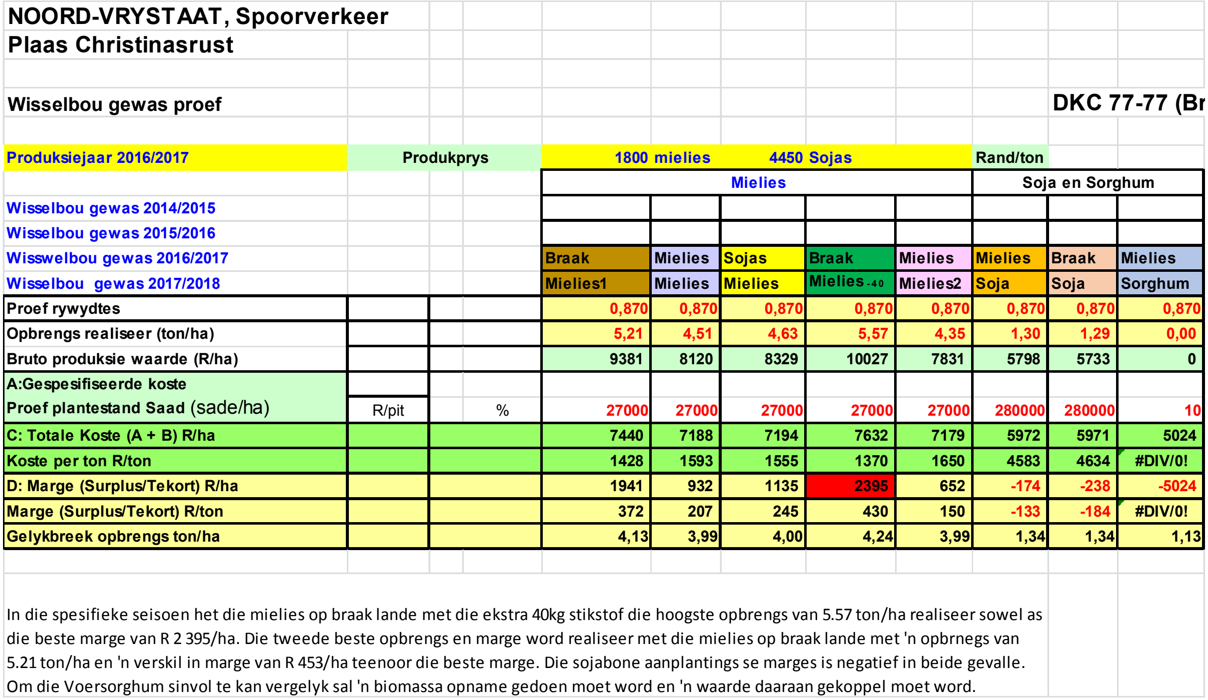
Appendix 1: Economic analysis: Trial 1: Regenerative CA crop-livestock integrated system with rotations of maize/summer/winter diverse ley crops (Deelpan)



NOORD-VRYSTAAT, Spoorverkeer						
Plaas Deelpan Kroonstad						
Berekening van proef marges						
Plantdatum 11 Des 2017	**PAN 5R 791 BR**					
Produksiejaar 2017/2018	**Produkprys**			**1800**		
			Perseel	**1**	**3**	**4**
Seisoen	**2016**	**/**	**2017**	**Mielies**	**Somer DG**	**Winter DG**
Seisoen	**2017**	**/**	**2018**	**Mielies**	**Mielies**	**Mielies**
Bewerking				ROR	ROR	ROR
Proef rywydtes				**1,500**	**1,500**	**1,500**
Opbrengs realiseer (ton/ha)				**7,46**	**7,45**	**7,13**
Bruto produksie waarde (R/ha)				**13428**	**13410**	**12834**
A:Gespesifiseerde koste **Proef plantestand Saad** (sade/ha)	R/pit		%	**21000**	**21000**	**21000**
C: Totale Koste (A + B) R/ha				**6453**	**6373**	**6373**
Koste per ton R/ton				**865**	**855**	**894**
D: Marge (Surplus/Tekort) R/ha				**6975**	**7037**	**6461**
Marge (Surplus/Tekort) R/ton				**935**	**945**	**906**
Gelykbreek opbrengs ton/ha				**3,59**	**3,54**	**3,54**

As gekyk word na opbrengste het die mielies op mielies slegs 10kg beter gedoen as die Mielies op die somergewas. Die marge is egter R 63/ha beter by die Mielies op die somer dekgewas. Die mielies op winter dekgewas het egter 320kg/ha minder gelewer as die mielies op somer dekgewas. Die marge van die mielies op winter dekgewas was egter R 576/ha swakker. Die verskil in marge kan moontlik wees a.g.v. die plantbeskikbare water voor plant wat dalk minder kon wees by die mielies na winter dekgewas.

Appendix 2: Economic analysis: Trial 2: Reduced tillage, stubble-mulch, cash crop rotations with maize/soybean/ forage sorghum (Christinasrus)



NOORD-VRYSTAAT, Spoorverkeer

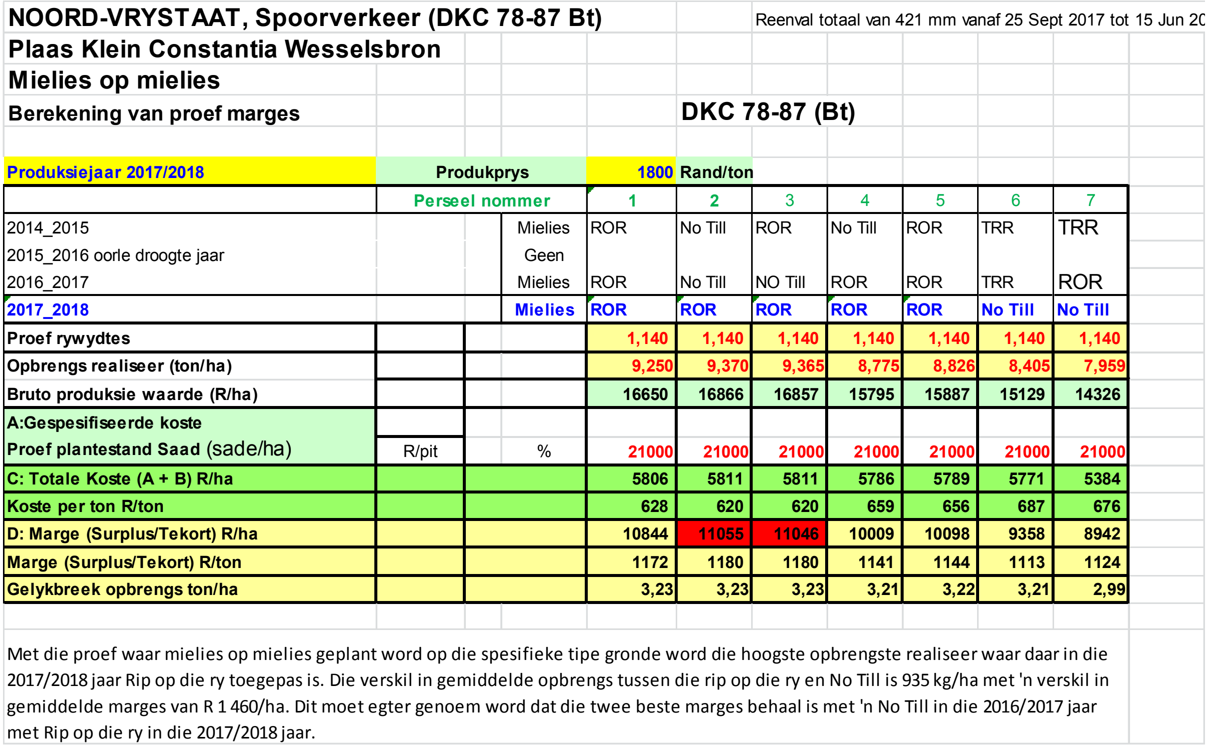
Plaas Christinasrust

Wisselbou gewas proef **DKC 77-77 (Br**

Produksiejaar 2016/2017	**Produkprys**		**1800 mielies**			**4450 Sojas**		**Rand/ton**		
			Mielies					**Soja en Sorghum**		
Wisselbou gewas 2014/2015										
Wisselbou gewas 2015/2016										
Wisswelbou gewas 2016/2017			Braak	Mielies	Sojas	Braak	Mielies	Mielies	Braak	Mielies
Wisselbou gewas 2017/2018			Mielies1	Mielies	Mielies	Mielies -40	Mielies2	Soja	Soja	Sorghum
Proef rywydtes			0,870	0,870	0,870	0,870	0,870	0,870	0,870	0,870
Opbrengs realiseer (ton/ha)			5,21	4,51	4,63	5,57	4,35	1,30	1,29	0,00
Bruto produksie waarde (R/ha)			9381	8120	8329	10027	7831	5798	5733	0
A:Gespesifiseerde koste **Proef plantestand Saad** (sade/ha)	R/pit	%	27000	27000	27000	27000	27000	280000	280000	10
C: Totale Koste (A + B) R/ha			7440	7188	7194	7632	7179	5972	5971	5024
Koste per ton R/ton			1428	1593	1555	1370	1650	4583	4634	#DIV/0!
D: Marge (Surplus/Tekort) R/ha			1941	932	1135	2395	652	-174	-238	-5024
Marge (Surplus/Tekort) R/ton			372	207	245	430	150	-133	-184	#DIV/0!
Gelykbreek opbrengs ton/ha			4,13	3,99	4,00	4,24	3,99	1,34	1,34	1,13

In die spesifieke seisoen het die mielies op braak lande met die ekstra 40kg stikstof die hoogste opbrengs van 5.57 ton/ha realiseer sowel as die beste marge van R 2 395/ha. Die tweede beste opbrengs en marge word realiseer met die mielies op braak lande met 'n opbrnegs van 5.21 ton/ha en 'n verskil in marge van R 453/ha teenoor die beste marge. Die sojabone aanplantings se marges is negatief in beide gevalle. Om die Voersorghum sinvol te kan vergelyk sal 'n biomassa opname gedoen moet word en 'n waarde daaraan gekoppel moet word.

Appendix 3: Economic analysis: Trial 3: Comparison of reduced vs. no tillage under mono culture maize (Klein Constantia)



NOORD-VRYSTAAT, Spoorverkeer (DKC 78-87 Bt) Reenval totaal van 421 mm vanaf 25 Sept 2017 tot 15 Jun 20

Plaas Klein Constantia Wesselsbron

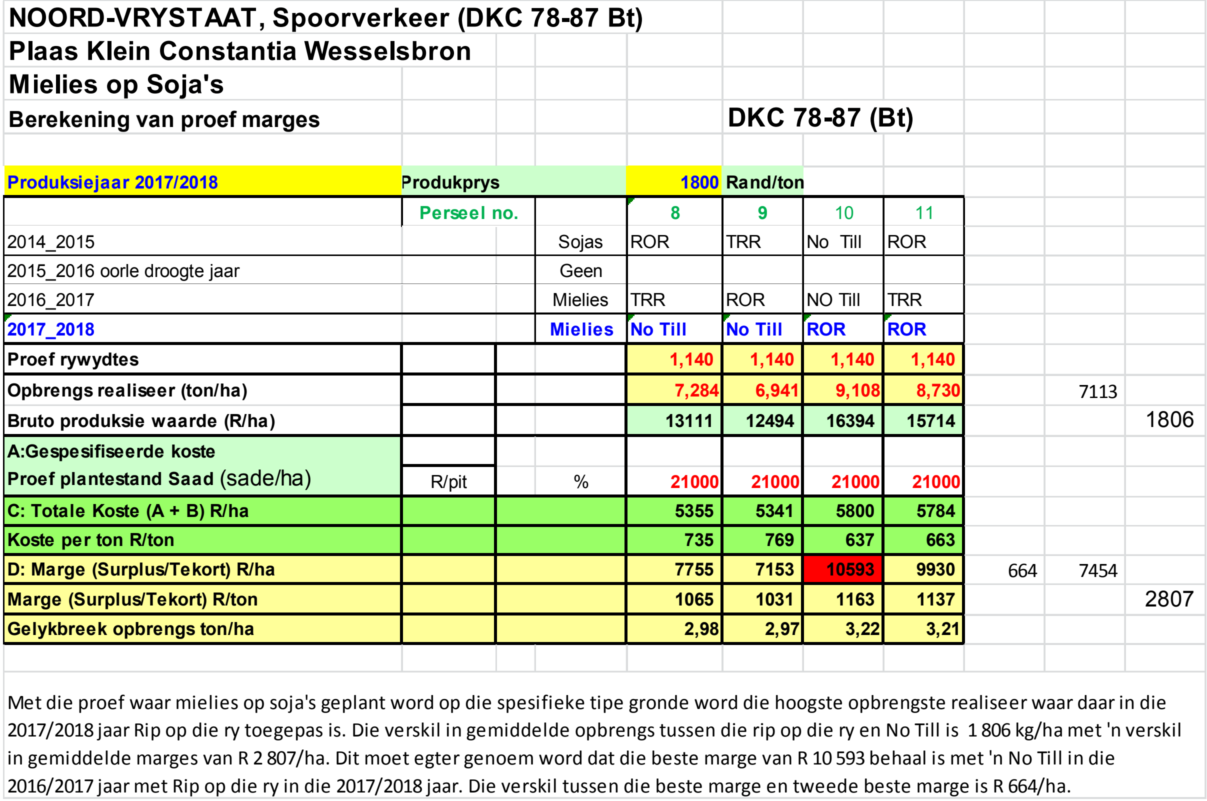
Mielies op mielies

Berekening van proef marges **DKC 78-87 (Bt)**

Produksiejaar 2017/2018 **Produkprys** **1800 Rand/ton**

	Perseel nommer		1	2	3	4	5	6	7
2014_2015		Mielies	ROR	No Till	ROR	No Till	ROR	TRR	TRR
2015_2016 oorle droogte jaar		Geen							
2016_2017		Mielies	ROR	No Till	NO Till	ROR	ROR	TRR	ROR
2017_2018		**Mielies**	**ROR**	**ROR**	**ROR**	**ROR**	**ROR**	**No Till**	**No Till**
Proef rywydtes			1,140	1,140	1,140	1,140	1,140	1,140	1,140
Opbrengs realiseer (ton/ha)			9,250	9,370	9,365	8,775	8,826	8,405	7,959
Bruto produksie waarde (R/ha)			16650	16866	16857	15795	15887	15129	14326
A:Gespesifiseerde koste									
Proef plantestand Saad (sade/ha)	R/pit	%	21000	21000	21000	21000	21000	21000	21000
C: Totale Koste (A + B) R/ha			5806	5811	5811	5786	5789	5771	5384
Koste per ton R/ton			628	620	620	659	656	687	676
D: Marge (Surplus/Tekort) R/ha			10844	11055	11046	10009	10098	9358	8942
Marge (Surplus/Tekort) R/ton			1172	1180	1180	1141	1144	1113	1124
Gelykbreek opbrengs ton/ha			3,23	3,23	3,23	3,21	3,22	3,21	2,99

Met die proef waar mielies op mielies geplant word op die spesifieke tipe gronde word die hoogste opbrengste realiseer waar daar in die 2017/2018 jaar Rip op die ry toegepas is. Die verskil in gemiddelde opbrengs tussen die rip op die ry en No Till is 935 kg/ha met 'n verskil in gemiddelde marges van R 1 460/ha. Dit moet egter genoem word dat die twee beste marges behaal is met 'n No Till in die 2016/2017 jaar met Rip op die ry in die 2017/2018 jaar.



NOORD-VRYSTAAT, Spoorverkeer (DKC 78-87 Bt)

Plaas Klein Constantia Wesselsbron

Mielies op Soja's

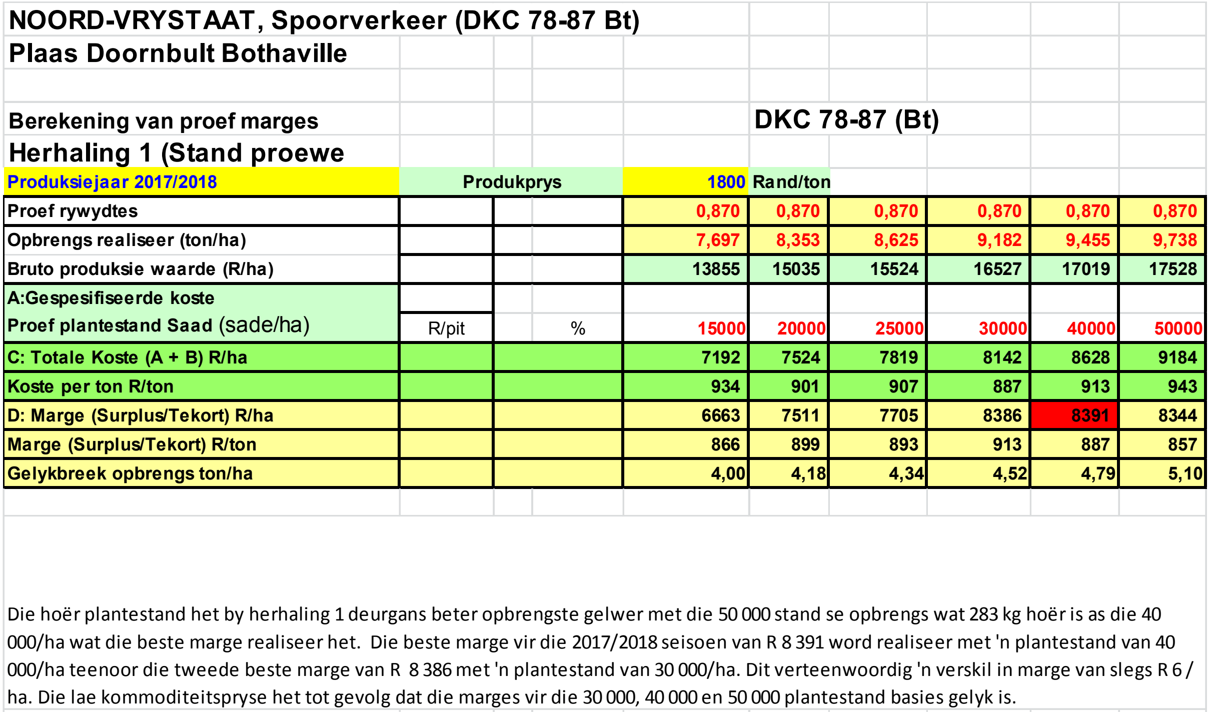
Berekening van proef marges **DKC 78-87 (Bt)**

Produksiejaar 2017/2018 **Produkprys** **1800 Rand/ton**

	Perseel no.		8	9	10	11			
2014_2015		Sojas	ROR	TRR	No Till	ROR			
2015_2016 oorle droogte jaar		Geen							
2016_2017		Mielies	TRR	ROR	NO Till	TRR			
2017_2018		**Mielies**	**No Till**	**No Till**	**ROR**	**ROR**			
Proef rywydtes			1,140	1,140	1,140	1,140			
Opbrengs realiseer (ton/ha)			7,284	6,941	9,108	8,730		7113	
Bruto produksie waarde (R/ha)			13111	12494	16394	15714			1806
A:Gespesifiseerde koste									
Proef plantestand Saad (sade/ha)	R/pit	%	21000	21000	21000	21000			
C: Totale Koste (A + B) R/ha			5355	5341	5800	5784			
Koste per ton R/ton			735	769	637	663			
D: Marge (Surplus/Tekort) R/ha			7755	7153	10593	9930	664	7454	
Marge (Surplus/Tekort) R/ton			1065	1031	1163	1137			2807
Gelykbreek opbrengs ton/ha			2,98	2,97	3,22	3,21			

Met die proef waar mielies op soja's geplant word op die spesifieke tipe gronde word die hoogste opbrengste realiseer waar daar in die 2017/2018 jaar Rip op die ry toegepas is. Die verskil in gemiddelde opbrengs tussen die rip op die ry en No Till is 1 806 kg/ha met 'n verskil in gemiddelde marges van R 2 807/ha. Dit moet egter genoem word dat die beste marge van R 10 593 behaal is met 'n No Till in die 2016/2017 jaar met Rip op die ry in die 2017/2018 jaar. Die verskil tussen die beste marge en tweede beste marge is R 664/ha.

Appendix 4: Economic analysis: Trial 4: The effect of plant population and row width on the yield of maize (Doornbult)

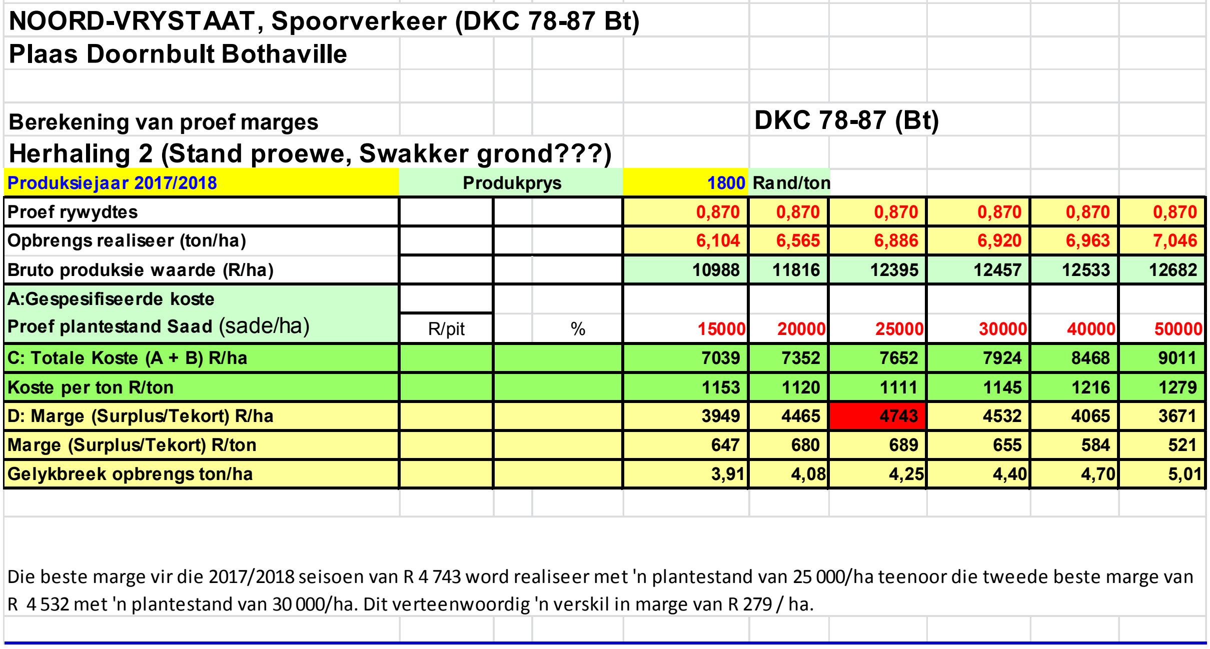


NOORD-VRYSTAAT, Spoorverkeer (DKC 78-87 Bt)
Plaas Doornbult Bothaville

Berekening van proef marges **DKC 78-87 (Bt)**
Herhaling 1 (Stand proewe

Produksiejaar 2017/2018	**Produkprys**		**1800**	**Rand/ton**				
Proef rywydtes			0,870	0,870	0,870	0,870	0,870	0,870
Opbrengs realiseer (ton/ha)			7,697	8,353	8,625	9,182	9,455	9,738
Bruto produksie waarde (R/ha)			13855	15035	15524	16527	17019	17528
A:Gespesifiseerde koste **Proef plantestand Saad** (sade/ha)	R/pit	%	15000	20000	25000	30000	40000	50000
C: Totale Koste (A + B) R/ha			7192	7524	7819	8142	8628	9184
Koste per ton R/ton			934	901	907	887	913	943
D: Marge (Surplus/Tekort) R/ha			6663	7511	7705	8386	8391	8344
Marge (Surplus/Tekort) R/ton			866	899	893	913	887	857
Gelykbreek opbrengs ton/ha			4,00	4,18	4,34	4,52	4,79	5,10

Die hoër plantestand het by herhaling 1 deurgans beter opbrengste gelwer met die 50 000 stand se opbrengs wat 283 kg hoër is as die 40 000/ha wat die beste marge realiseer het. Die beste marge vir die 2017/2018 seisoen van R 8 391 word realiseer met 'n plantestand van 40 000/ha teenoor die tweede beste marge van R 8 386 met 'n plantestand van 30 000/ha. Dit verteenwoordig 'n verskil in marge van slegs R 6 / ha. Die lae kommoditeitspryse het tot gevolg dat die marges vir die 30 000, 40 000 en 50 000 plantestand basies gelyk is.

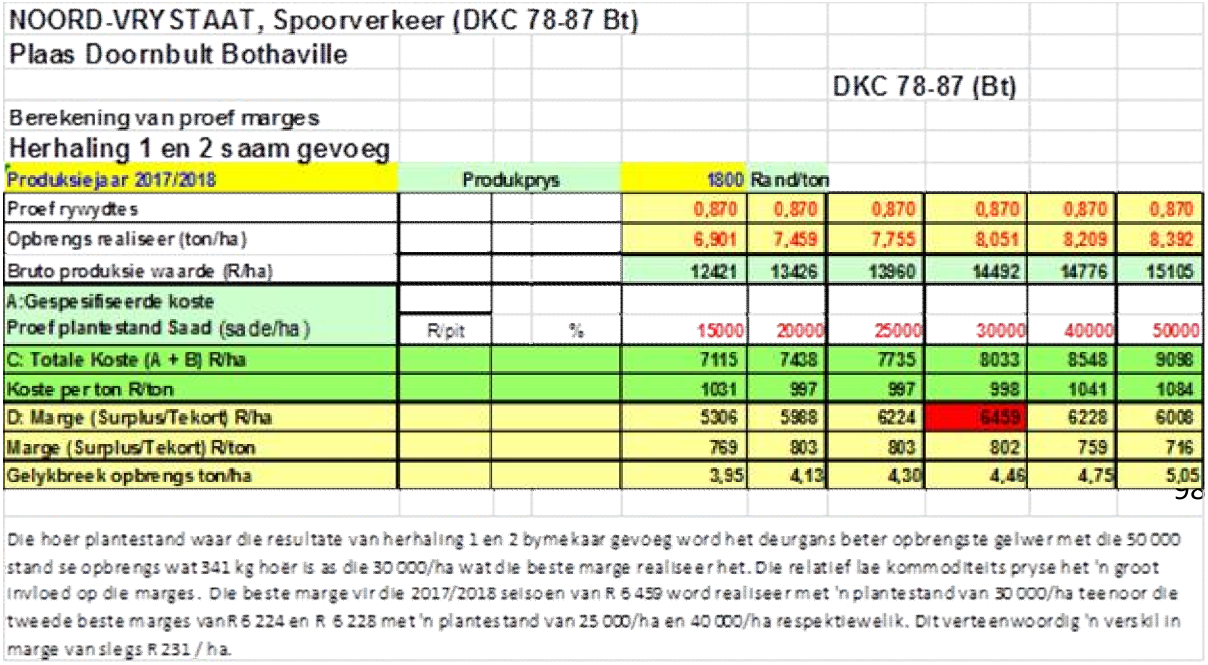


NOORD-VRYSTAAT, Spoorverkeer (DKC 78-87 Bt)
Plaas Doornbult Bothaville

Berekening van proef marges **DKC 78-87 (Bt)**
Herhaling 2 (Stand proewe, Swakker grond???)

Produksiejaar 2017/2018	**Produkprys**		**1800**	**Rand/ton**				
Proef rywydtes			0,870	0,870	0,870	0,870	0,870	0,870
Opbrengs realiseer (ton/ha)			6,104	6,565	6,886	6,920	6,963	7,046
Bruto produksie waarde (R/ha)			10988	11816	12395	12457	12533	12682
A:Gespesifiseerde koste **Proef plantestand Saad** (sade/ha)	R/pit	%	15000	20000	25000	30000	40000	50000
C: Totale Koste (A + B) R/ha			7039	7352	7652	7924	8468	9011
Koste per ton R/ton			1153	1120	1111	1145	1216	1279
D: Marge (Surplus/Tekort) R/ha			3949	4465	4743	4532	4065	3671
Marge (Surplus/Tekort) R/ton			647	680	689	655	584	521
Gelykbreek opbrengs ton/ha			3,91	4,08	4,25	4,40	4,70	5,01

Die beste marge vir die 2017/2018 seisoen van R 4 743 word realiseer met 'n plantestand van 25 000/ha teenoor die tweede beste marge van R 4 532 met 'n plantestand van 30 000/ha. Dit verteenwoordig 'n verskil in marge van R 279 / ha.



NOORD-VRYSTAAT, Spoorverkeer (DKC 78-87 Bt)
Plaas Doornbult Bothaville

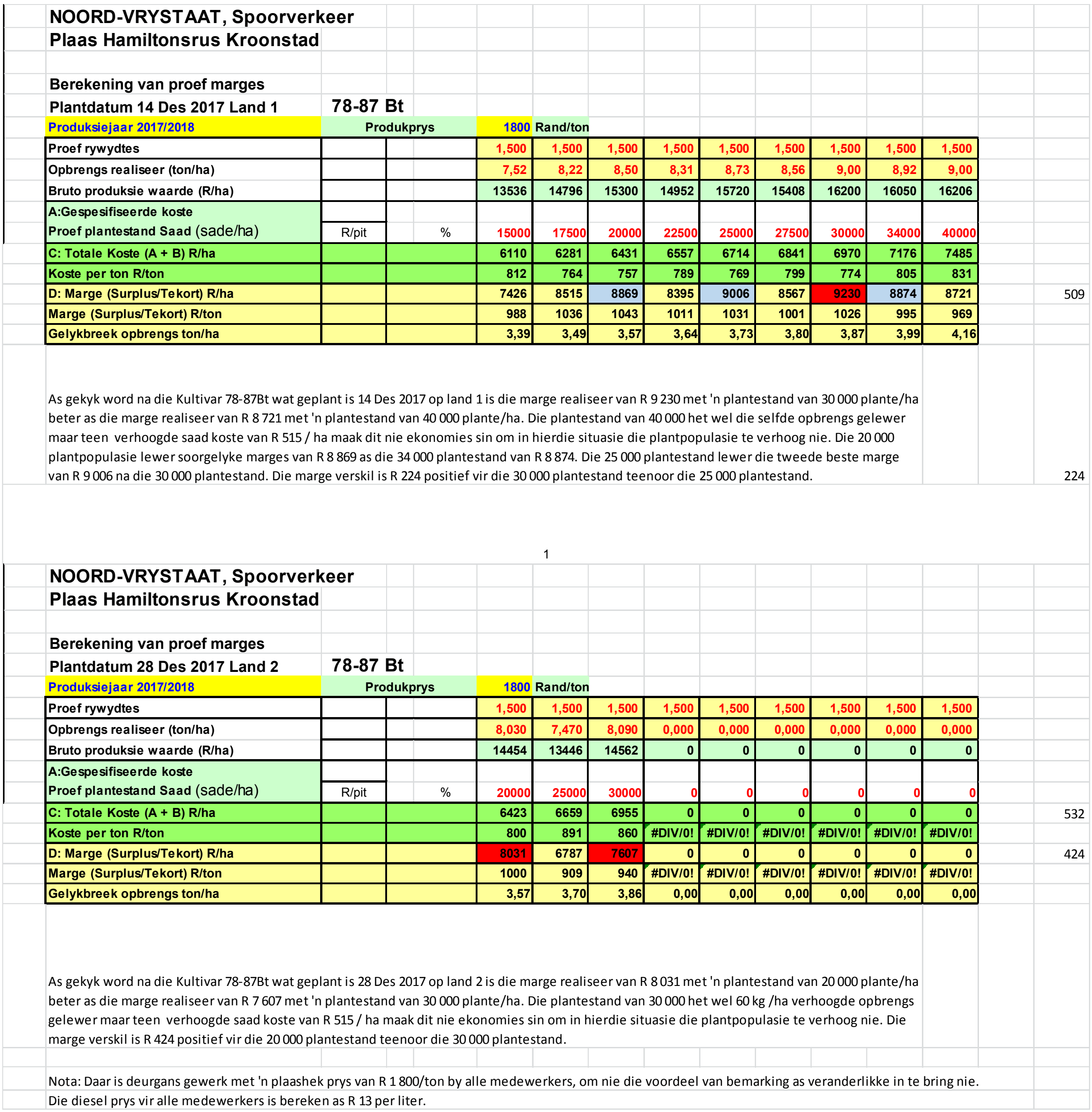
DKC 78-87 (Bt)

Berekening van proef marges
Herhaling 1 en 2 saam gevoeg

Produksiejaar 2017/2018	Produkprys		1800	Rand/ton				
Proef rywydtes			0,870	0,870	0,870	0,870	0,870	0,870
Opbrengs realiseer (ton/ha)			6,901	7,459	7,755	8,051	8,209	8,392
Bruto produksie waarde (R/ha)			12421	13426	13960	14492	14776	15105
A:Gespesifiseerde koste Proef plantestand Saad (sade/ha)	R/pit	%	15000	20000	25000	30000	40000	50000
C: Totale Koste (A + B) R/ha			7115	7438	7735	8033	8548	9098
Koste per ton R/ton			1031	997	997	998	1041	1084
D: Marge (Surplus/Tekort) R/ha			5306	5988	6224	6459	6228	6008
Marge (Surplus/Tekort) R/ton			769	803	803	802	759	716
Gelykbreek opbrengs ton/ha			3,95	4,13	4,30	4,46	4,75	5,05

Die hoer plantestand waar die resultate van herhaling 1 en 2 bymekaar gevoeg word het deurgans beter opbrengste gelwer met die 50 000 stand se opbrengs wat 341 kg hoër is as die 30 000/ha wat die beste marge realiseer het. Die relatief lae kommoditeits pryse het 'n groot invloed op die marges. Die beste marge vir die 2017/2018 seisoen van R 6 459 word realiseer met 'n plantestand van 30 000/ha teenoor die tweede beste marges van R 6 224 en R 6 228 met 'n plantestand van 25 000/ha en 40 000/ha respektiewelik. Dit verteenwoordig 'n verskil in marge van slegs R 231 / ha.

Appendix 5: Economic analysis: Trial 5: The effect of plant population on the yield of maize (Hamiltonsrus)



NOORD-VRYSTAAT, Spoorverkeer
Plaas Hamiltonsrus Kroonstad

Berekening van proef marges
Plantdatum 14 Des 2017 Land 1 **78-87 Bt**

Produksiejaar 2017/2018	Produkprys			1800	Rand/ton								
Proef rywydtes				1,500	1,500	1,500	1,500	1,500	1,500	1,500	1,500	1,500	
Opbrengs realiseer (ton/ha)				7,52	8,22	8,50	8,31	8,73	8,56	9,00	8,92	9,00	
Bruto produksie waarde (R/ha)				13536	14796	15300	14952	15720	15408	16200	16050	16206	
A:Gespesifiseerde koste													
Proef plantestand Saad (sade/ha)		R/pit	%	15000	17500	20000	22500	25000	27500	30000	34000	40000	
C: Totale Koste (A + B) R/ha				6110	6281	6431	6557	6714	6841	6970	7176	7485	
Koste per ton R/ton				812	764	757	789	769	799	774	805	831	
D: Marge (Surplus/Tekort) R/ha				7426	8515	8869	8395	9006	8567	9230	8874	8721	509
Marge (Surplus/Tekort) R/ton				988	1036	1043	1011	1031	1001	1026	995	969	
Gelykbreek opbrengs ton/ha				3,39	3,49	3,57	3,64	3,73	3,80	3,87	3,99	4,16	

As gekyk word na die Kultivar 78-87Bt wat geplant is 14 Des 2017 op land 1 is die marge realiseer van R 9 230 met 'n plantestand van 30 000 plante/ha beter as die marge realiseer van R 8 721 met 'n plantestand van 40 000 plante/ha. Die plantestand van 40 000 het wel die selfde opbrengs gelewer maar teen verhoogde saad koste van R 515 / ha maak dit nie ekonomies sin om in hierdie situasie die plantpopulasie te verhoog nie. Die 20 000 plantpopulasie lewer soorgelyke marges van R 8 869 as die 34 000 plantestand van R 8 874. Die 25 000 plantestand lewer die tweede beste marge van R 9 006 na die 30 000 plantestand. Die marge verskil is R 224 positief vir die 30 000 plantestand teenoor die 25 000 plantestand. 224

1

NOORD-VRYSTAAT, Spoorverkeer
Plaas Hamiltonsrus Kroonstad

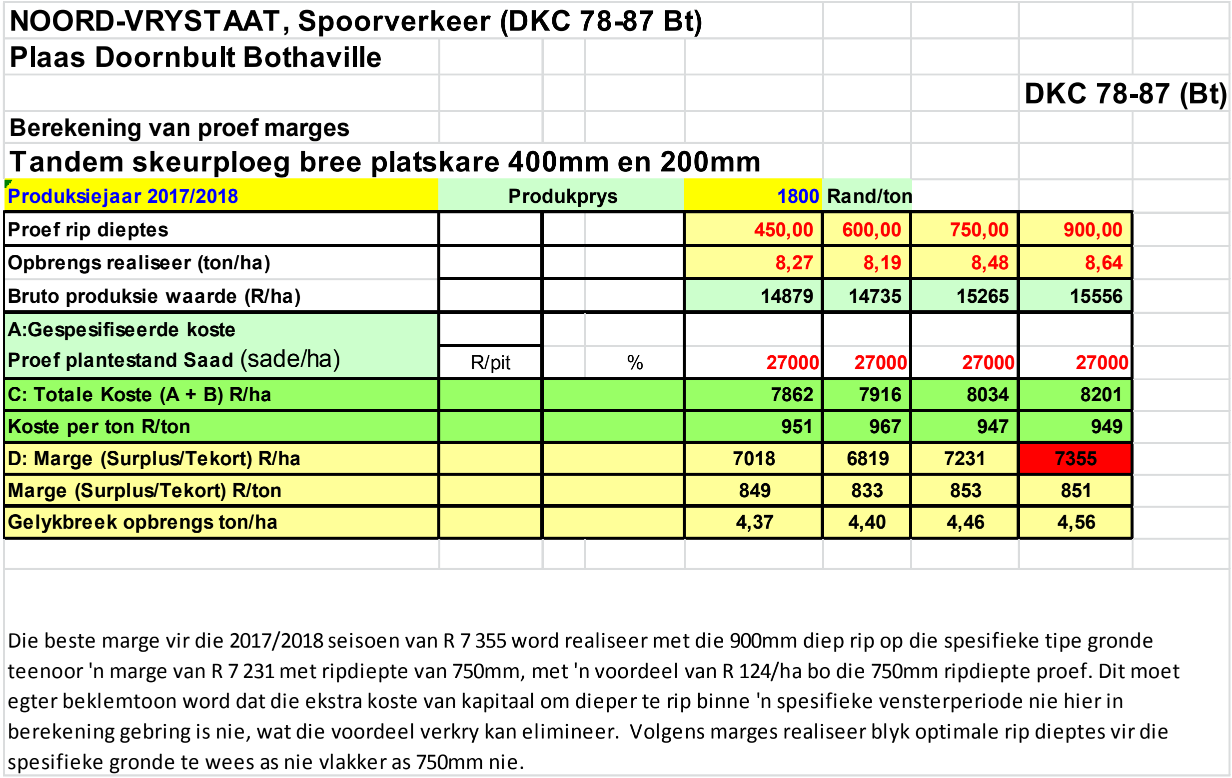
Berekening van proef marges
Plantdatum 28 Des 2017 Land 2 **78-87 Bt**

Produksiejaar 2017/2018	Produkprys			1800	Rand/ton								
Proef rywydtes				1,500	1,500	1,500	1,500	1,500	1,500	1,500	1,500	1,500	
Opbrengs realiseer (ton/ha)				8,030	7,470	8,090	0,000	0,000	0,000	0,000	0,000	0,000	
Bruto produksie waarde (R/ha)				14454	13446	14562	0	0	0	0	0	0	
A:Gespesifiseerde koste													
Proef plantestand Saad (sade/ha)		R/pit	%	20000	25000	30000	0	0	0	0	0	0	
C: Totale Koste (A + B) R/ha				6423	6659	6955	0	0	0	0	0	0	532
Koste per ton R/ton				800	891	860	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	
D: Marge (Surplus/Tekort) R/ha				8031	6787	7607	0	0	0	0	0	0	424
Marge (Surplus/Tekort) R/ton				1000	909	940	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	
Gelykbreek opbrengs ton/ha				3,57	3,70	3,86	0,00	0,00	0,00	0,00	0,00	0,00	

As gekyk word na die Kultivar 78-87Bt wat geplant is 28 Des 2017 op land 2 is die marge realiseer van R 8 031 met 'n plantestand van 20 000 plante/ha beter as die marge realiseer van R 7 607 met 'n plantestand van 30 000 plante/ha. Die plantestand van 30 000 het wel 60 kg /ha verhoogde opbrengs gelewer maar teen verhoogde saad koste van R 515 / ha maak dit nie ekonomies sin om in hierdie situasie die plantpopulasie te verhoog nie. Die marge verskil is R 424 positief vir die 20 000 plantestand teenoor die 30 000 plantestand.

Nota: Daar is deurgans gewerk met 'n plaashek prys van R 1 800/ton by alle medewerkers, om nie die voordeel van bemarking as veranderlikke in te bring nie.
Die diesel prys vir alle medewerkers is bereken as R 13 per liter.

Appendix 6: Economic analysis: Trial 6: Depth of ripping for monoculture maize (Doornbult).



NOORD-VRYSTAAT, Spoorverkeer (DKC 78-87 Bt)

Plaas Doornbult Bothaville

DKC 78-87 (Bt)

Berekening van proef marges

Tandem skeurploeg bree platskare 400mm en 200mm

Produksiejaar 2017/2018	Produkprys		1800	Rand/ton		
Proef rip dieptes			450,00	600,00	750,00	900,00
Opbrengs realiseer (ton/ha)			8,27	8,19	8,48	8,64
Bruto produksie waarde (R/ha)			14879	14735	15265	15556
A:Gespesifiseerde koste						
Proef plantestand Saad (sade/ha)	R/pit	%	27000	27000	27000	27000
C: Totale Koste (A + B) R/ha			7862	7916	8034	8201
Koste per ton R/ton			951	967	947	949
D: Marge (Surplus/Tekort) R/ha			7018	6819	7231	7355
Marge (Surplus/Tekort) R/ton			849	833	853	851
Gelykbreek opbrengs ton/ha			4,37	4,40	4,46	4,56

Die beste marge vir die 2017/2018 seisoen van R 7 355 word realiseer met die 900mm diep rip op die spesifieke tipe gronde teenoor 'n marge van R 7 231 met ripdiepte van 750mm, met 'n voordeel van R 124/ha bo die 750mm ripdiepte proef. Dit moet egter beklemtoon word dat die ekstra koste van kapitaal om dieper te rip binne 'n spesifieke vensterperiode nie hier in berekening gebring is nie, wat die voordeel verkry kan elimineer. Volgens marges realiseer blyk optimale rip dieptes vir die spesifieke gronde te wees as nie vlakker as 750mm nie.

Appendix 7: Bank account statement for period 2017-11-27 – 2017-12-26

Stuur terug na:
Privaatsak X18, Johannesburg, 2000

Tjekrekeningnommer: **40-7617-4899**

Sandgrond Ontwikkelings Kommitee

SANDGROND ONTWIKKELINGS KOMMITEE
POSBUS 7042
KROONPARK
9502

008140
003645

Bb Northern Free State (00)
1ste Vloer Absa Gebou
1ste Vloer Absa Gebou
Crossstraat
Kroonstad
9499

☎056 216 7312

Tjekrekeningstaat

27 Nov 2017 tot 26 Des 2017

Rekeningtipe: Klassieke Besig Rek
Staatnr: 0091
Kliënt BTW-reg-no:

Uitgereik op: 26 Des 2017

Rekeningopsomming:

Saldo oorgedra	636 095,87
Diverse Debiete	22 074,93-
Koste	90,00-
Saldo	**613 930,94**
Oortrekkingslimiet	**0,00**

U transaksies

Datum	*Transaksiebeskrywing*		*Koste*		*Debietbedrag*	*Kredietbedrag*	*Saldo*
27/11/2017	Saldo Oorgedra						636 095.87
27/11/2017	Bankstaat	Hoofkntoor	25.00	A			636 095.87
1/12/2017	Mndeliks Rek-fooi	Hoofkntoor		*	65.00		636 030.87
1/12/2017	Admin Koste	Hoofkntoor		*	25.00		636 005.87
17/12/2017	Ibank Betaling Na Absa Bank Agri Consult Trust	Vereffenin			22 074.93		613 930.94

DIENSGELD : 75.00/0.00/75.00 MNDLKS REK-FOOI : R65.00

KREDIETRENTE SOOS OP 27/11/2017 STANDAARD - VERWYS NA TAK

ABSA BESIGHEIDSBANKDIENSTE HERSIEN SY FOOIE EN KOSTE VANAF 1 JANUARIE 2018
KONTAK ASSEBLIEF U VERHOUDINGSKAKEL VIR MEER GEDETAILLEERDE INLIGTING OF
BESOEK ABSA.CO.ZA

* = BTW R11.05- INGESLUIT

KOSTE : A = ADMINISTRASIE D = DIENSGELD G = GEMENGDE K = KONTANTDEPOSITO T = TRANSAKSIE

Belangrik State word as korrek aanvaar tensy navraag binne 30 dae gedoen word. Tjeks wat op hierdie staat verskyn en nie aangeheg / gefotografeer is nie, sal by u volgende staat ingesluit word.

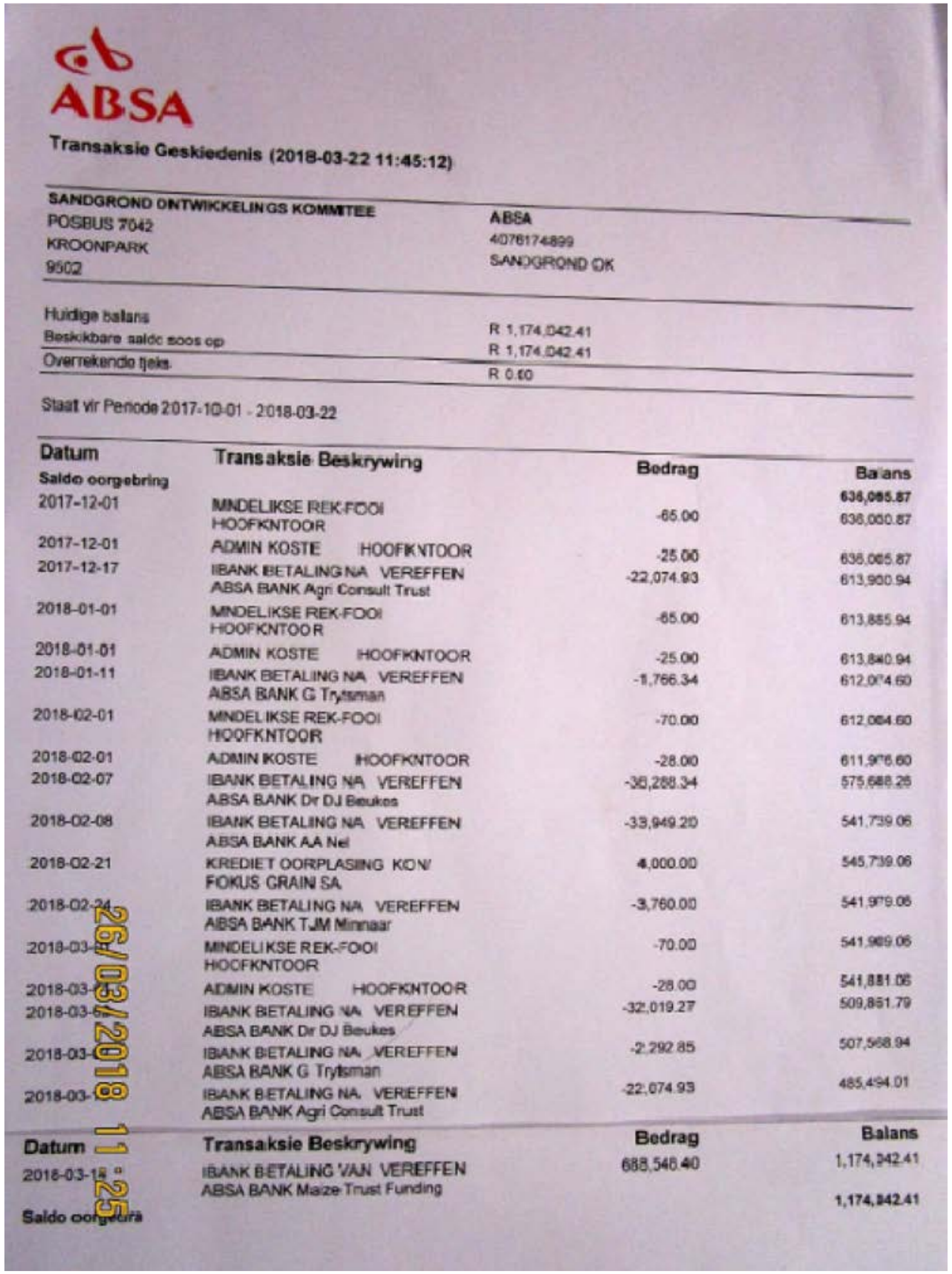
Bladsy 1 van 1
CSP002CQ (05/2017)

Absa Bank Beperk
Gemagtigde Finansiëlediensteverskaffer - Geregistreerde Kredietverskaffer, Reg-no NCRCP7

Belastingfaktuur
SOKOMM002

SOKOMM002 4076174899 0091 26/12/2017

Appendix 8: Bank account statement for period 2017-10-01 – 2018-03-22



ABSA

Transaksie Geskiedenis (2018-03-22 11:45:12)

SANDGROND ONTWIKKELINGS KOMMITEE	ABSA
POSBUS 7042	4076174899
KROONPARK	SANDGROND OK
9502	

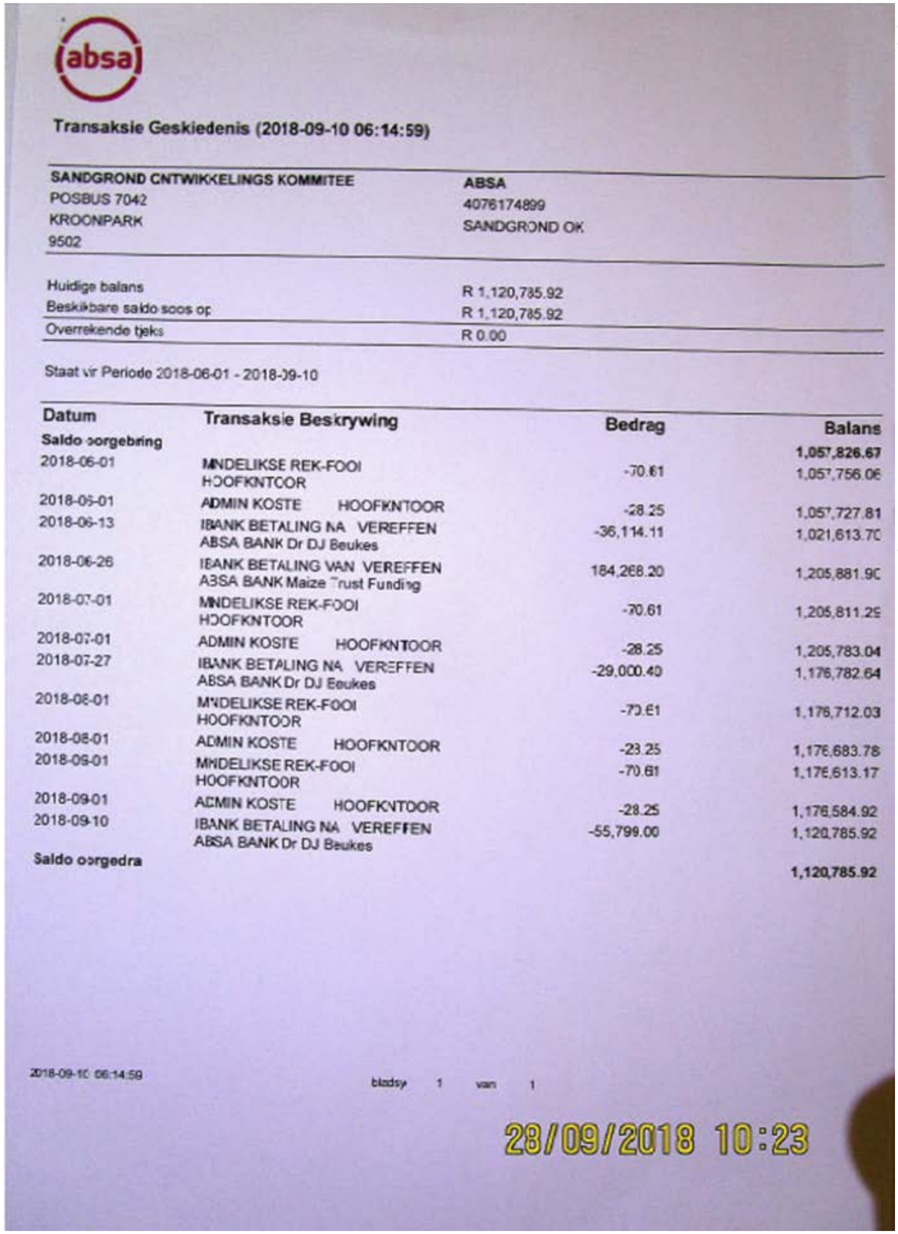
Huidige balans	R 1,174,042.41
Beskikbare saldo soos op	R 1,174,042.41
Overrekende tjeks	R 0.00

Staat vir Periode 2017-10-01 - 2018-03-22

Datum	Transaksie Beskrywing	Bedrag	Balans
Saldo oorgebring			**636,065.87**
2017-12-01	MNDELIKSE REK-FOOI HOOFKNTOOR	-65.00	636,000.87
2017-12-01	ADMIN KOSTE HOOFKNTOOR	-25.00	636,065.87
2017-12-17	IBANK BETALING NA VEREFFEN ABSA BANK Agri Consult Trust	-22,074.93	613,900.94
2018-01-01	MNDELIKSE REK-FOOI HOOFKNTOOR	-65.00	613,885.94
2018-01-01	ADMIN KOSTE HOOFKNTOOR	-25.00	613,840.94
2018-01-11	IBANK BETALING NA VEREFFEN ABSA BANK G Trytsman	-1,766.34	612,074.60
2018-02-01	MNDELIKSE REK-FOOI HOOFKNTOOR	-70.00	612,004.60
2018-02-01	ADMIN KOSTE HOOFKNTOOR	-28.00	611,976.60
2018-02-07	IBANK BETALING NA VEREFFEN ABSA BANK Dr DJ Beukes	-36,288.34	575,688.26
2018-02-08	IBANK BETALING NA VEREFFEN ABSA BANK AA Nel	-33,949.20	541,739.06
2018-02-21	KREDIET OORPLASING KONV FOKUS GRAIN SA	4,000.00	545,739.06
2018-02-24	IBANK BETALING NA VEREFFEN ABSA BANK TJM Minnaar	-3,760.00	541,979.06
2018-03-	MNDELIKSE REK-FOOI HOOFKNTOOR	-70.00	541,909.06
2018-03-	ADMIN KOSTE HOOFKNTOOR	-28.00	541,881.06
2018-03-	IBANK BETALING NA VEREFFEN ABSA BANK Dr DJ Beukes	-32,019.27	509,861.79
2018-03-	IBANK BETALING NA VEREFFEN ABSA BANK G Trytsman	-2,292.85	507,568.94
2018-03-	IBANK BETALING NA VEREFFEN ABSA BANK Agri Consult Trust	-22,074.93	485,494.01

Datum	Transaksie Beskrywing	Bedrag	Balans
2018-03-1	IBANK BETALING VAN VEREFFEN ABSA BANK Maize Trust Funding	688,548.40	1,174,042.41
Saldo oorgedra			**1,174,042.41**

Appendix 9: Bank account statement for period 2018-06-01 – 2018-09-10



Transaksie Geskiedenis (2018-09-10 06:14:59)

SANDGROND ONTWIKKELINGS KOMMITEE POSBUS 7042 KROONPARK 9502	**ABSA** 4076174899 SANDGROND OK
Huidige balans	R 1,120,785.92
Beskikbare saldo soos op	R 1,120,785.92
Overrekende tjeks	R 0.00

Staat vir Periode 2018-06-01 - 2018-09-10

Datum	Transaksie Beskrywing	Bedrag	Balans
Saldo oorgebring			**1,057,826.67**
2018-06-01	MNDELIKSE REK-FOOI HOOFKNTOOR	-70.61	1,057,756.06
2018-06-01	ADMIN KOSTE HOOFKNTOOR	-28.25	1,057,727.81
2018-06-13	IBANK BETALING NA VEREFFEN ABSA BANK Dr DJ Beukes	-36,114.11	1,021,613.70
2018-06-26	IBANK BETALING VAN VEREFFEN ABSA BANK Maize Trust Funding	184,268.20	1,205,881.90
2018-07-01	MNDELIKSE REK-FOOI HOOFKNTOOR	-70.61	1,205,811.29
2018-07-01	ADMIN KOSTE HOOFKNTOOR	-28.25	1,205,783.04
2018-07-27	IBANK BETALING NA VEREFFEN ABSA BANK Dr DJ Beukes	-29,000.40	1,176,782.64
2018-08-01	MNDELIKSE REK-FOOI HOOFKNTOOR	-70.61	1,176,712.03
2018-08-01	ADMIN KOSTE HOOFKNTOOR	-28.25	1,176,683.78
2018-09-01	MNDELIKSE REK-FOOI HOOFKNTOOR	-70.61	1,176,613.17
2018-09-01	ADMIN KOSTE HOOFKNTOOR	-28.25	1,176,584.92
2018-09-10	IBANK BETALING NA VEREFFEN ABSA BANK Dr DJ Beukes	-55,799.00	1,120,785.92
Saldo oorgedra			**1,120,785.92**

2018-09-10 06:14:59 bladsy 1 van 1

28/09/2018 10:23

Appendix 10: Programme for report back and planning meeting on 11 Sept 2018.

TERUGVOER EN BEPLANNINGSVERGADERING

SOK-PROJEK: Investigating the impacts of conservation agriculture practices on soil health as key to sustainable dry land maize production systems on semi-arid sandy soils with water tables in the north western Free State

AANGEBIED DEUR: SANDGRONDONTWIKKELINGSKOMITEE
DATUM: 11 SEPT 2018, 09H00 – 13H00
PLEK: SENWES RAADSAAL, KROONSTAD

FOKUS

TERUGVOER OOR RESULTATE VAN 2017/18-SEISOEN EN BEPLANNING VIR 2018/19-SEISOEN

PROGRAM (Voorsitter: Danie Minnaar)

09H00-09H10 VERWELKOMING EN OPENING:

- Jaco Minnaar, Hoofbetuurder, Graan SA
- Danie Crous (Skriflesing)

09h10-11H00 TERUGVOER OOR RESULTATE VAN 2017/18-SEISOEN:

- Boeremedewerkers: Danie M, Danie C, Lourens, Thabo
- Tegniese medewerkers:
  LNR-IGG (Sonia, Adrian, Owen): Mikrobiologie en patogene
  LNR-Irene (Gerrie): Dekgewasproef
  Andre & Danie: Groei en opbrengs; Grondeienskappe
  Senwes (Boet & Petrus): Ekonomiese ontledings; Grondwater
  Omnia (Kobus): Grondontledings

11H00-11H10 BIOLOGIESE BREEK

11H10-12H00 BEPLANNING VIR 2018/19-SEISOEN:

- Boeremedewerkers: Danie M, Danie C, Lourens, Thabo
- Tegniese medewerkers: LNR-IGG, LNR-Irene, Senwes (Boet & Petrus), Andre & Danie, Kobus (Omnia), Daan Grabe (Nulandis)

12H00-12H05 VORDERINGSVERSLAG EN AANSOEK AAN MIELIETRUST:

- Insette en sperdatums (Danie)

12H05-12H15 ENIGE ANDER SAKE:

- …………………
- …………………
- …………………

12H15-12H20 SAMEVATTING EN AFSLUITING:

- Jaco Minnaar, Hoofbestuurder, Graan SA

12H20-13H00 LIGTE MIDDAGETE

13H15 VERTREK

Kontakbesonderhede: Danie: 0824420484; danie.beukes122@gmail.com
Andre Nel: 0836549430; nelaa1954@gmail.com

Appendix 11: Programme for Farmers Day on 22 February 2018 at Springboklaagte

BOEREDAG

AANGEBIED DEUR: SANDGRONDONTWIKKELINGSKOMITEE

DATUM: 08H30 VIR 09H00 DONDERDAG 22 FEB 2018
DISTRIK: KROONSTAD
PLAAS: SPRINGBOKLAAGTE (DANIE MINNAAR)

TEMA

BEWARINGSLANDBOU: PRODUKSIESTELSELS WAT WATERVERBRUIKSDOELTREFFENDHEID BEVORDER OP SANDGRONDE EN GRAAN SA: STREEK 22 INLIGTINGSESSIE

PROGRAM

09H00-09H15 VERWELKOMING EN OPENING

- Jaco Minnaar, Voorsitter, Graan SA
- Danie Crous, Skriflesing en gebed

09H15-10H45 BESOEK AAN VELDPROEWE

- Standproef (Danie Minnaar en André Nel)
- Profielgate: Mielies op oorlê, Jaar-op-jaar mielies, Wisselbou (Kobus van Zyl)
- Ondergrondse wateraanvulling as alternatief vir oorlê (Douw Steyn, Netafim en Danie Minnaar)

11H00-11H30 TERUGVOER OOR BEWARINGSLANDBOUPROEWE

- Stand en rywydte, Ripdiepte, Wisselbou (Thabo van Zyl)
- Bewerkingspraktyke (Lourens van der Linde)
- Stand- en kultivarproef (Danie Minnaar)

11H30-13H00 GRAAN SA: STREEK 22 INLIGTINGSESSIE

- Graan SA Fokus 2018 (Jannie de Villiers, HUB, Graan SA)
- Inligting: Spesifieke aktiwiteite (Luan van der Walt)

13H00-13H05 SAMEVATTING

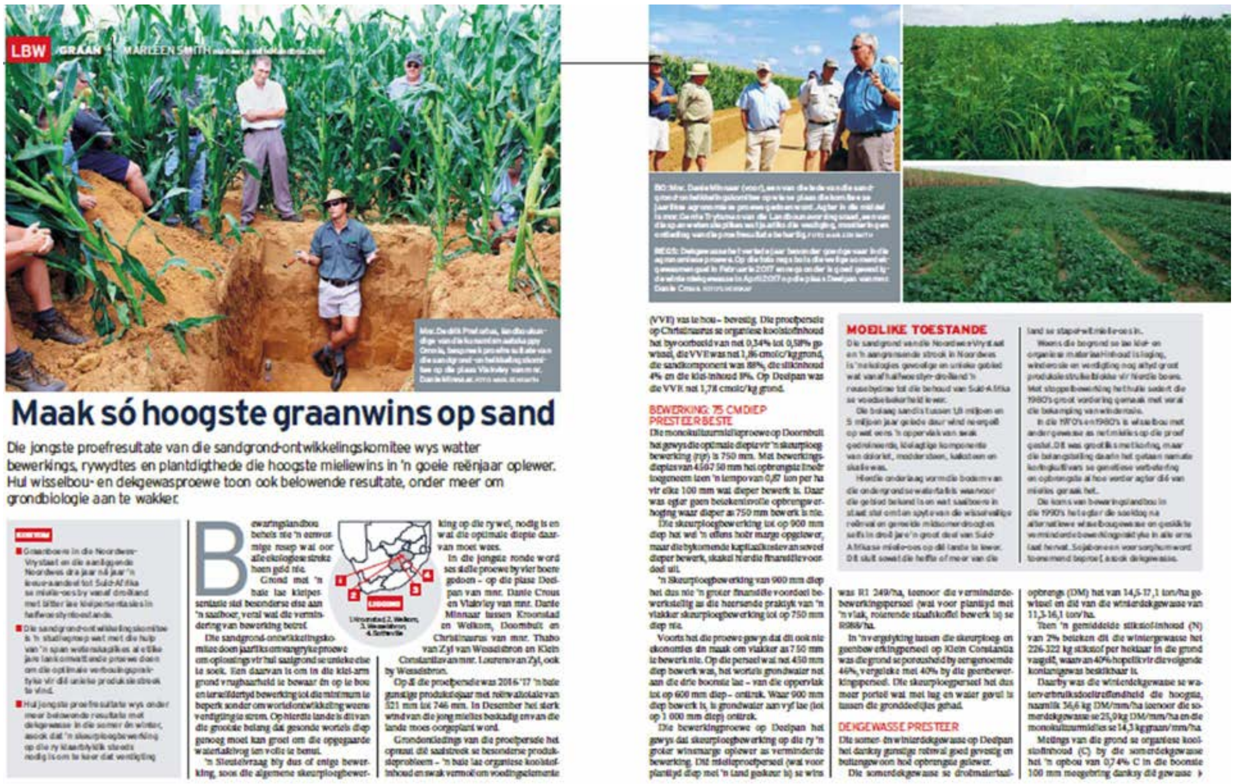
- Kobus van Zyl, OMNIA

13H05-13H50 LIGTE MIDDAGETE

14H00 VERTREK

Antwoord voor of op 19 Februarie 2018: E-pos: linda@compuking.co.za
Sel: 082 337 2473

Appendix 12: Article in Landbouweekblad: Farmers Day on 22 February 2018 at Springboklaagte



Maak só hoogste graanwins op sand

Die jongste proefresultate van die sandgrond-ontwikkelingskomitee wys watter bewerkings, rywydtes en plantdigthede die hoogste mieliewins in 'n goeie reënjaar oplewer. Hul wisselbou- en dekgewasproewe toon ook belowende resultate, onder meer om grondbiologie aan te wakker.

BEWERKING: 75 CM DIEP PRESTEER BESTE

MOEILIKE TOESTANDE

DEKGEWASSE PRESTEER

Appendix 12: Article in Landbouweekblad: Farmers Day on 22 February 2018 at Springboklaagte (Continue)

LBW

Mnr. Douw Steyn van die besproeiingsmaatskappy Netafim bespreek 'n nuwe konsep wat dié maatskappy as deel van die sandgrond-ontwikkelingskomitee se jaarlikse agronomiese proewe toets. Die doel is om vas te stel of ondergrondse drupbuise gebruik kan word om die gebied se ondergrondse watertafels buite die produksieseisoen aan te vul. FOTO: [illegible]

◂ se enorme hoeveelhede wortels en ander plantmateriaal.

Die seisoensmetings het gewys dat die grondwaterinhoud in die sandgrond vinnig tot verwelkpunt val as die interval tussen opeenvolgende reënbuie langer as 18 dae is.

Grondtemperatuurwisselings het gewys dat die grond onder die somerdekgewasse die koelste was en dié onder die winterdekgewasse die warmste.

Die somerdekgewasmengsel, per hektaar, was 10 kg sorghum, 4 kg babala, 10 kg akkerbone, 2 kg sunhennep, 1 kg booradyse, 2 kg mielies, 2 kg sojabone en 2 kg sonneblomsaad. Dit is op 1 Desember 2016 as 'n mengsel geplant.

In die winterdekgewasmengsel was, ook per hektaar, 1 kg soetklawer, 1 kg booradyse, 1 kg voerradyse, 5 kg swarthawer, 10 kg sandwicke, 5 kg rog, 5 kg hawer en 1 kg rape. Dit is op 15 Februarie vanjaar geplant.

DIVERSITEIT EN GRONDLEWE

Die ontleding van mikrobiologiese grondbedrywigheid in die wisselbouproewe op Thabo se plaas Christinasrus het hoër bakterietellings en mikrobiese ensiembedrywigheid in die mielie-sojaboon-wisselboustelsel as in die monokultuurmielieland getoon, teenoor hoër swamtellings in die monokultuurmielieland.

Op Deelpan se dekgewaspersele was die mikrobiese bedrywigheid gemeet aan die ensieme glukosidase en fosfatase betekenisvol hoër as op die perseel met monokultuurmielies. Die bedrywigheid van urease (die ensiem wat ureum in koolstofdioksied en ammoniak afbreek) het egter nie tussen die onderskeie persele verskil nie.

VERSURING

Die proewe het weer bevestig dat versuring, veral in die ondergrond, 'n wesenlike probleem by die sandgronde is. In die algemeen was die ondergrond se pH-waardes betreklik laag in die proewe op Christinasrus – onder die norm van 4,5 vir mielies – met gepaardgaande hoë suurversadigingswaardes. Dit word aanbeveel dat dolomitiese landboukalk toegedien word omdat die grond se magnesium (Mg)-vlak laag is.

In die boonste 600 mm grond was die nitraat (NO_3)-N-waardes baie laag – van 4,3-7 mg/kg – en die NH_4-N-waardes taamlik hoog, van 38-49 mg/kg. "Die gebruik van ureum of NH_4-kunsmis as stikstofdraer by hierdie sandgrond met sy baie lae suurbuffervermoë behoort ontmoedig te word," sê dr. Danie Beukes.

Op Deelpan het die proewe ook gewys dat die loging van duur voedingstowwe, veral NO_3-N, 'n ernstige probleem is. 'n Ontleding van twee watertafels op die proefpersele het baie hoë NO_3-waardes uitgewys – 84-504 mg/liter. Terselfdertyd was die NO_3-waardes in die grond baie laag – 4-5,5 mg/kg, en die mielies het duidelike tekens van 'n stikstoftekort getoon. Voorts was die nitrietkonsentrasies in die watertafels baie hoog, wat groot gesondheidsrisiko's inhou. Daar was aansienlike hoeveelhede ander plantvoedingstowwe, soos fosfaat, kalium, kalsium en Mg, in albei watertafels.

"'n Strategie sal bedink moet word oor hoe om die loging van duur voedingselemente uit die sandgrond te verminder," sê Danie.

NOUER RYE, HOËR STAND EN DIE REGTE KULTIVAR

Sowel rywydte as plantdigtheid het spruitvorming en mielie-opbrengs merkbaar beïnvloed.

Mielieplante in 1,524 m-rye het 2,5 maal meer spruite gehad as die in 1,016 m-rye.

Teen 'n saadprys van R3 260 per 60 000 sade en 'n graanprys van R1 650/ton was die optimum plantdigthede op die proefpersele by Thabo onderskeidelik 37 800 plante/ha en 34 300 plante/ha vir die 1,016- en 1,524 m-rye. "Hou egter in gedagte dat dit 'n goeie reënjaar was, wat hoë plantdigthede begunstig het," sê Danie.

Die 1,016 m-rye het 7,46 ton mieliegraan per ha gelewer, wat 1,37 t/ha meer was as die 1,524 m-rye.

As na die opbrengs per plant gekyk word, lyk dit asof die betrokke kultivar (DKC78-87B) weerstand getoon het teen stremming weens hoër plantdigthede, voeg Danie by.

Die groot verskil in opbrengs tussen die verskillende rywydtes kan gedeeltelik aan 'n verskil in die bemestingspraktyk toegeskryf word, meen hy: "In die 1,016 m-rye is kunsmis langs die ry toegedien. By die 1,524 m-rye is die helfte van die kunsmis langs die ry toegedien, en die ander helfte tussen die rye. Die wisselwerking tussen rywydtes en bemesting op mieliegroei en -opbrengs moet dus nog verder uitgepluis word."

Op Doornbult is grondwater onder 'n mieliestand van 15 000 plante/ha in 1,5 m-rye tot op 400 mm diep onttrek. Daarteenoor het 25 000 plante/ha grondwater tot op 600 mm diep onttrek en 50 000 plante/ha tot op 1 000 mm diep.

Op Danie Minnaar se plaas, Vlakvley, het kultivarkeuse 'n merkbare rol in spruitvorming gespeel. Elke kultivar wat getoets is, het verskillend op saaidigtheid gereageer.

Die bewese optimale saaidigtheid, sonder inagneming van die saadprys, was hier klaarblyklik hoër as 23 000 plante per hektaar. Gegewe die heersende lae mieliepryse was die ekonomies optimum stand vir die kultivar 78-87Bt klaarblyklik 22 000 tot 24 000 plante per ha. Vir 78-17Bt het 26 000 plante/ha 'n hoër wins (R11 443/ha) gelewer as 24 000 plante/ha (R10 891/ha). Die kultivar 78-87Bt teen 24 000 plante/ha het dus R803/ha meer wins gelewer as 78-17Bt teen 26 000 plante/ha. LBW

SPANPOGING

Die sandgrond-ontwikkelingskomitee (SOK), 'n plaaslike studiegroep wat boere van Kroonstad, Bothaville en Wesselsbron insluit, doen al vyf jaar lank met finansiering van die Mielietrust omvattende proewe om hul verbouingsresep te verfyn.

Die jaarlikse proewe is 'n spanpoging van die plaaslike boere en landboukundiges en wetenskaplikes van verskillende instellings. Dit sluit in die agronomiese konsultante drs. Danie Beukes en André Nel, mnr. Gerrie Trytsman, dekgewasspesialis by die Landbounavorsingsraad (LNR) se Instituut vir Diereproduksie, drr. Marylke Craven en Sonia Steenkamp en mnr. Owen Rhode van die LNR se Instituut vir Graangewasse, mnre. Petrus van Staden en Boet van Zyl, landboukundiges van Senwes, en dr. Hendrik Smith, hoof van Graan SA se bewaringslandbou-afdeling.

Aan die insetverskaffer-kant het die landboukundiges mnre. Kobus van Zyl van Omnia en Pieter Rademeyer en Nico Barnard van Pannar bygedra.

❯ NAVRAE: Dr. Danie Beukes, e-pos: danie.beukes122@gmail.com, sel 082 442 0484; dr. André Nel, e-pos: nelaa1954@gmail.com, sel 083 654 9430.

48 | Landbouweekblad | www.landbou.com 23 Maart 2018

Appendix 13: Article in April 2018 SA Grain: Farmers Day on 22 February 2018 at Springboklaagte

Sandgrondproewe trek produsente se aandag

DANIE BEUKES en **DR ANDRÉ NEL**, projekleiers, Sandgrondontwikkelingskomitee

Die Sandgrondontwikkelingskomitee (SOK) se jaarlikse boeredag is op 22 Februarie vanjaar in die Kroonstad-distrik op mnr Danie Minnaar se plaas, Springboklaagte, gehou. Die doel was om veldproewe en resultate van die SOK-projek oor bewaringslandbou bekend te stel.

Die tema vir die dag was produksiestelsels onder bewaringslandbou wat waterverbruiksdoeltreffendheid op sandgronde bevorder. Streek 22 van Graan SA het terselfdertyd 'n inligtingsessie aangebied. Die dag is bygewoon deur 78 produsente en verteenwoordigers van verskeie maatskappye.

Die boeredag het afgeskop met 'n veldbesoek aan verskeie proewe – waarin groot belangstelling getoon is.

Minnaar (**Foto 1**) het agtergrond oor 'n standproef van mielies verskaf. Terwyl sy mieliestande as 'n reël 20 000 plante tot 22 000 plante per hektaar is, het die afgelope twee uitstekende reënvalseisoene dit genoodsaak om hoër stande – tot 40 000 plante per hektaar – te ondersoek.

Mnr Kobus van Zyl van Omnia (**Foto 2**) het verduidelik dat bevredigende wortelontwikkeling die sleutel hou tot 'n bogemiddelde mielie-oes. Op die sandgronde van die omgewing, wat geneig is om te verdig, is 'n tandem-skeurploegbewerking die enigste versekering van goeie wortelontwikkeling.

Na die veldbesoek het die produsentemedewerkers op die SOK-projek 'n oorsig gegee van die vorige seisoen se proefresultate. 'n Resultaat wat in mnr Thabo van Zyl se proef op sy diep sandgronde onder mielies uitgestaan het, is dat 750 mm die mees ekonomiese diepte vir skeurploegbewerking is.

Mnr Lourens van der Linde, ook 'n produsentemedewerker) se bewerkings- en wisselbouproewe het erg deurgeloop – eers onder erge windskade en daarna onder oorvloedige reën. Vir die huidige seisoen lyk die proewe egter uiters belowend.

Minnaar het, onder andere, bewys dat hoewel opbrengs toeneem met 'n toename in plantestand, daar duidelike kultivarverskille was – 'n aspek wat die produsent in gedagte moet hou.

▲ 1: Danie Minnaar verskaf agtergrond oor sy standproef met mielies.

In die inligtingsessie van Streek 22 het mnr Jannie de Villiers (HUB) die uiters sensitiewe saak van grondonteiening sonder vergoeding omvattend bespreek. Hy het genoem dat Graan SA 'n aantal strategieë in plek het om hierdie saak te hanteer. Hy het benadruk dat die lesse uit Afrika getoon het dat voedselsekerheid slegs haalbaar is waar eiendomsreg bestaan.

Dr Dirk Strydom (bestuurder: Graanekonomie en Bemarking, Graan SA) het in sy praatjie oor markinligting genoem dat daar tans nasionaal en internasionaal 'n oorskot van mielies en koring is. Teen die agtergrond van 'n wêreldekonomie wat so min groei toon, is dit nodig dat produsente se fokus van optimale opbrengs na optimale wins verskuif – met inagneming van al die produksiekostekomponente.

In sy samevatting het Van Zyl van Omnia genoem dat die produsent moet onthou dat “'n mielieplant nie jok nie” en dat grond 'n geheue het in terme van eksterne invloede soos bewerking en aksies wat grondgesondheid bevorder. Produsente moet hul risiko's beter bestuur, die regte dinge beter doen en veral wisselbou begin toepas. ■

▲ 2: Kobus van Zyl bespreek wortelontwikkeling onder skeurploegbewerking. Let op die vrywater in die kleiner gat, wat dui op 'n watertafel – 'n kenmerk van die sandgronde in goeie reënvaljare.

◥ 3: In gesellige luim na afloop van 'n uiters suksesvolle boeredag: Lourens van die Linde, Jaco Minnaar (voorsitter, Graan SA), Jannie de Villiers, Danie Beukes (SOK-projekleier), Danie Minnaar, dr André Nel (SOK-projekleier) en Thabo van Zyl. Afwesig: Danie Crous (produsentemedewerker).