Sandy soils Development Committee

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.

Final report for the period October 2020 to September 2023

Submitted to the Maize Trust

December 2023

Compiled by:

André Nel, Danie Beukes and Melanie de Bruyn

THE MAIZE TRUST

		Reg no. IT8214/98
Block D Grain Building Agri-hub Office Park 477/478 Witherite Street THE WILLOWS 0184	P.O. Box 74626 LYNNWOOD RIDGE Pretoria 0040	Tel: +27 (12) 807-3958 e-mail: beatrix@llagrimanage.co.za

Maize Production Research Final Report

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Name of Lead Researchers:	Dr AA Nel, Agronomy Dr DJ Beukes, Soil Science
Contact details of Lead Researcher ***E-mail address:*** ***Phone:***	Dr AA Nel nelaa1954@gmail.com Cell: 083 654 9430
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Other role players: AECI Plant Health, Dekalb. Pannar, Pioneer, Senwes

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1 Summary

Crop rotation:

- The yield of crops is dominated by the seasonal weather, mainly the amount and distribution of rainfall.
- The yield of maize was once significantly suppressed and three times enhanced out of a possible 24 instances, by crop rotation. Calculated over the six seasons, the yield of maize improved by 12% over than of monoculture maize generally known as the “rotational effect”.
- After six seasons, difference in the soil fertility and soil health states did not yet occur.
- Crop rotation could not reduce the prevalence of plant-parasitic nematodes.
- From 2020/21 to 2022/23 the operating margin of rotated maize was in five out of a 12 instances higher than that of mono cultured maize.
- Indications are that the inclusion of soybean alone or, soybean plus a cover crop, with its relatively high operating margins and rotational effects, once every two or three seasons in rotation with maize, will outperform maize in monoculture.

Plant population density:

- Recommendations of optimal maize plant population densities related to yield potentials, were refined and confirmed.

Timing of top-dressed nitrogen fertilization:

- No evidence from one successful trial, could be found that the timing of top-dressed nitrogen fertilization had any effect on the yield of maize.

Nitrogen rate:

- The optimum nitrogen rate for maize at a yield of 8 t ha^{-1} was quantified.

Soil tillage:

- The yield of maize on seasonal 75 cm deep ripped soil is 0.99 t ha^{-1} higher than the yield of no-till soil or ripping every second season.

Use of different top-dressing nitrogen fertilizers:

- Different nitrogen containing products and urease plus nitrification inhibitors affected the yield in one out of three trials.
- Top-dressed nitrogen improved the yield compare to a pre-plant nitrogen application.
- CAN (calcium ammonium nitrate) based fertilizer mixtures had a 5% yield advantage over urea based fertilizers.

2 Research objectives and aims

The following objectives and aims were set and the outcomes are as follows:

Objectives and aims	Outcome
Compare, under reduced tillage and stubble-mulch, cash crop rotations with monoculture maize.	Results from three seasons were successfully collected for this long-term trial.
Evaluate plant population density as component to the sustainable cultivation of monoculture maize, as well as maize in rotation with soybean.	Three out of six trials were successfully contributing to previously generated data. Water logging caused damage in three trials.
Investigate the effects of two soil cultivation systems on the yield of maize and compare seasonal ripping with ripping every second season under stubble-mulch with mono-culture maize.	This objective was successfully completed.
Quantify the effect of timing of nitrogen fertilisation on the yield of maize.	One out of two trials were successful. The unsuccessful trial was damaged by water logging. This objective needs further exploration.
Evaluate the effects of various cropping systems under rip-on-row and no-tillage with inclusion of a grazing component.	Partially completed. The farmers involved terminated their participation and the collaborating researcher resigned.
Investigate various levels of nitrogen fertilisation of maize on extremely sandy soil with a water table.	One out of three trials were successful. Further study on this objective is needed.
Quantify water use efficiency of maize as a function of planting density.	Successfully completed.
Quantify water table chemistry as function of levels of fertilizer application.	Data was collected from two trials. Further study on this objective is needed to get a wider perspective.
Characterize and quantify nematode infestation under crop rotation.	Successfully completed by the NWU.
Characterize and quantify soil health as a function of various crop production systems.	Successfully completed.
The effect nitrogen fertilisation on milling quality of maize.	Successfully completed.
The effect of the application of different nitrogen fertilizer products on the yield of maize.	This objective was pursued in three trials in only one season with inconclusive results and it needs further investigation.

3 Additional information

3.1 Overview of elapse of growing season

Seasonal rainfall

Reporting by Drs DJ Beukes and AA Nel

Figure 3.1 shows seasonal rainfall (Sept-May) for the 2022/23 growing season at the trial localities. H/rus represents rainfall at Trials 3, 5 and 6; V/kuil represents rainfall at Trial 1; K/Const represents rainfall at Trials 2 and 9; E/deel represents rainfall at Trial 11.

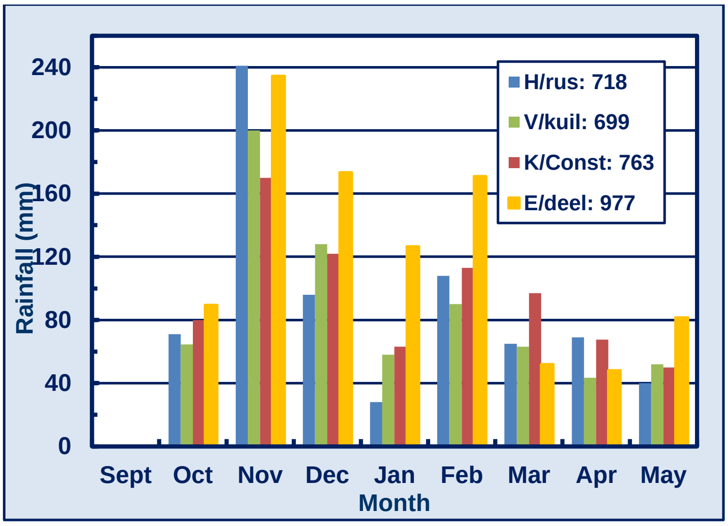


Figure 3.2: Monthly rainfall at trial localities (H/rus=Hamiltonsrus; V/kuil=Visagieskuil; K/Const=Klein Constantia; E/deel=Erfdeel).

The following are of note:

- The seasonal rainfall distribution was ideal to ensure good crop growth and yields, although the relatively low rainfall in January could have prompted signs of the typical 'mid-summer drought' due to the coincidence with the sensitive flowering stage of the maize. Nevertheless, by the beginning of March lush maize growth was evident (Plate 3.1).
- Heavy rainfall was experienced shortly after crop emergence during November, leading to resultant damage to crop growth and yield at some trial localities.

3.2 Perspectives by a farmer co-worker

Thabo van Zyl (Bothaville district): Thabo reminisced that during the last decade what was regarded as 'abnormal', has become the new 'normal'. He said that they prepared for the forewarned La Nina phenomenon (above normal rainfall) by planting more soybean, while those farmers with wet soils decided to plant their maize very early. The forewarning realized when during November and December heavy rains were experienced. Then came January with the typical 'midsummer drought' – followed by the 'normal' rainfall pattern. Thabo said that despite the 'abnormal' rainfall pattern he obtained above-normal soybean yields, while his maize yields were back to 'normal'. He will keep focusing on crop rotation and improve crop choices.

Thabo says that the present unpredictable rainfall patterns have prompted dry land farmers to reconsider, *inter alia*, crop rotation, the type of crops, planting density, fertilizer types and application rates, as well as pest control, in order to reduce risk and the cost of farming in order to increase profitability.

Plate 3.1: Lush maize stand (6 March 2023) at Springboklaagte.

3.3 Views and perspectives of North-Western Free State farmers on crop diversification

Reporting by Mrs M de Bruyn and Dr AA Nel

A questionnaire was distributed during the Information Day of the SSDC, held on 21 March 2023 on the farm Klein Constantia, Wesselsbron district (Plate 3.3). The purpose of the questionnaire was to determine the target area of the SSDC, as well as whether the field trials should be adjusted to focus on present-day topical issues. A total of 45 questionnaires were completed, by four company representatives and 41 farmers, respectively.

Plate 3.3: Visitors at a profile pit during the 2023 Information Day listening to a soil expert.

Thirty-seven (37) of the 41 farmers indicated their planted area (ha) of maize, soybean, wheat, sunflower and/or cover crop for the previous season (2021/22), as well as the current season (2022/23). In the 2021/22 season a total of 86 824 ha were planted compared to the 2022/23 season in which 82 508 ha were planted (4 316 ha less). Figure 3.3.1 shows the difference in the average planted area per farmer of the two seasons. Although there was a difference in planted area for most crops, a paired sample t-test showed that there was a statistically significant difference for soybean, with a mean difference of 331 ha in 2022/23 vs 2021/22.

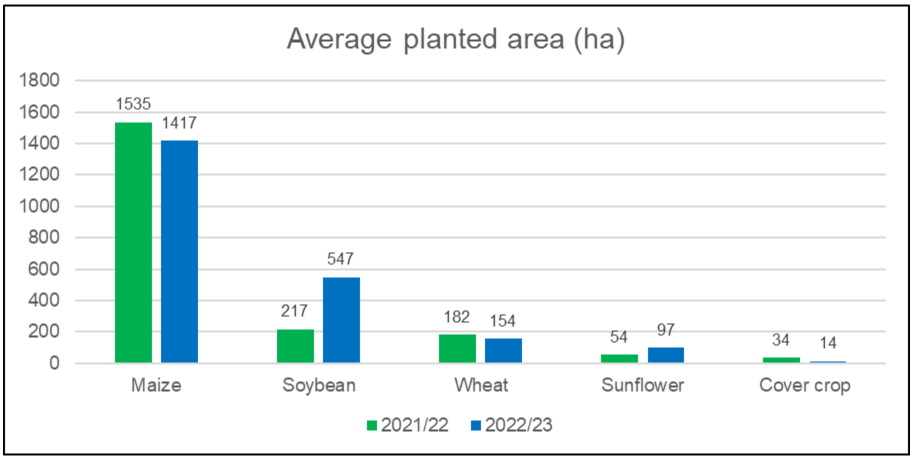


Figure 3.3.1: Average planted area of various crops per farmer for the 2021/22 and 2022/23 seasons.

In addition, farmers indicated their intended crop percentages for the forth-coming season (2023/24). Figure 3.3.2 shows the average intended maize, soybean, wheat, sunflower and/or cover crop area for 2023/24 together with the planted areas of the previous and current seasons. It appeared that farmers intend to plant relatively more wheat, sunflower and cover crops in the 2023/24 season.

All questionnaire participants found the day interesting and informative. Most comments were positive (Table 3.3.1): Farmers were thankful for a successful day. The only negative comments had to do with the screen/projector. There was also a suggestion that Figures be explained in depth and that the legends, as well as the x- and y-axes are discussed for better understanding.

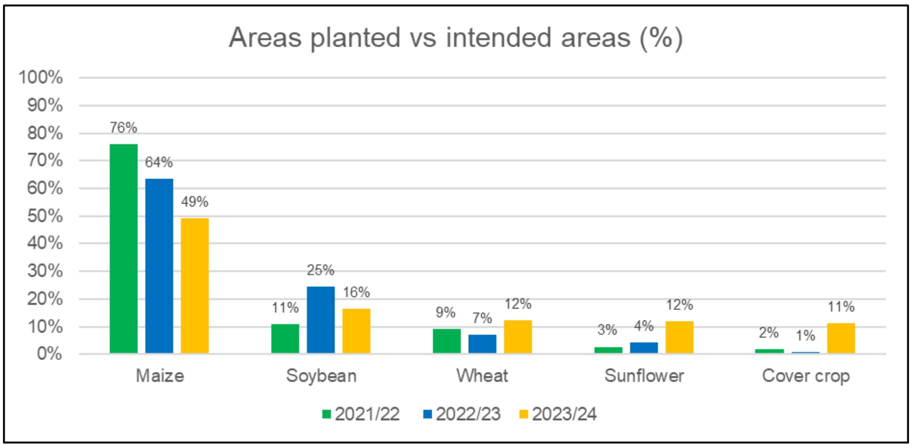


Figure 3.3.2: Percentage area of crops planted/intended for three seasons.

Lastly, participants were asked to suggest relevant future research topics. There were many requests, most of which involved fertilisation and foliar nutrition. In addition to this, there were several requests regarding soybean research, which included fertilisation, density, and cultivars. All the research requests, and their frequencies, are shown in Table 3.3.2.

Table 3.3.1: Participant's comments regarding the Information Day

Very good/ thank you very much.
Projector's contrast was unclear.
Willing to pay membership fees (R1000).
Figures' legends, x- and y-axes need to be explained so that Figures are better understood.
Please share the slide show.
Informative, especially the profile pits and that trials are done statistically.
Is a 'learning school', it is a must.
Nice to learn from farmers with the same problems and challenges.
Stimulates thinking, questions are stimulating.
Trial data helps a lot.
Density trials go a long way in getting the optimum density on the farm.
A good guideline of where to change.
Weather presentation was good.

Table 3.3.2: Research topics suggested by participants.

Research topic	Frequency
Fertilisation (rate, means of application).	6
Chemical trials (degradability, application).	3
N-source: Urea, NH_4 or LAN.	1
Foliar nutrition.	4
Nematode control.	2
Nematodes in soybean.	1
Sclerotinia on soybean.	1
Fertilisation trials on soybean.	1
Soybean in dry years on dry lands.	1
Soybean density and sustainability of soybean.	2
Nitrogen levels. Soybean cultivars and density.	1
Subsoil acidification.	2
Accuracy of weather predictions.	1
More research in long term weather predictions.	1
Microbes in soil.	1
Micro-elements. Different formulae. New technology nano-planning of deficiencies.	1
Comparison of input costs. Production with limited fertilizer availability.	1
Long-term data is important.	1
Effect of water pH on herbicides.	1
Precision farming.	1
Whether to cut or plough in crop residues, or leave it on the soil surface? The effect of crop residues on the soil surface, or incorporation.	1
What is the effect of sunflower in crop rotation with soybean, maize, and sunflower?	1

3.4 Trial 1: Local CA, reduced tillage, stubble-mulch with cash crop rotations compared to mono-culture maize on sandy soil (Farmer co-worker: Thabo van Zyl, Christinasrus).

Reporting by Drs AA Nel, DJ Beukes and Mrs M de Bruyn

3.4.1 Aim

The aim of this replicated trial, now in its sixth season, is to compare the performance of crop rotation systems namely:

Rotation system	Abbreviation
Maize – maize (control)	MM
Maize - soybean	MS
Maize – maize - soybean	MMS
Maize – cover crop - soybean	MCS

The trial layout is a randomised complete-block design with three replicates. A plot was allocated every season to each crop in each system to be able to distinguish between seasonal and rotational effects.

3.4.2 Materials and methods

The soil was cultivated with a tandem ripper 0.75 m deep (rip-on-row) during September 2022. At the same time 100 kg urea ha^{-1} was applied at a depth of 0.3 m to 0.4 m to the whole trial area. Maize, cultivar DKC 77-77BR, was planted on 1 December 2022 with 320 kg 11:5:2 (18) at a seeding density of 30 000 ha^{-1} at a mean row width of 1.01 m. A topdressing of 100 kg 3:0:1 (29) was applied 5 weeks after planting. The final plant population density was 29 700 ha^{-1}.

Rhizobium inoculated seed of the soybean cultivar PAN 1507R was planted on 23 November 2022 without any additional fertilizer apart from the urea that was applied to the trial area. The mean row width was 0.87 m. The seeding density was 300 000 ha^{-1} and the final plant population density 206 896 ha^{-1}.

The cover crop mixture was planted on 23 December 2022 with 320 kg 11:5:2 (18). No additional fertilizer was applied. The mixture consisted of pearl millet (cultivars Okashana and Agrigreen), forage sorghum (SupaSweet), sorghum x sudangrass hybrid (Multicut), cowpeas (Glenda) and dolichos (Highworth). The legumes and grasses were planted in alternate 0.87 m spaced rows.

Soil samples (0-15 cm depth) were taken on 24 March 2023, *i.e.* 114 days after planting, on the maize plots to assess the soil health status. The analyses were done by the Soil Health Support Centre. Root samples were taken by a team from North West University, on plots, for characterization and assessment of nematode infestation.

3.4.3 Results and discussion

Reporting by Drs AA Nel and Mrs M de Bruyn

Vegetative growth

Soybean and maize grew well without visible damage as can be seen in Plate 3.4.1. The cover crop suffered severe damage due to its relatively late planting and heavy rains shortly after planting.

Plate 3.4.1: Lush growth of maize (16 January 2023) and soybean (24 March 2023).

Yields

Cover crop

The dry cover crop biomass was measured on 24 March 2023, 91 days after planting. The yield, in areas where the growth was relatively good, was 2.64 t ha^{-1} of which 66% was contributed by the grasses and 33% by legumes. This low yield can be considered a failure as cover crop yields are regularly double the maize grain yield. A cover crop yield of at least 10 t ha^{-1} should have materialised.

Soybean

The analysis of variance with crop systems (seasons 2017/18 and 2019/20 to 2022/23) (Table 3.4.1), including seasons as a source of variation, shows that the soybean yield was affected by a crop system (C) x season (S) interaction at $p \leq 0.10$. The interaction is due to the yield ranking of the crop systems that changed from season to season (Figure 3.4.1). The symbols for the crop systems in Figure 3.4.1 represent: MS = maize – soybean, MMS 1 = maize – maize – soybean and

Table 3.4.1: Analysis of variance of soybean yields at Christinasrus.

Source	df	Sum of squares	Mean sum of squares	F-ratio	Probability (p)
Crop systems (C)	2	0.002	0.00	0.00	1.00
Seasons (S)	4	49.4	12.4	67.57	<0.01
Replications	2	0.5	0.25	1.36	0.31
C x S interaction	8	4.5	0.57	3.10	0.07
Error	25	4.6	0.18		
Total	44	59.1			

MCS = maize – cover crop – soybean. Yield differences among the crop systems within seasons varied from 0.14 t ha^{-1} to 1.2 t ha^{-1}

The mean soybean yields of the MS, MMS 1 and MCS crop systems over the four seasons of respectively 2.21, 2.19 and 2.19 t ha^{-1}, were remarkably similar (Figure 3.4.1). Despite the interaction, soybean performed consistently well after maize and cover crops across seasons indicating that the yield differences within seasons are most likely by chance.

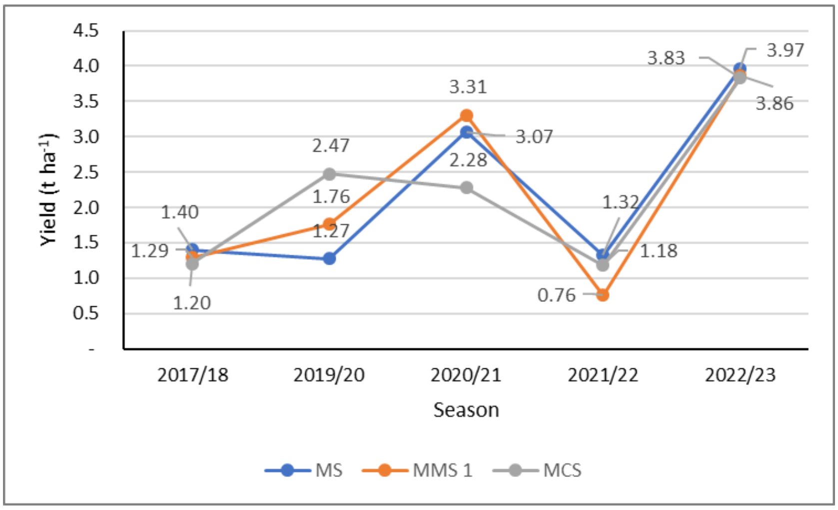


Figure 3.4.1: The yield of soybean as affected by season X crop rotation systems. No yield was recorded in 2018/19.

Maize

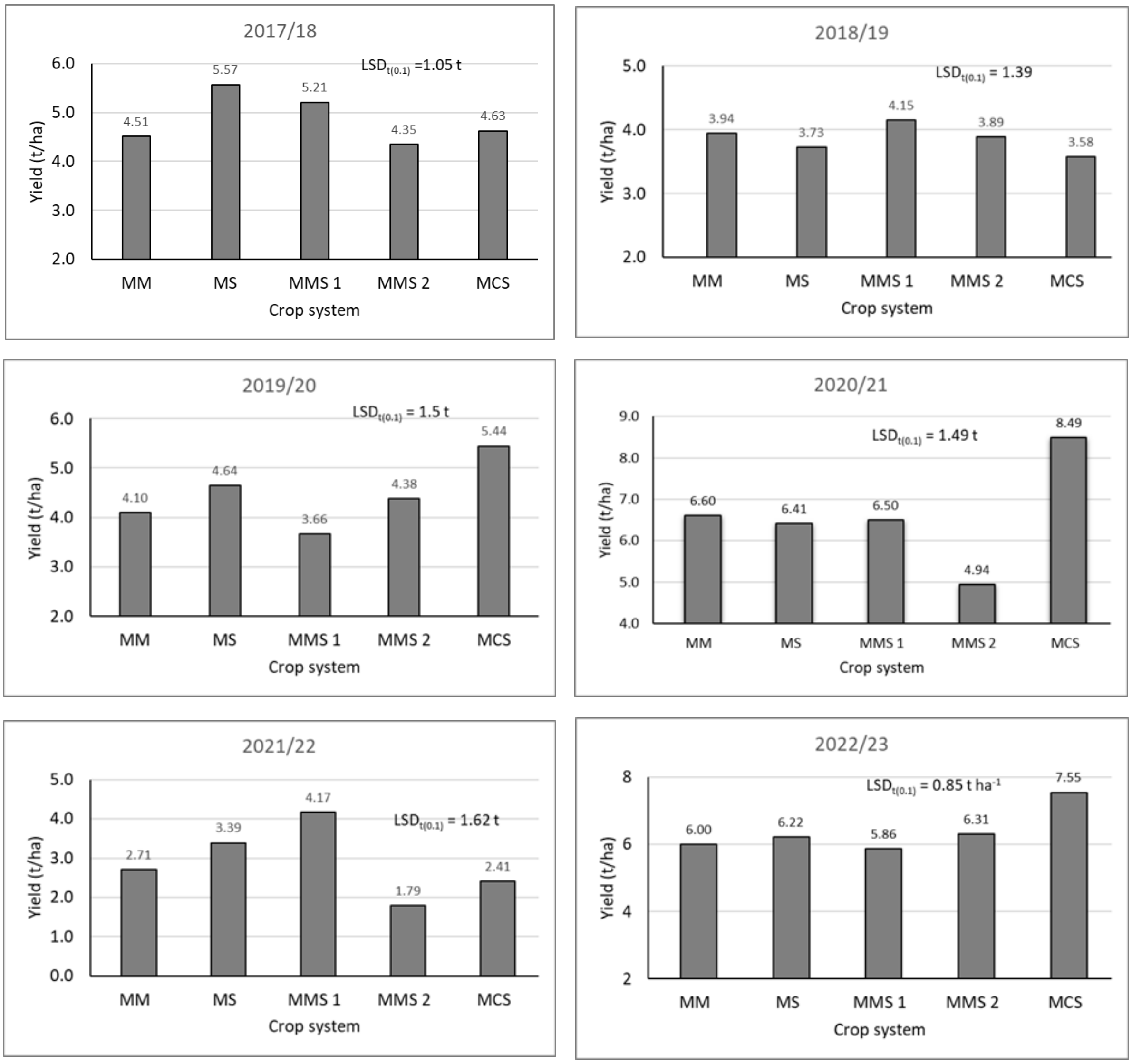
Table 3.4.2 includes an analysis of variance as a function of crop rotation systems from 2018/19 to 2021/23. The yield of maize was affected by crop systems, seasons and by a crop system (C) X season (S) interaction at $p \leq 0.10$.

The crop system yields of maize from 2017/18 to 2022/23 are shown in Figure 3.4.2. The symbols for the crop systems in Figure 5 are: MS = maize – soybean, MMS 1 and MMS 2 = first and second season maize respectively, in the maize – maize – soybean systems and MCS = maize – cover crop – soybean.

Table 3.4.2: Analysis of variance of maize yields at Christinasrus

Source	df	Sum of squares	Mean sum of squares	F-ratio	Probability (p)
Cop systems (C)	4	11.7	2.91	2.91	0.03
Seasons (S)	5	155.3	31.05	30.99	<0.01
Replications	2	10.4	5.18	5.17	0.01
C x S interaction	20	32.1	1.61	1.6	0.09
Error	45	45.1	1.00		
Total	84	59.1			

The yields of maize from 2017/18 to 2021/23 are shown in Figure 3.4.2. The symbols for the crop systems in Figure 3.4.2 represent: MS = maize – soybean, MMS 1 and MMS 2 = first and second season maize respectively, in the maize – maize – soybean systems and MCS = maize – cover crop – soybean system.



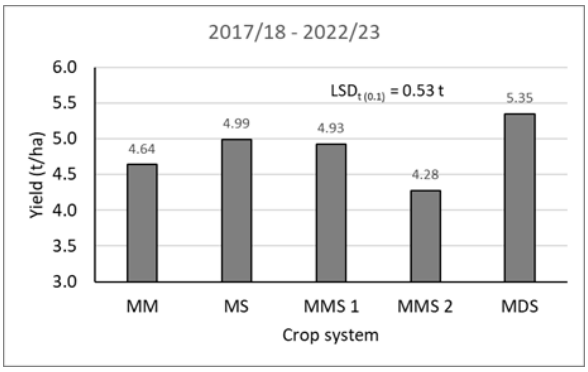


Figure 3.4.2: The yield of maize as affected by the crop rotation systems in each season and across seasons.

The yield was strongly affected by seasons and to a lesser extent by crop systems and a crop systems x seasons interaction. Mean seasonal yields varied from 2.90 t ha^{-1} in 2021/22 due to water logging, to 6.59 t ha^{-1} in 2019/20.

The significant crop systems x seasons interaction indicates that the yield ranking order of the crop systems, varied from season to season with no single system dominating over seasons. Notably is the fact that the monoculture maize system (MM) never had the top ranking position although its yield was often not significantly different from the system with the top yield.

In three seasons, maize following soybean (either the MS or MMS 1 system) had the highest yield. The yield difference between the maize following soybean and that of the MM system varied from -0.14 t ha^{-1} (or -2%) to 1.07 t ha^{-1} (or 39%). Averaged over the six seasons, the yield increase was 12% which is in line with the 11% to 13% found in research done on sandy soils.

Within seasons, the yield of the maize in the MMS 2 system was from 1.66 t ha^{-1} (or 25%) lower to 0.31 t ha^{-1} (or 5%) higher than the yield of the MM system. However, over seasons the MMS 2 yield was 0.37 t ha^{-1} (or 9%) lower than that of the MM system. This is probably a coincidence as it cannot be logically explained and it has been shown before that the yield improvement of second season maize is half that of first year maize following soybean. In this case a yield advantage of 4% to 5% over the yield of the MM was expected.

The yield of the MCS system is remarkable. In two seasons it's yield were a significant 1.89 t ha^{-1} (or 29%) and 1.55 t ha^{-1} (26%) respectively higher than the yield of the MM system. These two seasons (2020/21 and 2022/23) had probably the most favourable amount and spread of rainfall. The yield difference between the MCS and the MM systems (MCS minus MM) varied from -0.36 t ha^{-1} (or -9%) to 1.89 t ha^{-1} (or 29%). Over all seasons, the yield of the MCS system was 12% higher than the yield of the MM system corresponding with the yield increase of maize following soybean in the MS and MMS 1 systems.

The maize yield increase brought about by the rotational effect of soybean and the cover crop is a mystery as both soybeans and legumes in the cover crop, enhances the abundance of root-knot nematodes (Appendix 1) which can damage maize.

Soil fertility status

Reporting by Dr DJ Beukes

Soil samples (0-20 cm and 20-50 cm depths) were taken on 24 March 2023 on mono maize and maize/soybean plots by Omnia for standard soil fertility analyses. An adjacent *E curvula* natural grass stand was also sampled at four depth increments for analyses. Soil pH (KCl) and some soil nutrient values of the cropped lands and the grass stand are displayed in Figures 3.4.3 a-f. For comparison purposes, the Haney analysis values are included in the Figures (red and blue symbols) for mono maize [M (Mono)-H] and maize-soybean rotation [M (Soy)-H], respectively.

In general, there is some agreement with either the Omnia values or the FSSA (2007) norms. It should be noted that the Haney soil tests use different analytical procedures (for example, weaker extractants) compared to those of Omnia.

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 the service provider, OMNIA. The following observations are of note for both analytical procedures:

- Soil pH (KCl) (Figure 3.4.3 a): pH (KCl) values under crops were above the critical norm of 4.5 for maize but decrease sharply with depth, prompting some acid saturation (6%) in the subsoil. As can be expected on the sandy soil, top soil pH values under the *E curvula* land were low.
- Inorganic N (NO_3 and NH_4) (Figures 3.4.3 b-c): Compared to the maize guideline of 33 mg NO_3-N kg^{-1} soil at 6-8 weeks after planting (Adriaanse, 2021), very low values were measured under the crops (Figure 3.4.3 b). The Haney values (*e.g.* M (Soy-H)) were even

lower, probably due to the weaker extractant of this procedure. Leaching of NO_3-N on these sandy soils appears to be a serious problem.

- Similar to previous seasons, relatively high NH_4-N values were measured under both the crops and grass land (Figure 3.4.3 c). These high values cannot be explained yet.
- Furthermore, the measured NO_3-N and NH_4-N values bear no relationship with amounts of N applied (kg ha^{-1}) to the crops: Maize: 102; Soybeans: 46; and Cover Crops: 81.
- The high NH_4-N that was measured under the grass land (Figure 3.4.3 c) did not receive any fertilizer, cannot be explained yet. Although a low (1.87 cmolc kg^{-1}) profile cation exchange capacity (CEC) was measured, could it be that NH_4 ions were sufficiently retained in the soil profile?
- Phosphorus (P) (Figure 3.4.3 d): High topsoil P values were measured – well above the sufficiency level of 25 mg kg^{-1} required for maize (dotted line, FSSA, 2007). As expected, subsoil P values under the grass land were much lower than the fertilized crop lands. The high P value in the topsoil of the grass land cannot be explained yet. Relatively high Haney values were also measured.
- Potassium (K) (Figure 3.4.3 e): The Omnia and Haney methods gave similar soil K values that were in fair agreement with the FSSA guide (dotted line). The very high K-values under the grass land cannot be explained yet.
- Calcium (Ca) and magnesium (Mg) (Figures 3.4.3 f-g): For all crops, values for both Ca and Mg were in agreement with FSSA guide lines (dotted lines). For Mg, there was fair agreement between the Omnia and Haney values (Figure 3.4.3 g).
- Soil organic C (Figure 3.4.3 h): The relatively high soil C values under both maize lands were in agreement with those under the *E curvula* – a phenomenon which is very encouraging. However, the Haney extractant yielded much lower soil C values.

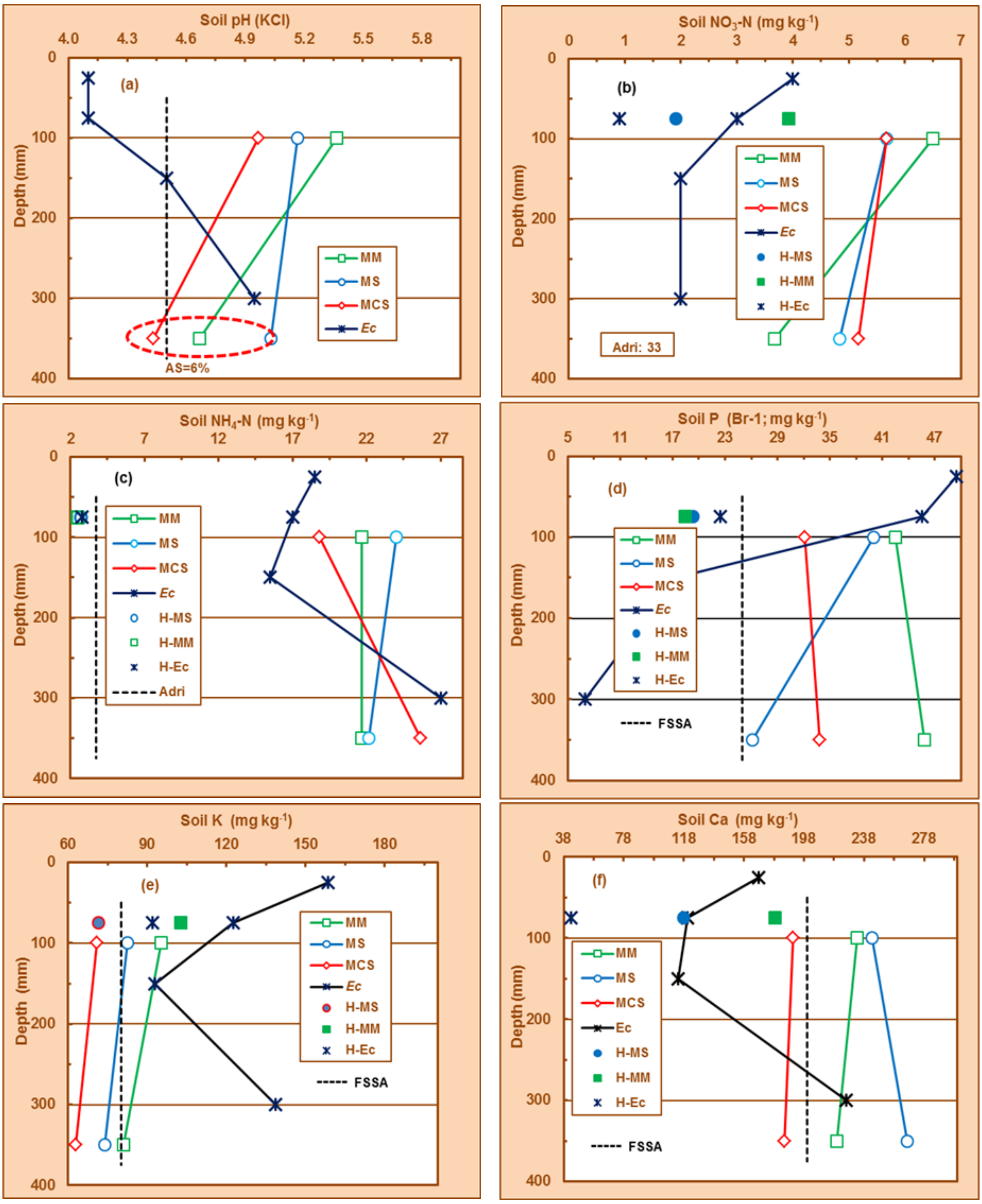


Figure 3.4.3 a-f: Soil analysis values of the crop rotation trial at Christinasrus and the adjacent *E curvula* land on 24 March 2023. MM = mono maize; MS = maize – soybean; MCS = maize – cover crop – soybean; Ec = *Eragrostis curvula*; H-MS = Haney analysis for maize – soybean; H-MM = Haney analysis for mono maize; H-Ec = Haney analysis for *E curvula*; AS = Acid saturation; Adr = Adriaanse (2021); FSSA = Fertilizer Society of South Africa (2007).

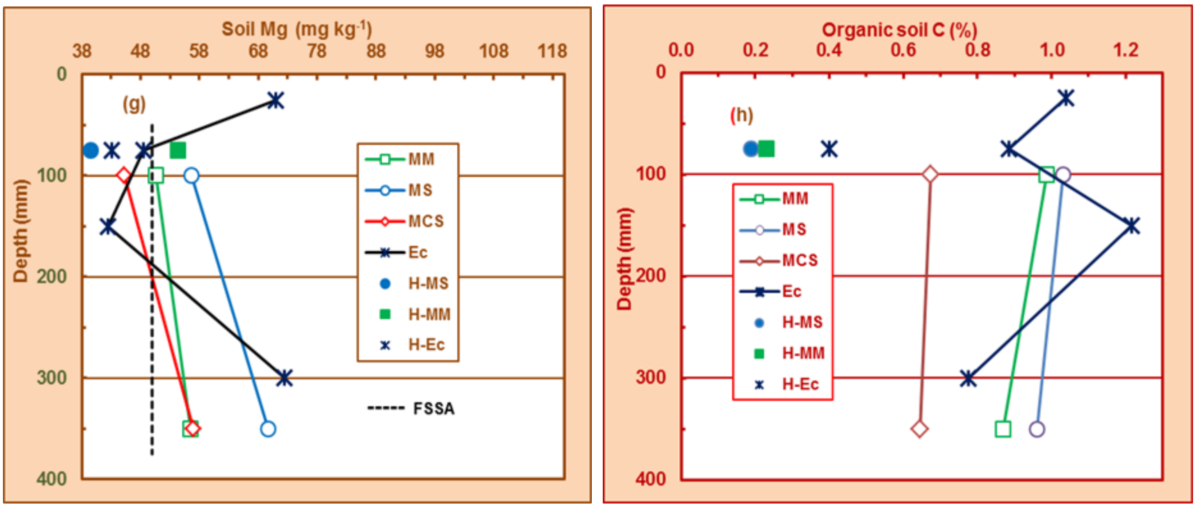


Figure 3.4.3 g-h: Soil analysis values of the crop rotation trial at Christinasrus and the adjacent *E curvula* land on 24 March 2023. MM = mono maize; MS = maize – soybean; MCS = maize – cover crop – soybean; Ec = *Eragrostis curvula*; H-MS = Haney analysis for maize – soybean; H-MM = Haney analysis for mono maize; H-Ec = Haney analysis for *E curvula*; AS = Acid saturation; Adr = Adriaanse (2021); FSSA = Fertilizer Society of South Africa (2007).

Soil health status

Reporting by Dr AA Nel and Mrs M de Bruyn

The soil health results are shown in Table 3.4.3. At a significance level of $p \leq 0.10$, crop rotation systems affected only the soil health index and soil respiration. In the table crop systems are maize – maize – soybean (MMS), maize - soybean (MS), maize – maize (MM) and maize – cover crop – soybean (MCS). For comparison, values of the adjacent *E curvula* grass land are also included.

Contrary to expectation, the MMS 2 system had the highest health score and the highest soil respiration rate. The MMS 1 system the lowest health index and the MS system the lowest respiration rate. These results cannot be logically explained as it was expected that the MCS system, due to its diversity of crops, would have the highest health score and respiration rate.

Some of the soil health and fertility parameters of the adjacent grass land were higher than that of the trial area such as the soil health index, organic matter content and H_2O total organic carbon. This is expected and an indication of the soil degradation caused by crop production.

The soil health and several of the soil biological parameters of the trial and the grass land are described as low, below average or, are substantially below ideal values. The mean soil organic matter of the trial of 0.37% (0.17% to 0.22% soil organic carbon (SOC)) is particularly low compared to the 1.5% to 2.0% indicated by Lal (2016) as lower threshold SOC levels for soil health processes to be functional. Although higher, the SOC of the undisturbed grass land is also far below the stated lower threshold. The decomposing rate of organic matter in this soil is most likely too high for the build-up of soil organic matter to a level where the soil health system is fully functional. This may also be the reason for the inconsistency of significantly affected parameters from 2021/22 to 2022/23.

Table 3.4.3: Soil health and fertility parameters as affected by crop rotation and the adjacent grass land. All values, except indexes and ratios, are presented in mg kg^{-1} or percentages as indicated.

Health and fertility parameters	Crop system and 2022/2023 crop					ANOVA			Mean	
	MM Maize	MS Soybean	MMS 1 Soybean	MMS 2 Maize	MCS Soybean	F-ratio	Proba-bility	LSD_t*	trial	grass
Soil health index	3.58	3.53	3.08	3.92	3.73	3.66	**0.06**	0.43	3.57	4.10
pH (H_2O)	7.43	7.70	7.56	7.82	7.60	1.64	0.25	0.30	7.62	7.70
Organic Matter (%)	0.37	0.37	0.33	0.40	0.40	0.26	0.89	0.14	0.37	0.7
Soil respiration**	11.3	10.7	11.0	13.3	12.4	3.04	**0.08**	1.61	11.8	10.9
H_2O Total Organic C	87.0	86.9	68.6	89.3	86.3	2.7	0.11	13.5	83.6	112
Soil Organic Carbon (%)	0.21	0.21	0.19	0.23	0.23	0.26	0.89	0.08	0.22	0.4
Water Extractable Organic C : Tot SOC (%)	4.19	4.19	3.69	3.84	3.80	0.23	0.91	1.27	3.94	2.7
Microbial Active C (%)	13.6	12.5	16.7	15.1	14.5	1.6	0.26	3.29	14.5	9.7
Organic C:N	12.3	12.1	11.3	11.1	11.4	1.0	0.44	1.34	11.6	15.2
H_2O Total N	10.5	10.8	9.6	13.9	13.2	2.5	0.12	3.02	11.6	10.6
H_2O Organic N	10.53	10.79	9.61	13.86	13.16	2.52	0.12	3.02	11.6	7.4
H3A Nitrate	1.49	1.68	1.91	3.92	3.53	1.25	0.36	2.65	2.50	0.9
H3A Ammonium	1.92	1.68	2.19	1.97	1.98	1.27	0.36	0.43	1.95	2.3
H3A Inorganic Nitrogen	3.41	3.36	4.10	5.89	5.51	1.12	0.41	2.94	4.45	3.1
Total N (Organic + Inorganic)	10.49	10.58	10.16	13.99	13.13	1.99	0.19	3.28	11.7	10.5
Organic N: Inorganic N ratio	2.10	2.14	1.50	1.80	1.44	0.91	0.50	0.90	1.80	2.4
H3A Total Phosphorus	24.0	31.1	24.7	23.8	32.1	0.89	0.51	11.49	27.1	28
H3A Inorganic Phosphorus	18.1	24.6	19.3	18.4	25.1	0.86	0.53	9.84	21.1	22.5
H3A Organic Phosphorus	5.87	6.46	5.46	5.38	7.02	1.00	0.46	1.83	6.04	5.8
P Organic: Inorganic	0.33	0.27	0.29	0.30	0.28	0.81	0.55	0.06	0.29	0.3
H3A Potassium	103.8	81.8	71.4	102.8	90.2	1.47	0.30	30	90	92
H3A Calcium	145	169	118	179	201	1.29	0.35	74	163	101
H3A Aluminium	290	280	269	285	294	0.08	0.99	93	284	166
H3A Sulphur	3.18	4.51	2.67	3.57	3.53	1.25	0.37	1.59	3.49	3.0
H3A Zinc	2.51	2.46	2.12	2.83	2.83	0.92	0.50	0.80	2.55	1.5
H3A Magnesium	49.5	53.3	39.6	54.3	59.1	2.07	0.18	13.4	51.2	43.1
H3A Sodium	10.52	12.45	15.80	9.67	13.71	0.77	0.58	7.40	12.4	7.4
% P Saturation (Al/Fe)	5.22	6.64	5.83	5.08	7.10	0.93	0.49	2.40	5.97	10.8
% P Saturation (Ca)	16.4	19.7	21.7	13.2	17.3	1.14	0.40	8.1	17.7	27.9

*Least significant difference at $p \leq 0.10$.

** CO_2-C (mg kg^{-1} C)

Soil nematode study

Reporting by Prof D Fourie, North West University

The full report on the nematode study is attached as Appendix 1. Important conclusions and recommendations from this report are:

- The majority of the cropping sequences migrated to the 'maturing and N-enriched' quadrat from 2021 to 2023. The plant-parasitic nematodes still dominated and overshadowed the positive contribution by beneficial nematodes (Plate 3.4.2).
- The two endoparasitic genera *Meloidogyne* and *Pratylenchus* as well as ectoparasites belonging to the families *Criconematidae* and *Trichodoridae* are the target nematode pests causing nematode infection of crops grown at this trial site.
- The significant increases in abundance of plant-parasitic nematode eggs of the genera *M. incognita* and *M. arenaria* and *Pratylenchus* species in the maize-cover crop-soybean and the maize-maize-soybean systems in particular, as well as substantial numerical increases for the other treatments over the three years of the study is an indication of the conduciveness of all the cropping sequences in maintaining high nematode pest densities.
- Cultivars with low susceptibility (representing poor or resistant hosts to root-knot nematodes) should be selected for inclusion in future.
- The use of environmentally friendly products to reduce densities of the predominant nematode pest genera, e.g., VELUM® 1GR should be considered.

Plate 3.4.2: Cowpea roots severely infected with root-knot nematodes (2021/22-season).

Economic analysis

Reporting by Agri Business Consulting

The economic analysis for the 2022/23 season can be found on page 2 of Appendix 2 and that of the 2020/21 and 2021/22 in their respective progress reports. The operating margins (gross product value minus total specified and fix costs) of the different crops from 2020/21 to 2022/23 are shown in Table 3.4.4.

Table 3.4.4: The operating margins in R ha^{-1} of the different crops in their respective crop systems, from 2020/21 to 2022/23 where MM = mono-culture maize, MS = maize – soybean, MMS 1 and MMS 2 = first and second season maize respectively, in the maize – maize – soybean systems and MCS = maize – cover crop – soybean system.

	Maize					Soybean			Cover
Season	MM	MS	MMS 1	MMS 2	MCS	MS	MMS	MCS	crop
2020/21	9090	8548	8818	4409	14413	13863	15603	9925	5288*
2021/22	-2363	-18	461	-5541	-5893	1417	-3369	213	3456
2022/23	8121	8890	6394	6717	13450	19913	19045	18790	1228*
Mean	4949	5807	5224	1862	7323	11731	10426	9643	3324*

* Estimates

The following observations are of note:

- The operating margin of both maize and soybean varied considerably from season to season.
- Except for the second season maize in the MMS system, the mean operating margin of rotated maize, especially that of maize in the MCS system, were higher than that of mono-cultured maize.
- The operating margin of soybean in the two year MS system was higher than that of the three year MMS and MCS systems.
- Estimating the operating margin for the cover crop in all seasons, the calculated mean operating margin of the crop systems are MS > MCS > MMS > MM.

The MCS system, with the integration of livestock for the utilisation of the cover crop, can be considered a form of "regenerative agriculture" which benefits the soil and sustainability. The relatively high estimated operating margin and the potential benefits of the MCS system valid further exploration.

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3.5 Trial 2: Plant population density as component to the sustainable cultivation of monoculture maize on sandy soil (Farmer co-worker: Lourens van der Linde, Klein Constantia).

Reporting by Dr AA Nel and Mrs M de Bruyn

3.5.1 Aim

The aim of this trial is to determine the effect of plant population density on the yield of maize and to serve as reference point for similar current and previous trials at Hamiltonsrus and Doornbult.

3.5.2 Materials and methods

Cultivar DKC 75-65BR was planted on 21 November 2022 in 1.142 m spaced rows. Fertilization rates were 111 kg N ha^{-1}, 27 kg P ha^{-1} and 19 kg K ha^{-1}. Thirty-seven percent of the fertilizer was applied before planting, the remainder during planting. Glyphosate was applied before planting and a mixture of metolachlor and triazines after planting for weed control. A Latin square layout was used and seeding density as treatment, varied from 20 000 to 45 000 ha^{-1}.

Due to the heavy rainfall shortly after planting, emergence of seedlings was affected, leaving patches where hardly any plants survived (Plate 3.5). The final plant population density, excluding bare patches, correlated moderately well with the seeding density (Figure 3.5).

3.5.3 Results and discussion

Due to the bare patches where the plant population was very low and uneven (Plate 3.5) it was decided to discontinue any further measurements on this trial.

Plate 3.5: Patches' photographed on 23 May 2023, overgrown by weeds. These initially bare patches were caused by heavy rains shortly after planting which led to the failure of seedlings emergence.

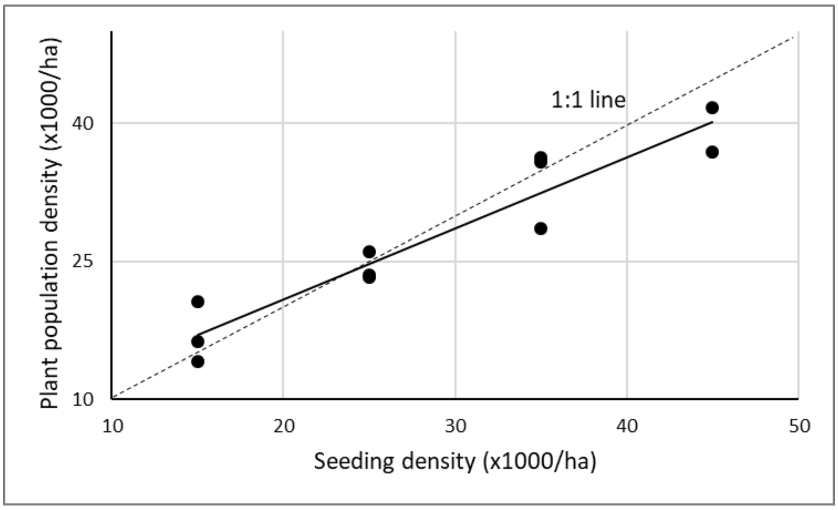


Figure 3.5: Final plant population density versus the seeding density of maize at Klein Constantia in 2022/23 on patches with good emergence.

3.6 Trial 3: Plant population density as component to the sustainable cultivation of maize in rotation with soybean on sandy soil (Farmer co-worker: Danie Minnaar, Hamiltonsrus).

Reporting by Dr AA Nel

3.6.1 Aim

The aim of this trial is to determine the optimal plant population density of maize over several seasons and to serve as reference point for the similar trials at other localities.

3.6.2 Materials and methods

The cultivar DKC 76-73R was planted on 25 November 2022 in 1.5 m spaced rows in a rip-on-row (75 cm deep) tillage system. At planting, 200 kg ha^{-1} 1:1:1 (29) was applied. Again, plots consisted of five rows (one planter width) for the length of the land. Treatments consisted of a series of seeding densities ranging from 17 500 to 40 000 ha^{-1}. The layout was a randomised complete-block design with four replicates.

3.6.3 Results and discussion

Heavy rains during emergence resulted in a severe loss of seedlings. A very poor relationship between the seeding rate and the final plant population density resulted due to the unfavourable conditions during germination and emergence (Figure 3.6). Due to the low and variable plant population density, invalidating all treatments, it was decided to abandon this trial.

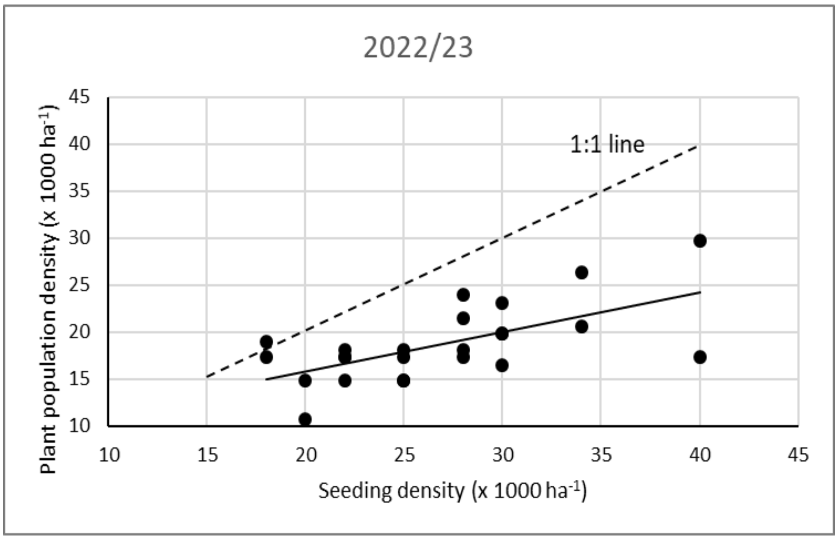


Figure 3.6: The final plant population density vs. the seeding density of maize at Hamiltonsrus in 2022/23.

3.7 Trial 4: Plant population density as component to the sustainable cultivation of maize in rotation with wheat on sandy soil (Farmer co-worker: Martin Stols, Arbeidadel).

Reporting by Dr AA Nel

3.7.1 Aim

The aim of this trial was to determine the optimal plant population density of maize over several seasons and to serve as reference point for previous similar trials at Klein Constantia and Hamiltonsrus.

3.7.2 Materials and methods

The cultivar PAN 5R-891BR was planted on 5 January 2023 in 0.82 m spaced rows in a rip-on-row (40 cm deep) tillage system. The previous crop was wheat which was harvested in November 2022. During the ripping action, 75 kg ha^{-1} KCl was applied. At planting, 180 kg ha^{-1} 3:2:1 (30) was applied and 1:0:0 (40) at 225 kg ha^{-1} was applied four weeks later. Treatments were seeding densities of 20 000, 30 000, 40 000 and 45 000 ha^{-1}. The layout was a randomised complete-block design with four replicates. The crop was harvested during July 2023.

3.7.3 Results

The final plant population density was not recorded, therefore only the planting density (or seeding density) can be considered. Surprisingly, the grain yield was unaffected ($p \leq 0.10$) by the planting density (Table 3.7).

Table 3.7: F-ratio's and probabilities of the planting density trial at Arbeidadel in 2022/23.

Source	F-ratio	Probability (p)
Density	1.81	0.21
Replicates	2.38	0.14

Yields for the planting densities are shown in Figure 3.7. The fitted curve follows the expected trajectory. Using the relationship shown in the figure, the estimated optimum is 34 000 plants ha^{-1} with a corresponding yield of 6.44 t ha^{-1}. Despite the low correlation coefficient and lack of significance, the estimated optimum planting density corresponds well with previously found optimums at Klein Constantia and Doornbult with the seed price at R2 887.50 per 60 000 seeds; grain price at R2 900 t^{-1}.

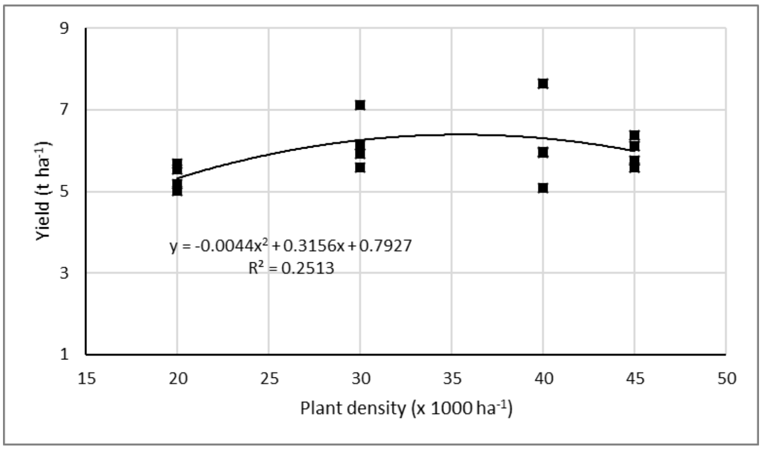


Figure 3.7: The yield vs planting density at Arbeidadel in 2022/23.

3.8 Trial 5: The effect of timing of nitrogen fertilization on the yield of maize on an extremely sandy soil (Farmer co-worker: Danie Minnaar, Klein Hamiltonsrus, 2022/23).

Reporting by Dr AA Nel

3.8.1 Aim

This has been the third season of this trial with the objective to determine if the timing of top dressed N will improve the efficiency of nitrogen uptake as reflected by the crop yield.

3.8.2 Results and discussion

The trial, among others, was severely damaged by an exceptionally amount of rain shortly after planting in November 2022 and before any treatments could be applied. Due to the lack of an even plant population density and possible leaching of already applied nitrogen, it was decided to abandon this trial.

3.9 Trial 6: The effect of crop rotation on the yield of maize in rotation with soybean on sandy soil (Farmer co-worker: Danie Minnaar, Springboklaagte).

Reporting by Dr AA Nel

3.9.1 Aim

The aim of this demonstration trial has been to compare the yield of maize in monoculture with the yield of maize rotated with soybean. The trial also serves as demonstration to visitors.

3.9.2 Materials and methods

Three strips, or replicates, of maize (cultivar DKC 75-65BR) were planted at a rate of 27 500 seed ha^{-1} in 1.5 m spaced rows on 24 October 2022 where soybean was planted in 2021/22. One of these strips had maize during 2021/22. The fertilizer mixture 18:5:4 (27) was pre-planted applied at a rate of 100 kg ha^{-1} during August 2022. At planting, 200 kg 18:5:4 (27) ha^{-1} was applied followed by a top dressing of 100 kg 18:5:4 (27) ha^{-1} four weeks after planting. Three replicates, or strips, of soybean (PAN 1521R) were planted at a rate of 300 000 seed ha^{-1} in 1.5 m spaced rows on 24 October 2022, where maize was planted in 2021/22. The fertilizer mixture 18:5:4 (27) was applied pre-planted at a rate of 125 kg ha^{-1} in August 2022 with no additional fertilizer later on.

3.9.3 Results and discussion

The crops were well established before the heavy rain of November 2022 and grew well (Plate 3.9). Although not clear from the photo, it was observed that the soybean appeared to be less affected by the wet conditions than the maize. The soybean yield was 3.7 t ha^{-1}. The yield of maize after soybean was 6.52 t ha^{-1} and in monoculture 6.58 t ha^{-1} which is the first time during the existence of this demonstration trial that these yields were similar. The results of this trial, however, confirms the conclusion reached from other research that the yield of maize after soybean equals, or, is higher than the yield of monoculture maize.

Plate 3.9: Soybean and maize in rotation in January 2023.

3.10 Trial 7: Evaluation of nitrogen fertilization rates of maize on sandy soil with a water table (Farmer co-worker: Danie Minnaar, Springboklaagte).

Reporting by Dr AA Nel

3.10.1 Aim

The objective was to find the optimum nitrogen fertilisation rate on sandy soil with a water table and is a continuation of the trial which started in 2019/20 and which is reported on in the September 2021 annual report. The 2021/22 trial failed due to extremely wet conditions during which the intended treatments could not be applied.

3.10.2 Materials and methods

This trial was planted in November 2022. The fertilizer mixture 1:1:1 (29) was applied at a rate of 200 kg ha^{-1}. Wheat was the previous crop, harvested during early November 2022. Shortly after harvesting, the land was ripped (65-70 cm deep) with no application of any pre-plant fertilizer. Due to poor emergence of seedlings, the trial was replanted on 28 December 2022 with the cultivar PAN 491B at 27 27 500 seeds ha^{-1}. During the replanting, 150 kg 1:1:1 (29) ha^{-1} was applied. The experimental design was a randomized complete-block with fertilization rates as treatments at five levels: 110, 140, 200, 250 and 310 kg N ha^{-1} with 3 replicates. Urea (46% N) was used for the treatments and applied five weeks after planting. Taking the initial applied fertilizer into account the final application rates or treatments were 84, 98, 126, 149 and 176 kg N ha^{-1}.

3.10.3 Results and discussion

No differences between the lowest and highest N rates (84 kg ha^{-1} vs. 176 kg ha^{-1}), nor any deficiency symptoms, were visible (Plate 3.10) during the growing season.

Plate 3.10: The N fertilization trial on 7 March 2023 (left 84 kg N ha^{-1} and right 176 kg N ha^{-1}).

The yield, however, was significantly affected ($p < 0.01$) by the application rates. The yield increased curvilinearly with increasing nitrogen fertilization rates (Figure 3.10) as expected.

Table 3.10.1: F-ratio's and probabilities of the nitrogen fertilization rate trial at Springboklaagte in 2022/23.

Source	F-ratio	Probability (p)
N-rate	13.5	<0.01
Replicates	0.91	0.44

Economically optimum fertilization rates are determined by the fertilizer price to grain prices ratio and the regression equation. The optimum fertilizer rates for a series of fertilizer and grain prices, derived from the relationship shown in Figure 3.10, are shown in Table 3.10.2 for a yield target of 8 t ha^{-1}. Further trials are needed to create guidelines for a range of target yields.

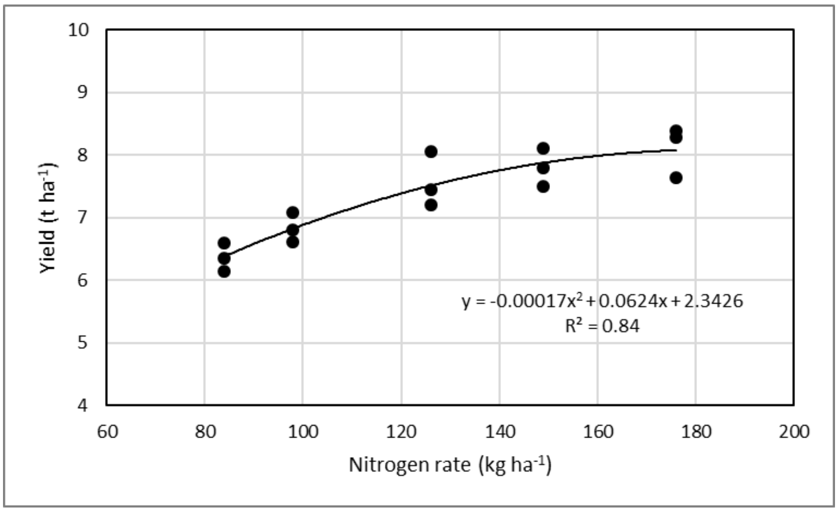


Figure 3.10: Yield response to top dressed nitrogen rates at Springboklaagte in 2022/23 with urea as nitrogen source.

Table 3.10.2: The economically optimum nitrogen fertilization rates in kg ha^{-1} for a series of fertilizer and grain prices at a yield potential of 8 t ha^{-1}

Nitrogen price	Grain price (R t^{-1})		
(R kg^{-1})	3000	3500	4000
20	164	167	169
28	156	160	163
36	148	153	157

3.11 Trial 8: Evaluation of nitrogen fertilisation rates of maize on sandy soil with a water table (Farmer co-worker: Martin Stols, Arbeidadel).

Reporting by Dr AA Nel

3.11.1 Aim

The objective is to find the optimum nitrogen fertilization rate on sandy soil with a water table.

3.11.2 Materials and methods

The trial was planted on 5 January 2023 with the cultivar PAN 5R-891BR at 24 000 ha^{-1} in 0.82 m spaced rows. Fertilizer (1:1:1 (21)) was applied at a rate of 200 kg ha^{-1}. Wheat was the previous crop, harvested during November 2022. In December 2022 the land was ripped (40 cm deep) and 75 kg KCl ha^{-1} applied. During planting, 180 kg 3:2:1 (30) ha^{-1} was applied. The experimental design was a randomized complete block design with fertilization rates as treatments at six levels: 75, 125, 175, 225, 275 and 325 kg 1:0:0 (40) ha^{-1} and five replicates. These treatments were applied four weeks after planting.

3.11.3 Results and discussion

Contrary to what was expected the yield was not affected ($p = 0.49$) by the nitrogen fertilization rates as indicated by the analysis of variance shown in Table 3.11.

Table 3.11: F-ratio's and probabilities of the nitrogen fertilization rate trial at Arbeidadel in 2022/23.

Source	F-ratio	Probability (p)
N-rate	0.91	0.49
Replicates	5.80	<0.01

The relationship between the yield and nitrogen rates are shown in Figure 3.11. The relationship is very weak and no meaningful deduction about the optimum nitrogen can thus be made.

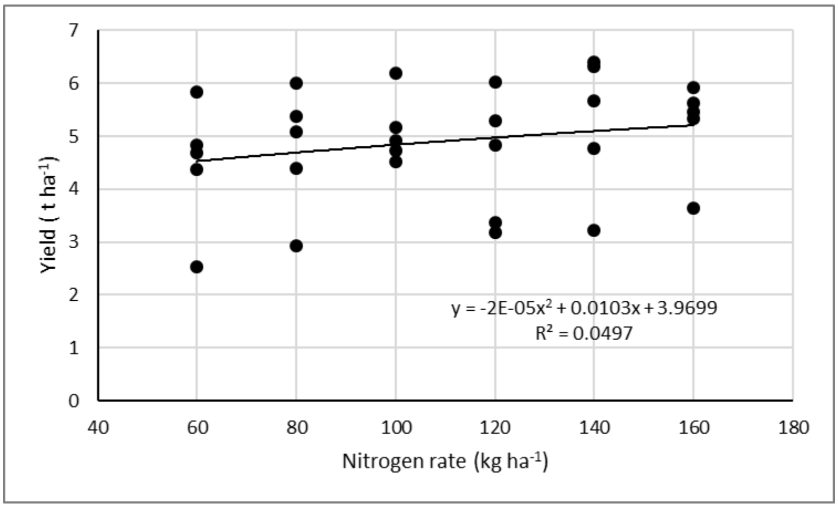


Figure 3.11: Yield versus the top dressed nitrogen application rate at Arbeidadel in 2022/23 with 1:0:0 (40) as nitrogen source.

3.12 Trial 9: Comparison of seasonal ripping with ripping every second season under stubble-mulch with mono-culture maize on sandy soil (Farmer co-worker: Lourens van der Linde, Klein Constantia, Wesselsbron).

Reporting by Dr AA Nel

3.12.1 Aim

The aim of this trial was to determine how the yield of maize is affected by a seasonal rip-on-row system compared to a rip-on-row every second season (or rip-on-row-no-till system) and a continues no-till system.

3.12.2 Materials and methods

Tillage systems, as treatments, consisted of rip-on-row and no-tillage. The ripping depth was 0.75 m using a tandem ripper. Cultivar DKC 75-65BR was planted on 15 November 2022 in 1.142 m spaced rows at a seeding density of 24 500 ha^{-1}. Fertilization rates were 111 kg N ha^{-1}, 27 kg P ha^{-1} and 19 kg K ha^{-1} with two-thirds applied at planting and one third as topdressing. Glyphosate was applied before planting and a mixture of metolachlor and triazines after planting for weed control. Due to the unstructured layout of the trial, seasonal treatment mean values were compared by using the comparison of two sample means, unpaired observations with equal variances.

3.12.3 Results

Yield

No waterlogging during the 2022/23 season and little damage, if any, was caused by the heavy rainfall shortly after planting. The final plant population density was 23 684 plants ha^{-1}, less than 4% lower than the seeding density.

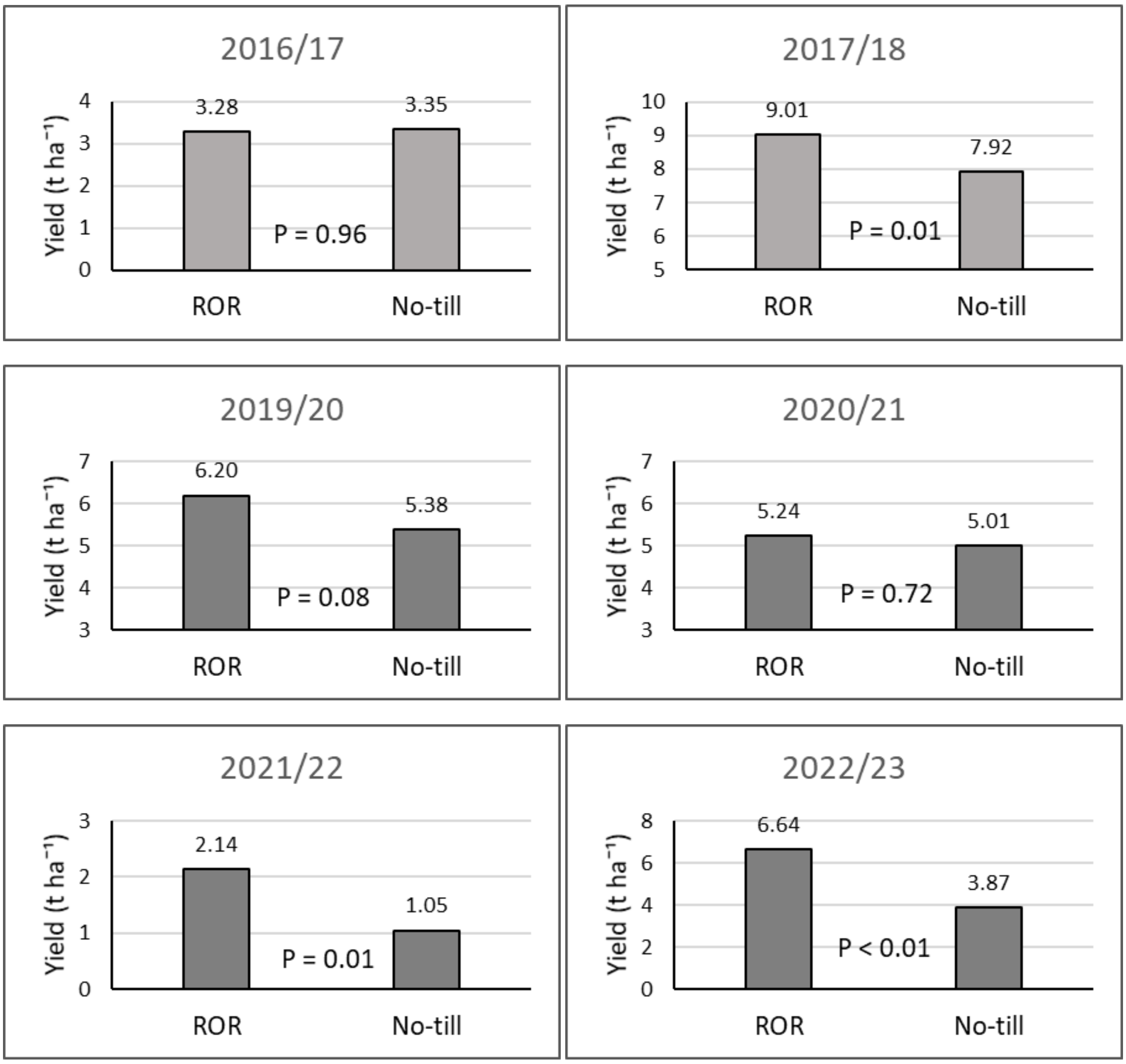
In 2022/23, as in previous seasons, yields of the seasonal alternating rip-on-row-no-till and continuous no-till systems, respectively, were similar. Accordingly, the yields of these two systems were combined and regarded as a single no-till treatment. The yields of the rip-on-row system was 2.75 t ha^{-1} higher than the yield of the no-till system in 2022/23 (Figure 3.12).

Also shown in Figure 3.12, are the results from seasons in which the trial was successful. In four of the seasons, the yield of the rip-on-row system was between 0.82 t ha^{-1} and 2.75 t ha^{-1} higher than the yield of the no-till system while in two seasons the yields were similar. This indicates that a tillage system x season interaction exists, meaning that the expected yield difference between the two systems can be nullified by a seasonal effect. Taking all six seasons into account, the mean yield of the rip-on-row system was 0.99 t ha^{-1} higher than the yield of the no-till system (Figure 3.12).

Economic analysis

By Agribusiness Consulting

The economic analysis for the 2022/23 season can be found on page 1 of Appendix 2. The conclusion from this report reads as follows: If the best margins and yields are taken into account over the period from the 2016/2017 season up and including the 2022/2023 year, it is a fact that the ROR practice has outperformed the no-till practice.



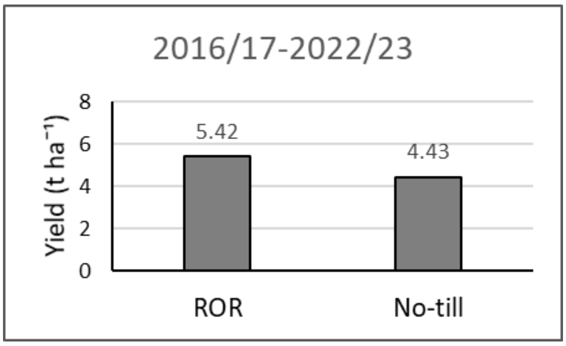


Figure 3.12: The yield of the rip-on-row and no-till systems from 2016/17 to 2022/23.

3.13 Trial 10: Comparing different nitrogen fertilizer products, with and without urease and nitrification inhibitors, on maize (Farmer co-worker: Danie Minnaar, Springboklaagte).

Reporting by Dr AA Nel

3.13.1 Aim

The aim of this trial was to determine if the yield of maize is affected by different types of N fertilizer products, with and without inhibitors, at equal N fertilization rates. This new trial was initialized in view of the sharp increase of fertilizer prices in 2022, as well as other concerns. This trial is a variation of similar trials at Erfdeel (Section 2.12), Mineview (Section 2.13) and Rietgat (Section 2.14).

3.13.2 Materials and methods

The trial was planted on 12 December 2022 on a land where wheat was harvested during November. The soil was ripped 65-75 cm deep. At planting, 200 kg 1:1:1 (29) ha^{-1} was applied. Due to heavy rain during emergence the plant population density was unsatisfactory. Subsequently, the trial was replanted 28 December 2022 with 150 kg 1:1:1 (29) ha^{-1}.

Table 3.13.1: Treatments and total N, P and K applied.

Top-dressed fertilizer products	Planting + top-dressed (kg ha^{-1})		
	N	P	K
Zero	34	34	34
Urea at 200 kg ha^{-1}	126	34	34
Urea + DetaiN at 200 kg ha^{-1}	126	34	34
10:1:2 (31) at 380 kg ha^{-1}	124	42	51

The cultivar was PAN5B-491B at a seeding rate of 24 000 ha^{-1} in 1.5 m spaced rows. The final plant population density was 22 700 ha^{-1}. Treatments consisted of top dressed fertilizer products applied 22 days after planting (Table 3.13.1). The trial layout was a randomized complete-block design with four replicates.

Soil samples (0-30 cm and 30-60 cm depth increments) were taken once a month during the season on three replicates. The temporary water table was also sampled and the depth recorded. The soil and water samples were analysed for their NO_3 and NH_4 contents. Leaf samples were collected on three replicates 105 days after planting and analysed for their nitrogen content.

3.13.3 Results and discussion

The maize grew very well, showing N deficient plants of the control (left), compared to the lush growth of a 200 kg urea ha^{-1} application (right) (Plate 3.13).

Plate 3.13: Growth differences as function of N product application (12 April 2023).

The yield was significantly affected ($p \leq 0.01$) by the products (Table 3.13.2). The yield of urea + DetaiN was 0.63 t ha^{-1} (9%) higher than the yield obtained with urea (Figure 3.13.1).

Table 3.13.2: F-ratio's and probabilities of the nitrogen products trial at Springboklaagte in 2022/23.

Source	F-ratio	Probability (p)
N-product	549	<0.01
Replicates	4.92	0.03

The yield obtained with 10:1:2 (31) was 0.89 t ha^{-1} (13%) higher than the yield measured with urea and a significant 0.26 t ha^{-1} (4%) higher than the yield of the urea + DetaiN. Such a reaction is expected when the P and, or, K contents of the soil were at deficient levels. However, the P (Bray 1) content was 29 mg kg^{-1} and the K content was 120 mg kg^{-1}, both considered to be in the non-yield limiting range.

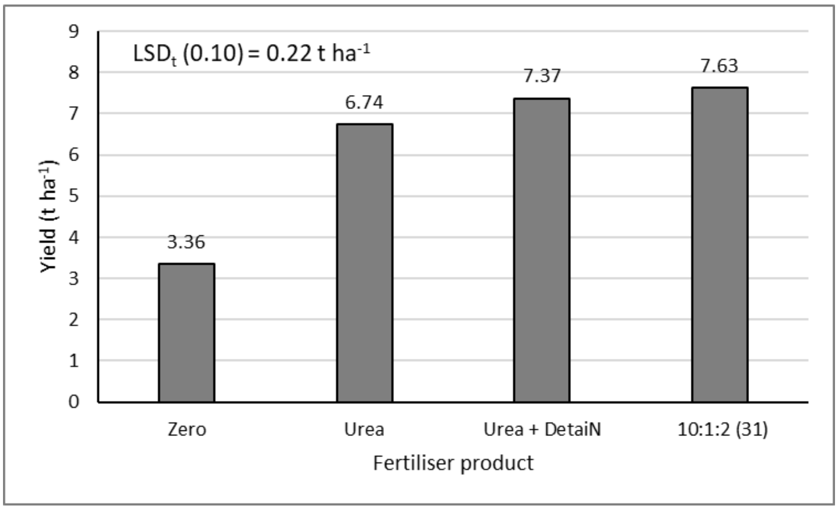


Figure 3.13.1: The yield of maize as affected by top dressed fertilizer products at Springboklaagte in 2022/23.

Soil and leaf nutrient study

Reporting by Drs AA Nel and DJ Beukes

Soil samples of the 0-30 cm and 30-60 cm depth increments of all plots were taken at regular intervals and analysed by EnviroTek Laboratory for NO_3-N and NH_4-N content. Maize leaf samples were taken on 12 April 2023 and analysed by EnviroTek Laboratory for leaf N. Statistical analyses were performed to test for treatment differences. The results are shown in Figure 3.13.2.

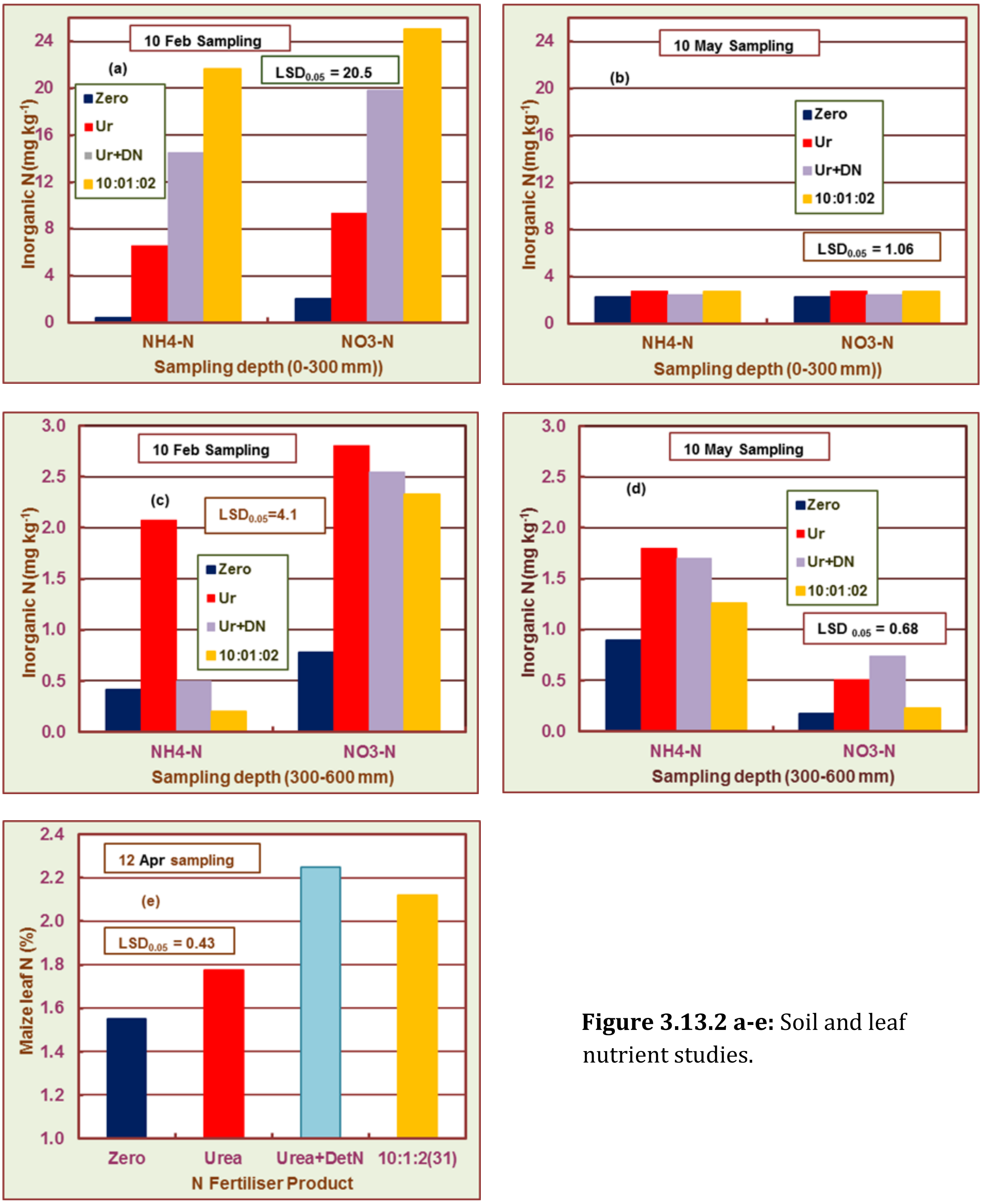


Figure 3.13.2 a-e: Soil and leaf nutrient studies.

The following observations are of note (Figures 3.13.2 a-e):

- Figure 3.13.2 a-b (0-300 mm): The sampling of 10 Feb 2023 indicated large differences (statistically significant) in soil inorganic N caused by the various N products. By 10 May 2023, however, this soil layer was almost depleted in terms of inorganic N, due to uptake of N by the maize.
- Figure 3.13.2 c-d (300-600 mm): This soil layer contained very little inorganic N (<3 mg N kg^{-1}) on 10 Feb 2023 and even less inorganic N by 10 May 2023. It must be noted that the treatments were surface applied.
- Figure 3.13.2 e (leaf N): The leaf N (12 Apr) trend as a function of the N products shows good similarity with the soil N trends of 10 Feb (Figure 3.13.2 a), indicating major N uptake by the maize around the latter date.

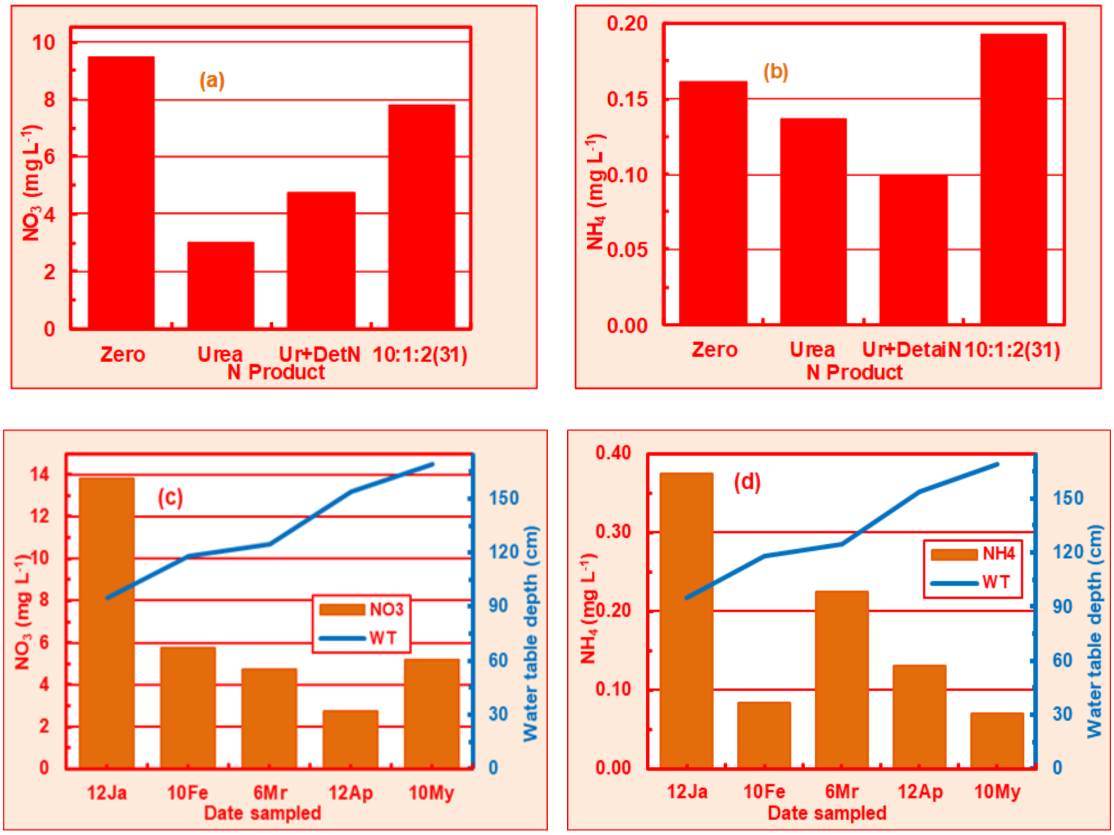
Seasonal water table study

Reporting by Drs AA Nel and DJ Beukes

To sample the water table (WT), conduit pipes with perforated bottom ends were installed in January 2023 to a depth of 2 m on four plots to represent the various types of N fertilizer products. Sampling of the WT by syphoning was done at regular intervals. Chemical analyses were done by the Analytical Laboratory of ARC-SCW.

The following observations are of note (Figures 3.13.3 a-e):

- Figure 3.13.3 a-b: Seasonal mean (January - May) soil NO_3- and NH_4-values as a function of the N products are depicted. Unlike previous studies, low NO_3- and NH_4-values were measured, perhaps masking the anticipated effects of the urease and nitrification inhibitors of DetaiN. Judging in general the DetaiN values, it does appear as if the inhibitors had a reducing effect on these two ions, thereby contributing to less contamination of the WT.
- Figure 3.13.3 c-d: As the growing season progressed, the NO_3- and NH_4-values in the WT kept reducing, probably due to increased uptake of these ions by the maize in the soil profile, thereby reducing flow of these ions to the WT. Noticeable is the lowering of the WT (also in Figure 3.13.3 e) as the season progressed due to water uptake by the maize in the soil profile, thereby intercepting any flow to the WT.
- Figure 3.13.3 e: Unlike other seasons, there is not a clear relationship between rainfall and the depth of the WT.



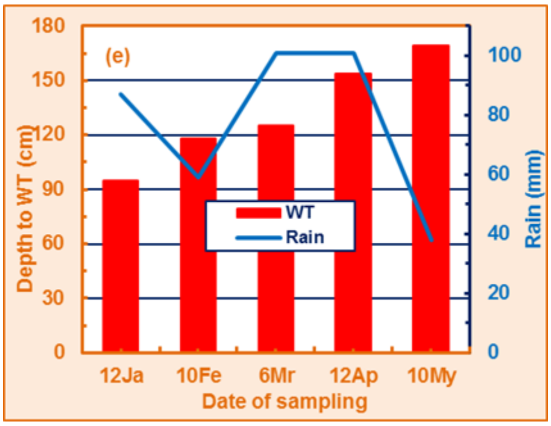


Figure 3.13.3 a-e: Seasonal water table characteristics.

3.14 Trial 11: Comparing different nitrogen fertilizer products, with and without urease and nitrification inhibitors, on maize (Farmer co-worker: Anievaalboerdery, Erfdeel).

Reporting by Dr AA Nel

3.14.1 Aim

To determine if the yield of maize is affected by different nitrogen fertilizers with and without inhibitors and application timing, consisting of two application dates, at equal nitrogen fertilization rates. This trial is a variation of similar trials at Springboklaagte, as well as at Mineview and Rietgat.

3.14.2 Materials and methods

The soil was ripped 75 cm deep (Rip-on-row) during October 2022 on a land where maize was produced in 2021/22. Compost with a composition of 293:120:329 (4.33) + 0.6% S was applied at a rate of 6.73 t ha^{-1} and incorporated to a depth of 5 cm on 27 October 2022. On 3 December 2022, cultivars PAN 5R-891BR (66%) and PAN 5R-785BR (2:1 mixture) were planted in 1.183 m spaced rows at a seeding density of 36 339 ha^{-1}. During planting on 3 December 2022, a fertilizer mixture of 176 kg 6:1:0 (26) ha^{-1} was applied.

Two fertilizer mixtures with and without inhibitors were applied either before planting or as a top-dressing (Table 3.14.1). Application timing was one or two days before planting (preplant) and 40 days after planting (top-dressed). The trial layout was a randomized complete block design with four replications.

Table 3.14.1: Fertilizer mixtures (with and without inhibitors) and application rates and application timing (pre-planting at 30 November and 1 December 2022 or top-dressed 40 days after planting on 12 and 13 January 2023).

No	Treatment combinations	Rate (kg ha^{-1})	Application date
1	Pre-plant 1:0:0 (40) + 6% S (urea + amm. sulphate)	207	30 Nov. 2022
2	Pre-plant 1:0:0 (40) + 6% S + DetaiN (urea + DetaiN + amm. sulphate)	208	1 Dec. 2022
3	Pre-plant 1:0:0 (26) + 4% S (CAN + amm. sulphate)	389	1 Dec. 2022
4	Pre-plant 1:0:0 (26) + 4% S + InnoX (CAN + Innox+ amm. sulphate)	316	30 Nov. 2022
5	Top-dress 1:0:0 (40) + 6% S (urea + amm. sulphate)	206	12 Jan. 2023
6	Top-dress 1:0:0 (40) + 6% S + DetaiN (urea + DetaiN + amm. sulphate)	210	12 Jan. 2023
7	Top-dress 1:0:0 (26) + 6% S (CAN + amm. sulphate)	314	12 Jan. 2023
8	Top-dress 1:0:0 (26) + 6% S + InnoX (CAN + Innox+ amm. sulphate)	317	13 Jan. 2023

3.14.3 Results and discussion

The yield was significantly affected by the application timing (p = 0.05) and by the fertilizer mixtures (Table 3.14.2). No significant interaction between the application timing and fertilizer mixture occurred.

Table 3.14.2: F-ratio's and probabilities of the fertilizer mixtures and application timing trial at Erfdeel in 2022/23.

Source	F-ratio	Probability (p)
Timing	4.24	0.05
Mixture	4.00	0.02
Interaction	1.41	0.27
Replicates	2.75	0.07

The mean yield of the top-dressed fertilizer was 0.27 t ha^{-1} (3%) higher than the yield of the pre-planting fertilizer (Figure 3.14.1). This is expected as top-dressed nitrogen fertilizer is more in time with the nitrogen uptake and less subjected to losses than pre-planted nitrogen fertilizer.

Yields recorded for the fertilizer mixtures are shown in Figure 3.14.2. The application of the inhibitors DetaiN and InnoX to urea and CAN based mixtures did not result in a yield increase.

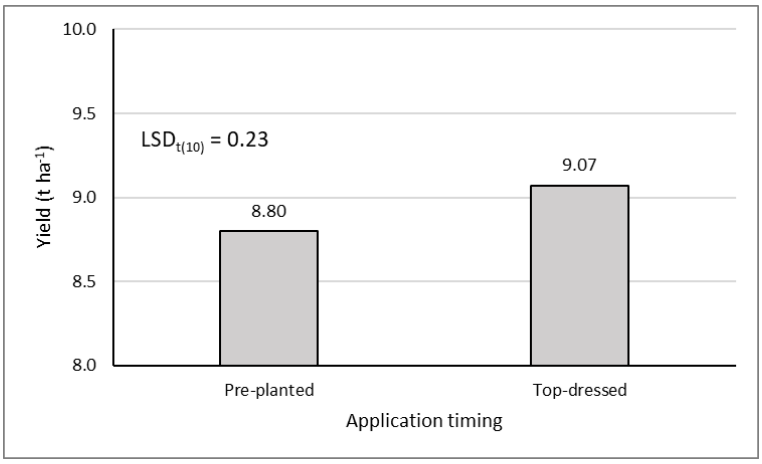


Figure 3.14.1: The yield of maize as affected by the application timing of nitrogen fertilizer mixtures at Erfdeel in 2022/23. Application timing was one or two days before planting (pre-plant) and 40 days after planting (top-dressed).

The two CAN based fertilizer mixtures had a mean yield advantage of 0.44 t ha^{-1} (or 5%) over the mean yield of the urea based fertilizer. It is well known that urea is more subjected to losses than other nitrogen based fertilizers which is most likely also what happened in this trial.

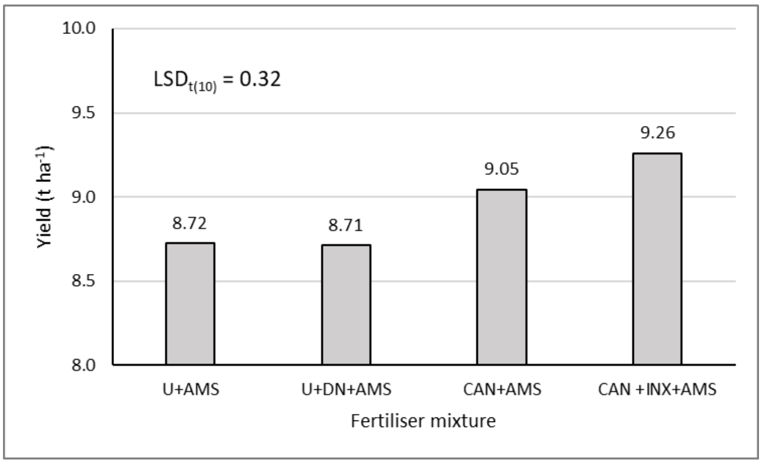


Figure 3.14.2: The yield of maize as affected by fertilizer mixture at Efdeel in 2022/23. The mixtures were: Urea + ammonium sulphate (U+AMS), Urea + DetaiN + ammonium sulphate (U+DN+AMS), calcium ammonium nitritate + ammonium sulphate (CAN + AMS) and calcium ammonium nitritate + InnoX + ammonium sulphate (CAN + INX + AMS).

3.15 Trial 12: Comparing different nitrogen fertilizer products, with and without urease and nitrification inhibitors, on maize (Farmer co-worker: Martin Stols, Mineview).

Reporting by Dr AA Nel

3.15.1 Aim

To determine if the yield of maize is affected by different nitrogen fertilizers plus inhibitors. This trial is a variation of similar trials at Springboklaagte, Erfdeel, and Rietgat.

3.15.2 Materials and methods

The trial was planted on 9 December 2022 on a land where soybean was produced in 2021/22. The soil was ripped 40 cm deep in September 2022. At planting, 250 kg 3:2:1 (30) kg ha^{-1} + 75 kg KCL kg ha^{-1} was applied. The cultivar was DKC75-65BR at a seeding rate of 24 000 ha^{-1}. In rows spaced 0.82 m apart. Treatments consisted of Greensulf fertilizer at a rate of 308 kg ha^{-1} with or without the inhibitor Innox applied as topdressing at growth stage V4 or growth stage V8. Growth stage V4 is reached about 20 days after planting and stage V8 about 32 days after planting. The fertilizer was spread on the soil surface.

3.15.3 Results and discussion

Grain yields were significantly ($p \leq 0.10$) affected by an interaction between InnoX and the growth stage as shown in Table 3.15. The interaction is displayed in Figure 3.15. Yields of the untreated Greensulf applied at V4 and V8 was similar while the yield of the InnoX treated Greensulf applied at stage V8 was 0.63 t ha^{-1} (8%) higher than when it was applied at growth stage V4. Remarkable, is that no rain fell between the two application stages which could have influenced the response. Almost 100 mm of rain was recorded shortly after the V8 application.

Table 3.15: F-ratio's and probabilities of the Greensulf + inhibitor and application timing combinations at Mineview in 2022/23.

Source	F-ratio	Probability (p)
Inhibitor	0.51	0.48
Timing	2.12	0.16
Interaction	3.42	0.08
Replicates	3.61	0.01

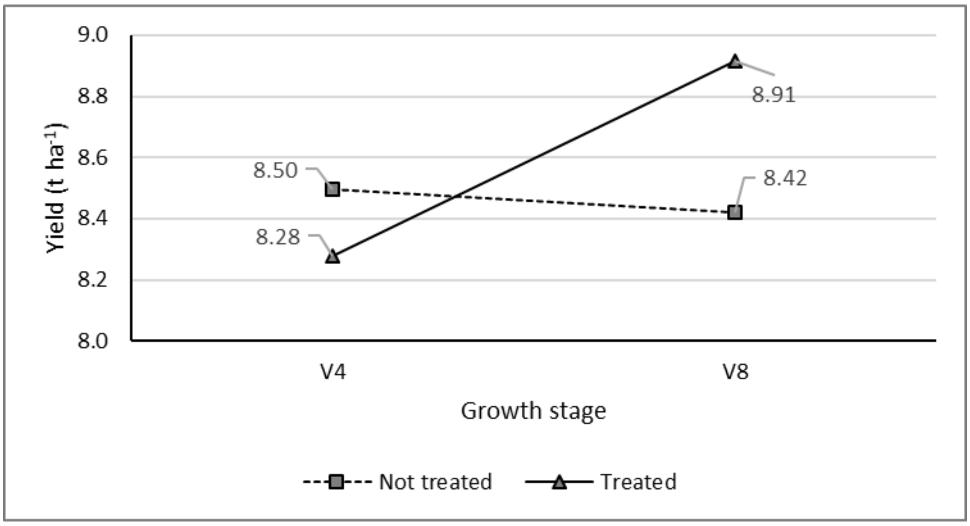


Figure 3.15: Yields obtained with Greensulf untreated, and treated with InnoX, applied at either growth stages V4 or V8 at Mineview in 2022/23.

3.16 Trial 13: Comparing different nitrogen fertilizer products and inhibitors, on maize (Farmer co-worker: Thabo van Zyl, Rietgat).

Reporting by Dr AA Nel

3.16.1 Aim

To determine if the yield of maize is affected by different nitrogen fertilizer mixtures, some with inhibitors, at equal nitrogen fertilisation rates. This trial is an extension of the trials at Springboklaagte, Erfdeel and Mineview.

3.16.2 Materials and methods

The trial was planted during December 2022 on a land where maize was produced in 2021/22. The soil was ripped 75 cm deep in September 2022. At the same time 100 kg urea ha^{-1} was applied at a depth of 0.3 m to 0.4 m to the whole trial area. Maize, cultivar DKC 77-77BR, was planted during December 2022 with 320 kg 11:5:2 (18) at a seeding density of 30 000 ha^{-1} at a mean row width of 1.01 m. The treatments consisted of top-dressed fertilizer at rates that equals 22 kg N ha^{-1}:

1. 3:0:1 (41) + 5.5% S (with urea as N-source)
2. 3:0:1 (41) + 5.5% S (with urea as N-source + Azanon)
3. 3:0:1 (41) + 5.5% S (with urea as N-source + DetaiN)
4. 3:0:1 (29) (with ammonium nitrate as N-source)
5. Urea
6. Greensulf (35) (with ammonium nitrate as N-source)

The trial had a randomised complete-block layout with four replications.

3.16.3 Results and discussion

Yields were not affected by the fertilizer products (Table 3.16). However, some significant differences were present between some individual fertilizers (Figure 2.16).

Table 3.16: F-ratio's and probabilities of the fertilizer product trial at Rietgat in 2022/23.

Source	F-ratio	Probability (p)
Fertilizers	1.85	0.19
Replicates	6.82	0.01

Yields obtained with the application of urea and Greensulf were significantly higher than yields obtained with 3:0:1 (29) and 3:0:1 (41) + Azanon. The addition of Azanon and DetaiN, the two inhibitors, to 3:0:1 (41) respectively, could not increase the yield as was expected. However, these unexpected results are unreliable due to an uneven occurrence of damage in plots, caused by water logging. Yields within plots varied from less than 2.5 t ha^{-1} to more than 8.4 t ha^{-1} (Field map 3.16).

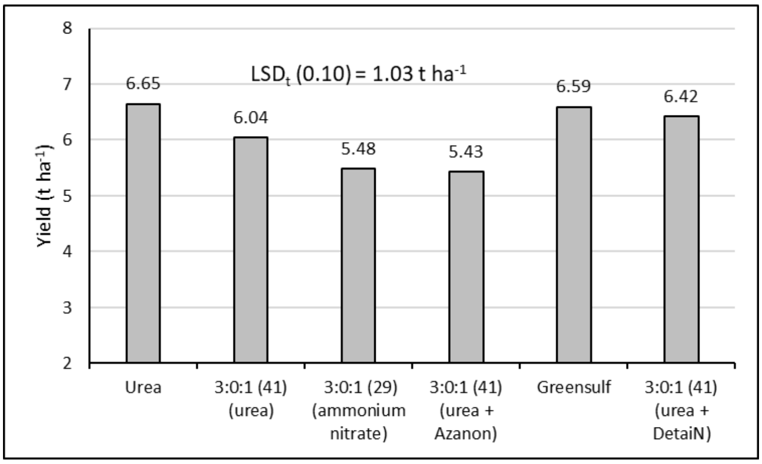
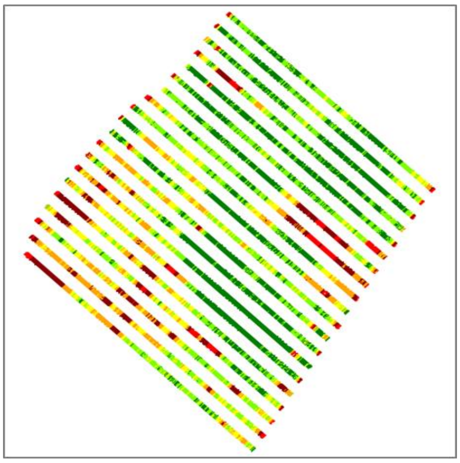
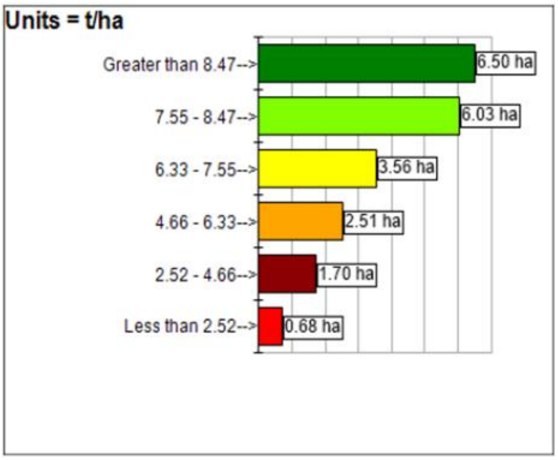


Figure 3.16: The yield of maize as affected by nitrogen fertilizer products and inhibitors at Rietgat in 2022/23.





Field map 3.16: Yield map of the 21 ha trial area showing the large yield variation due to water logging. Strips represent treatment plots.

4 Deliverables and milestones

The following Deliverables and Milestones are reported on in Section 2:

Deliverables:

- Views and perspectives of North-Western Free State farmers on crop diversification.
- Crop yields.
- Plant population density.
- Soil fertility data.
- Soil health parameters.
- Data on temporal chemical composition of water table.
- Soil nematode dynamics

Milestones:

Due to the variation in seasonal weather and its effects on the outcome of agronomic trials, milestones can only be reached after several years of repeating these trials. However, real progress has been made in terms of the following milestones since the onset of this project:

- Seasonal rainfall amounts and temporal distribution (2020/21 to 2022/23).
- General crop growth and biomass yields in the crop rotation trial (2020/21 to 2022/23).
- Effects of planting density on maize growth and grain yields (2020/21 to 2022/23).
- Evaluation of rates of nitrogen fertilisation on maize growth and grain yields (2020/21 to 2022/23).
- Effects of timing of N fertilisation on maize grain yields and milling quality of maize (2020/21).
- Effects of tillage depth on growth and yields of maize and soybean in 2020/21.
- Quantification of various crop rotation systems on the growth and yield of crops (2020/21 to 2022/23).
- Results that suggest that maize grain yield is affected by tillage x season interactions (2020/21 to 2022/23).
- Enterprise financial analyses (2020/21 to 2022/23).
- Temporal records of soil water and temperature regimes (2020/21).
- Soil water and temperature figures as function of trial treatments (2020/21).
- Water use and water productivity of crops as function of trial treatments (2020/21).
- Soil fertility and soil carbon values (2020/21 to 2022/23).
- Interaction between soil and maize leaf nitrogen status (2022/23).

5 Scientific Outputs

Scientific papers:	De Bruyn MA, Nel AA, Van Niekerk JA. 2022. Views and perspectives of local farmers on crop diversification in the North-Western Free State, South Africa. African Journal of Agricultural Research. 18 (11): 1006-1012. A submitted article: *The effect of crop rotation on soil health in the North-Western Free State, South Africa* by De Bruyn MA, Nel AA, Van Niekerk JA, was accepted in November 2023 for publication by the South African Journal of Plant and Soil.
Technical reports:	Annual progress reports 2021 and 2022.
Articles in industry magazines:	Published in SA Grain: Klimaatsverandering: Kan dekgewasse impak versag? November 2021. Beter resultate met dieper bewerking, wys Vrystaat-studie. February 2022. VS-sandgronde nie sondebok in aardverwarming. Junie 2022. Bemesting 'n fyn balanseertoertjie op dié gronde. Julie 2022. Factors influencing the crop rotation decisions of North-Western Free Sate Farmers. September 2022. Wisselbou: 'n Bousteen van volhoubare graanproduksie. February 2023. Published in Landbouweekblad Plantdigtheid: hier lê die goue middeweg. 23 December 2021. Bewerkingsdiepte op sandgrond: hoe diep is diep genoeg? 17 March 2022. Boer ál beter op SA se watertafelsandgrond. 28 April 2022.
Conference contributions:	"Measuring soil health of agricultural fields using nematodes as bioindicators: omitting crucial information about root health confounds results (authors: Prof Driekie Fourie, Me Mieke Daneel and Prof Gerhard du Preez) was presented at the 23rd NSSA symposium 19-23 September 2021.
Human capacity development:	A co-worker on the project, Ms. M de Bruyn, registered for a PhD in Sustainable Agriculture at the University of the Free State.
Technology transfer:	No information days in 2021 due to Covid 19 restrictions. Results were presented during information days and field visits to about 60 attendees on 24 March 2022 at Springboklaagte and to 100 attendees at Klein Constantia on 21 March 2023.
Other outputs (Procedures,Methods, Databases, etc):	A book of 73 pages was compiled from 12 previously published popular articles: Verminderde bewerking deel 1: Agtergrond en proefbehandelings Verminderde bewerking deel 2: Evaluering van bewerkingspraktyke onder monokultuur mielies Bewerking en wisselbou deel 3: Agtergrond en proefbehandelings Bewerking en wisselbou deel 4: Evaluering van wisselboustelsels as funksie van bewerkingspraktyke

	Bewerkingsdiepte op sandgrond: Hoe diep is diep genoeg? Wisselbou: Een van die boustene van volhoubare graanproduksie Factors influencing crop rotation decisions of North-Western Free State farmers Die plantestand van mielies op die sandgronde van die noordwes-Vrystaat Klimaatsverandering: Kan dekgewasse die impak versag? Noordwes-Vrystaat-sandgronde nie sondebok in aardverwarming Bemesting 'n fyn balanseertoertjie op dié gronde Grondbestuur - Boer ál beter op SA se watertafelsandgrond Forty-one books were sold during the 2023 Information Day to cover printing costs.

6 Conclusions and Comments

Despite the Covid pandemic and unusual rainfall events which damaged several trials, this project has so far, generated a number of insights and guidelines on aspects under control of the farmers with the ultimate aim to optimize maize production on sandy soils. The participating farmers are devotedly involved in this project and field trials are done with care by them and two new farming enterprises voluntarily joint the activities of this project.

It is also clear that this project created a lot of interest among maize and mixed crop farmers as a source of information. They see it as an important source of independent research done on their particular sandy soils and under semi-arid climatic conditions, which would most likely not be done by any other institution.

Worth mentioning is the participation by the North West University at minimum cost. They also have included some of the results in their knowledge base, as well as in publications. The soil analyses done by Omnia at no cost is also greatly acknowledged.

The SSDC will continue their activities for the period 2023/24 to 2025/26 under the project *"Optimising production practices for sustainable dryland maize production systems on semi-arid sandy soils with water tables in the north western free state*." which was approved by the Maize Trust during September 2023 for funding.

Among the remaining challenges of the area are:

- Through on-farm research, to relieve the ever increasing pressure on agriculture to produce sufficient, affordable and nutritious food for an ever increasing population while conserving and improving the soil and environment.
- The testing of new production technologies such as cultivation methods, cultivars, environmentally friendly fertilizers and crop protection to promote soil and environmental sustainability, as well as improving production efficiency.
- The recuperation of the poor state of the South African economy through seeking solutions for environmentally friendly and financially sustainable agricultural practices.
- Generation of data on the impacts of climate change such as increased temperatures, changing rainfall patterns and shortage of water in order to adapt dry land farming practices.

- Investigating the contribution of agricultural practices such as nitrogen fertilization of maize on environmental pollution.
- Quantification of the acid buffer capacity of sandy soils to refine lime application programmes.
- Quantification of subsoil acidity and ameliorative procedures.
- Investigating the economic and environmental sustainability of the inclusion of a cover crop, utilised by livestock, in crop rotation systems with maize.

7 Signature of Applicant and Research Authority

A.A. Nel, Springbokvlakte 27 November 2023

Name and Signature of Applicant; Place and Date

JDM Nienaar Chairperson Springbokvlakte 27 Nov 2023

Name and Signature and Position of Authorized Manager; Place and Date

APPENDIX 1

Confidential

Nematode report for a conservation agriculture rotation trial (2021, 2022 and 2023 growing seasons) and a nematicide trial done at Chrisinasrus, near Wesselsbron, Free State province, South Africa

Report compiled by Prof Driekie Fourie, Nematologist,
North-West University, Potchefstroom Campus, South Africa

Submission date: 13 July 2023

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Private Bag X6001, Potchefstroom
2520, South Africa

Web: http://www.nwu.ac.za

Unit for Environmental Sciences and Management
Sub-program: Integrated Pest Management
Tel: 018 285 3009 / 018 285 3006
E-pos: driekie.fourie@nwu.ac.za/

13 July 2023

To: Dr André Nel
Email address: nelaa1954@gmail.com

NEMATODE RESULTS

This report contains the nematode data for the Chrisinastrus conservation agriculture, rotation trial for the 2021, 2022 and 2023 growing seasons.

Table 1a. Basic information regarding nematode samples received and protocols used for analyses.

Crop(s)	**Maize, soybean and cover crops**
NWU referemce no	**2023_NemP45**
Client reference no	2022_NemP29 Wesselsbron (Chrisinasrus wisselbouproef)
Sample types	Roots and soil
Mass used for nematode extraction purposes	20 g roots en 200 g soil
Number of samples analysed	27 root- en 27 soil
Extraction methods used	Adapted decanting and sieving followed by the sugar-flotation method for soil, and the adapted sugar-flotation method combined with the NaOCl method for roots (Marais et al. 2017).
Nematode genera extracted	Plant-parasitic and beneficial nematodes

Table 1b. Treatments sampled in the nematode study,

Treatment	Code	Crop sampled in crop rotation system
1	MMS	Maize: Maize-maize-soybean
2	MS	Soybean: Maize-soybean
3	MM	Maize: Maize-maize
4	MCS	Cover crops: Maize-cover crop-soybean
5	MCS	Soybean: Maize-cover crop-soybean
6	MMS	Maize: Maize-maize-soybean
7	MS	Maize: Maize-soybean
8	MCS	Maize: Maize-cover crop-soybean
9	MMS	Soybean: Maize-maize-soybean

1. Results

Nematodes were extracted from root and soil samples for the conservation agriculture rotation trial using the methods listed in Table 1a as applied by trained personnel.

Nematode density data were log(x+1) transformed and subjected to ANOVA (data for each year) and Factorial ANOVA analyses (data for the three years), and the homogeneity test of Levene's (TIBCO Statistica™ Version 14.0.0.15; https://www.tibco.com). Treatment means were separated using the Tukey HSD test (P = 0.05) or by the Fisher LSD Test (P = 0.05). The latter post hoc test was used when a significant difference among treatments or years were indicated in either the ANOVA or Factorial ANOVA tables, but not mirrored by the Tukey HSD test which was an indication that the latter test was too strict for that specific data set.

Nematode-based indices (NBI) were calculated for both trials using the soil community data by means of the online NINJA (Nematode Indicator Joint Analysis Online Tool) application (Sieriebriennikov *et al.*, 2014). These included the Enrichment index (EI), Structure index (SI), and Maturity Index 2-5 (MI 2-5). Furthermore, the NBI data for each treatment and year were subjected to Factorial Analyses of Variance (ANOVA) using the TIBCO Statistica™ software (Version 14.0.0.15 Software Package (https://www.statistica.com). This was done to determine whether the treatments and year (Treatments*Year) had a significant ($p<0.05$) effect on the NBI. The assumptions of normality and homogeneity of variance were tested using Levene's Test. Significant differences between treatments and years were separated with the Fisher LSD test ($P = 0.05$).

1.1 Chrisinasrus conservation agriculture rotation trial

1.1.1 Root data

1.1.2 Plantparasitic nematode egg numbers per 20 g roots

The predominant endoparasitic nematode genera infecting the roots of crops were root-knot (*Meloidogyne*, sessile endoparasites) and lesion (*Pratylenchus*, migratory endoparasites) (Table 2). Therefore, the eggs present in the root samples are considered a mixture of these two genera, with those of *Meloidogyne* suggested to be dominating due to femailes producing eggs in egg masses compared to *Pratylenchus* females that produces single eggs (not in egg masses).

High levels of variation were evident for nematode density data among the three replicates of a treatment (Table 2). This applies for each of the three years that samples were analysed.

Table 2. Plant-parasitic nematode densities in 20 g root samples from different crops sampled at the Chrisinasrus rotation trial during for the 2021, 2022 and 2023 growing seasons.

Treatment & number	Replicate	2021 – Plant-parasitic nematode eggs	2022 - Plant-parasitic nematode eggs	2023 - Plant-parasitic nematode eggs	2021 - *Meloidogyne* (root-knot nematode juvenile and mature life stages)	2022 - *Meloidogyne* (root-knot nematode juvenile and mature life stages)	2023 - *Meloidogyne* (root-knot nematode juvenile and mature life stages)	2021 - *Pratylenchus* (lesion nematode)	2022 - *Pratylenchus* (lesion nematode)	2023 - *Pratylenchus* (lesion ematode)
#1 MMS Mielie 1 19/20: Sojabone: 1	1	1220	1400	250	60	50	8	620	775	1200
#13 MMS Mielies 19/20 Sojabone:1	2	220	225	33	0	167	0	260	400	1700
#23 MMS Mielies 19/20: Sojabone:1	3	40	2575	23800	220	29	4958	0	363	113
#2 MS Mielies 19/20: Sojabone:2	1	120	2625	5450	0	1171	325	560	525	500
#17 MS Mielies 19/20: Sojabone:2	2	220	10900	1125	160	1162	175	480	250	125
#25 MS Mielies 19/20: Sojabone:2	3	180	100	2775	800	254	975	520	275	1175
#3 MM Mielies 19/20: Mielies:3	1	220	450	1250	200	400	150	2580	225	1525
#15 MM Mielies 1 19/20: Mielies:3	2	100	1000	6200	40	42	975	620	75	750
#19 MM Mielies 19/20: Mielies:3	3	340	1475	2450	160	642	200	1980	350	600
#4 MDS Mielies 19/20: Sojabone:4	1	540	4450	73500	180	29033	14250	740	0	3150
#10 MDS Mielies 19/20 Sojabone:4	2	300	378000	50	80	25	75	500	50	1575
#21 MDS Mielies 19/20: Sojabone:4	3	260	50200	775	440	456	475	2120	374	300
#5 MDS Dekgewas 19/20: Mielies:5	1	1060	12250	4225	1140	25	400	640	500	525
#12 MDS Dekgewas 19/20 Mielies:5	2	13500	2039	1425	1000	0	325	420	900	67
#26 MDS Dekgewas 19/20: Mielies:5	3	500	1175	1800	460	8	500	580	263	600
#6 MMS Sojabone 19/20: Mielies:6	1	9120	17646	18550	1280	7133	3075	1440	400	375
#18 MMS Sojabone 19/20: Mielies:6	2	17450	1675	2750	10950	2075	175	3450	225	700
#20 MMS Sojabone 19/20: Mielies:6	3	140	2925	1100	240	8	50	700	375	600

#7 MS Sojabone 19/20: Mielies:7	1	29600	4200	65100	32200	159	8400	5450	2800	2100
#11 MS Sojabone 19/20 Mielies:7	2	320	1250	8	220	233	0	1420	500	2200
#22 MS Sojabone 19/20: Mielies:7	3	1000	250	18025	260	3667	1250	1740	0	1000
#8 MDS Soja 19/20: Dekgewas:7	1	1220	575	0	320	17	0	1460	38	0
#14 MDS Sojabone 19/20: Dekgewas:7	2	200	125	24520	40	200	2000	480	175	520
#27 MDS Sojabone 19/20: Dekgewas:7	3	60	8	62500	40	1450	2100	1700	175	400
#9 MMS Mielies 2 19/20: Mielies:7	1	1600	17500	8750	420	0	1400	580	42	1550
#16 MMS Mielies 2 19/20: Mielies:7	2	120	47600	51625	140	75	3325	220	675	550
#24 MMS Mielies 2 19/20: Mielies:7	3	360	11520	400	780	8	175	940	108	325

Significant differences were evident for egg densities over years (P = 0.039*, F = 3.451) for treatments/cropping sequences 4 (Cover crops: Maize-cover crop-soybean) and 9 (Soybean: Maize-maize-soybean), while no significant differences existed for treatments (P = 0.193, F = 1.461) (Fig. 1; see means for treatments in Table 2). No interaction was recorded for Treatment x Year (P = 0.726; F = 0.755) for *Meloidogyne* juvenile and mature life stages per 20 g roots.

Significant increases in plant-parasitic nematode egg numbers were evidenced during 2022 for Treatments 4 (MCS Maize-covercrop-soybean) and 9 (MMS Soybean; maize-maize-soybean) (Fig. 1; Table 2). The egg densities were highest in 2022 for Treatments 4 and 9 with increases of 99.7% and 97.4%, respectively, compared to data for 2021; and 82.8% and 20.7%, respectively, compared to data for 2023. The substantial increases in egg densities indicates the conduciveness of these specific treatments/rotation sequences in terms of their ability to expedite plant-parasitic nematode abundance roots of the crops included. Inclusion of susceptible soybean and cover crops (cowpea and *Dolichos*) demonstrate the increased egg numbers which are reflected in severely galled root systems due to root-knot nematode infection (see photo's taken during nematode sampling showing the severe root-knot nematode infection in roots of these two crops; Figs. 2 and 3a & b).

Although substantial numerical increases in nematode egg numbers were evident for most of the treatments, mean data for Treatments 5 (Soybean: Maize-cover crop-soybean) and 6 (Maize: Maize-maize-soybean) each stayed in similar numberical ranges for the three years (Table 2). However, substantial differences in egg densities among the replicates of these two treatments for the three years suggest that these cropping systems could also lead to high densities of plant-parasitic nematode egg numbers of the predominant plant-parasitic nematode genera *Meloidogyne* and *Pratylenchus* (Fig. 1).

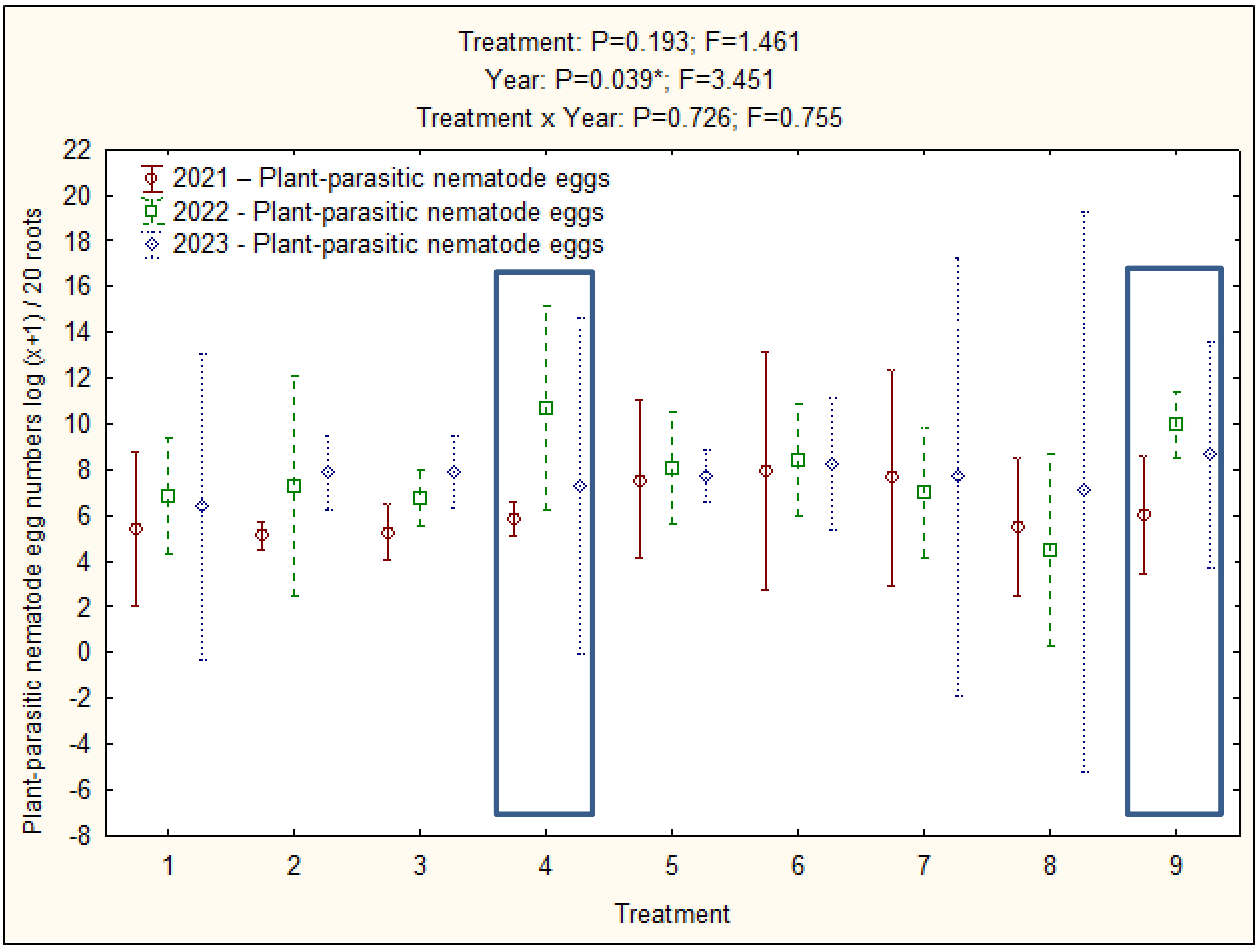


Figure 1. Plant-parasitic nematode egg numbers [log(x+1) transformed)] per 20 g roots for the 2021, 2022 and 2023 summer growing seasons for nine crop sequence treatments of which the impacts were investigated on conservation agriculture practices related to soil health in semi-arid sandy soils in the Free State province, farm Christinasrus, Wesselsbron (Codes for treatments: "1 = MMS Mielies 2; 2 = MS Sojabone; 3 = MM Mielies; 4 = MDS Dekgewasse; 5 = MDS Sojabone; 6 = MMS Mielie 1; 7 = MS Mielies; 8 = MDS Mielies; 9 = MMS Sojabone waar MM = mielies monokultuur; MS mielie-sojabone wisselbou; MMS = mielies-mielies-sojabone wisselbou; MDS = Dekgewass-mielies-soja wisselbou").

Figure 2a & b. Soybean roots severely infected with root-knot nematodes sampled during the 2022 summer growing season (a) and 2023 summer growing season (b) in the Christinarus experimental site, Wesselsbron, Free State, South Africa.

Figures 3a, b & c. Cowpea roots severely infected with root-knot nematodes (a & b) sampled from plots planted to cover crops during the 2022 summer growing season, as well as root-knot nematode infected *Dolichos* roots sampled during the 2023 summer growing season (c) in the Christinarus experimental site, Wesselsbron, Free State, South Africa.

1.1.3 *Meloidogyne* juvenile and mature life stadia

No significant differences were evident for treatments (P = 0.315, F = 1.203) and year (P = 0.527, F = 0.649) while no interaction was recorded for Treatment x Year (P = 0.412; F = 1.062) for *Meloidogyne* juvenile and mature life stages per 20 g roots (see means for treatments in Table 2).

1.1.4 *Pratylenchus*

Densities of *Pratylenchus* per 20 g roots differed significantly over the three years (P = 0.007*; F = 5.466) for treatments/cropping sequenses 4 (Cover crops: Maize-cover crop-soybean), 7(Maize: Maize-soybean) and 8 (Maize: Maize-cover crop-soybean) (Fig. 4). No significant differences were recorded for *Pratylenchus* numbers per 20 g roots among the treatments (P = 0.625; F = 0.776) (see means for treatmens in Table 2), while no significant interaction existed for Treatment x Year (P = 0.155; F = 1.449) (Fig. 4).

Substantial increases in *Pratylenchus* root numbers were evidenced from the 2021 to the 2023 growing season for all treatments (Table 2). This is an indication of the conduciveness of the treatments/rotation sequences to increase the populaiton density of the migratory endoparasitic lesion nematodes. It is suggested that the inclusion of soybean as well as the cover crops enabled this increase in numbers of lesion nematodes as was the case for the increase in plant-parasitic nematode egg numbers for this treatment too (see Section 1.1).

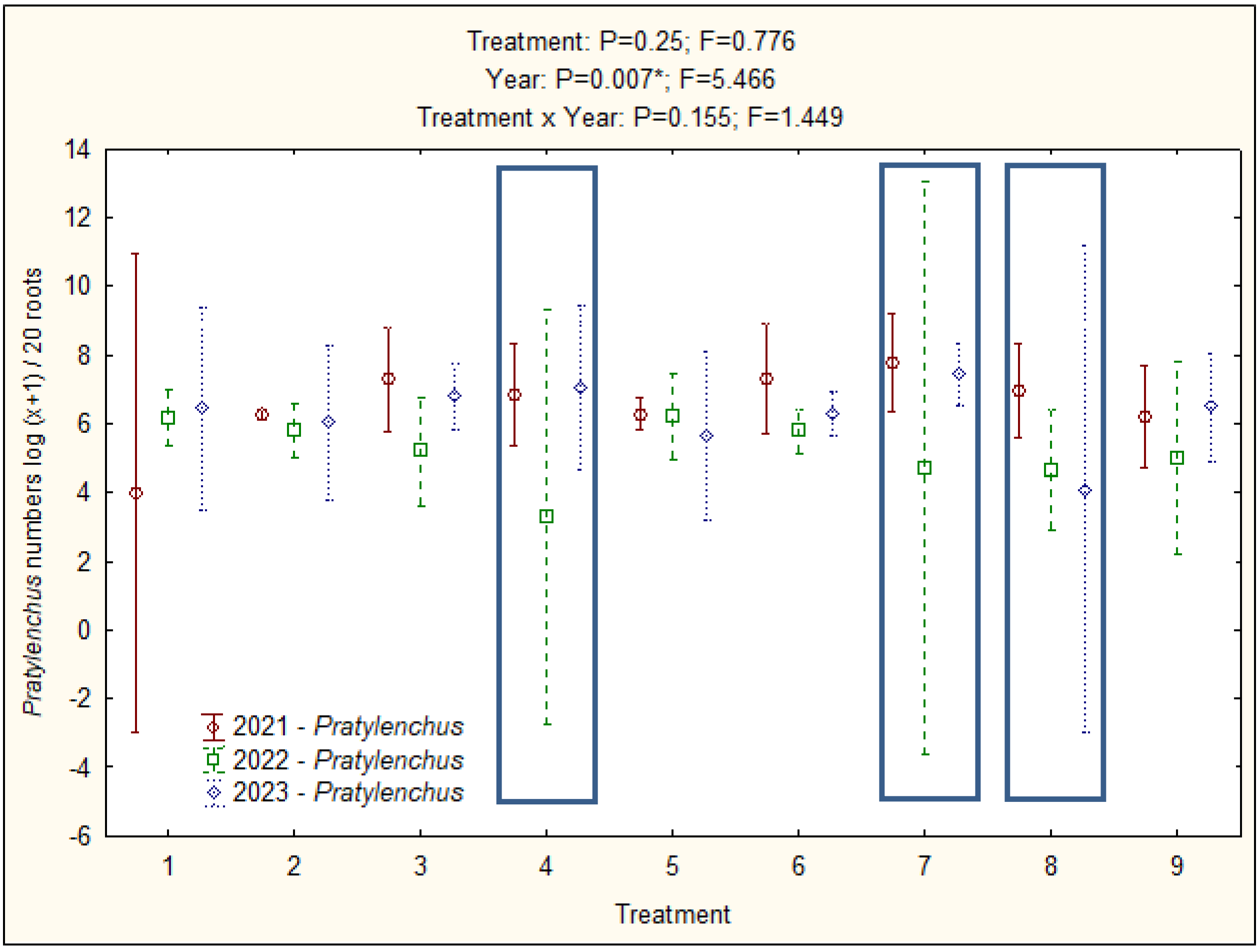


Figure 4. Numbers of *Pratylenchus* [log(x+1) transformed] per 20 g roots for the 2021, 2022 and 2023 growing seasons for nine crpping sequences of which the impacts were investigated on conservation agriculture practices related to soil health in semi-arid sandy soils in the Free State province, farm Christinasrus, Wesselsbron (Codes for treatments: "1 = MMS Mielies 2; 2 = MS Sojabone; 3 = MM Mielies; 4 = MDS Dekgewasse; 5 = MDS Sojabone; 6 = MMS Mielie 1; 7 = MS Mielies; 8 = MDS Mielies; 9 = MMS Sojabone waar MM = mielies monokultuur; MS mielie-sojabone wisselbou; MMS = mielies-mielies-sojabone wisselbou; MDS = Dekgewass-mielies-soja wisselbou").

1.2 Soil data

1.2.1 Plant-parasitic nematodes

Plant-parasitic nematodes from the genera *Hemicycliophora*, *Pratylenchus*, *Meloidogyne*, *Rotylenchulus* and *Scutellonema* were identified from soil samples, as well as individuals from the families Dolichodoridae, Criconematidae, Trichodoridae and Longidoridae ((see raw data in Excel sheet attached as Appendix 1). The endoparasitic genera *Meloidogyne* and *Pratylenchus* dominated in abundance, followed by the ectoparasitic families Criconematidae, and Trichodoridae.

Meloidogyne densities in 200-g soil did not differ significantly among treatments (P = 0.832; F = 0.53), but abundance of this genus was significantly different for treatments among the three years (P = 0.001* F = 45.45) for Treatments 1 (Maize: Maize-maize-soybean), 2 (Soybean: Maize-soybean), 4 (Cover crops: Maize-cover crop-soybean), 5 (Soybean: Maize-cover crop-soybean) and 6 (Maize: Maize-maize-soybean) (Fig. 5). A significant interaction existed for Treatment x Year (P = 0.031*; F = 1.99).

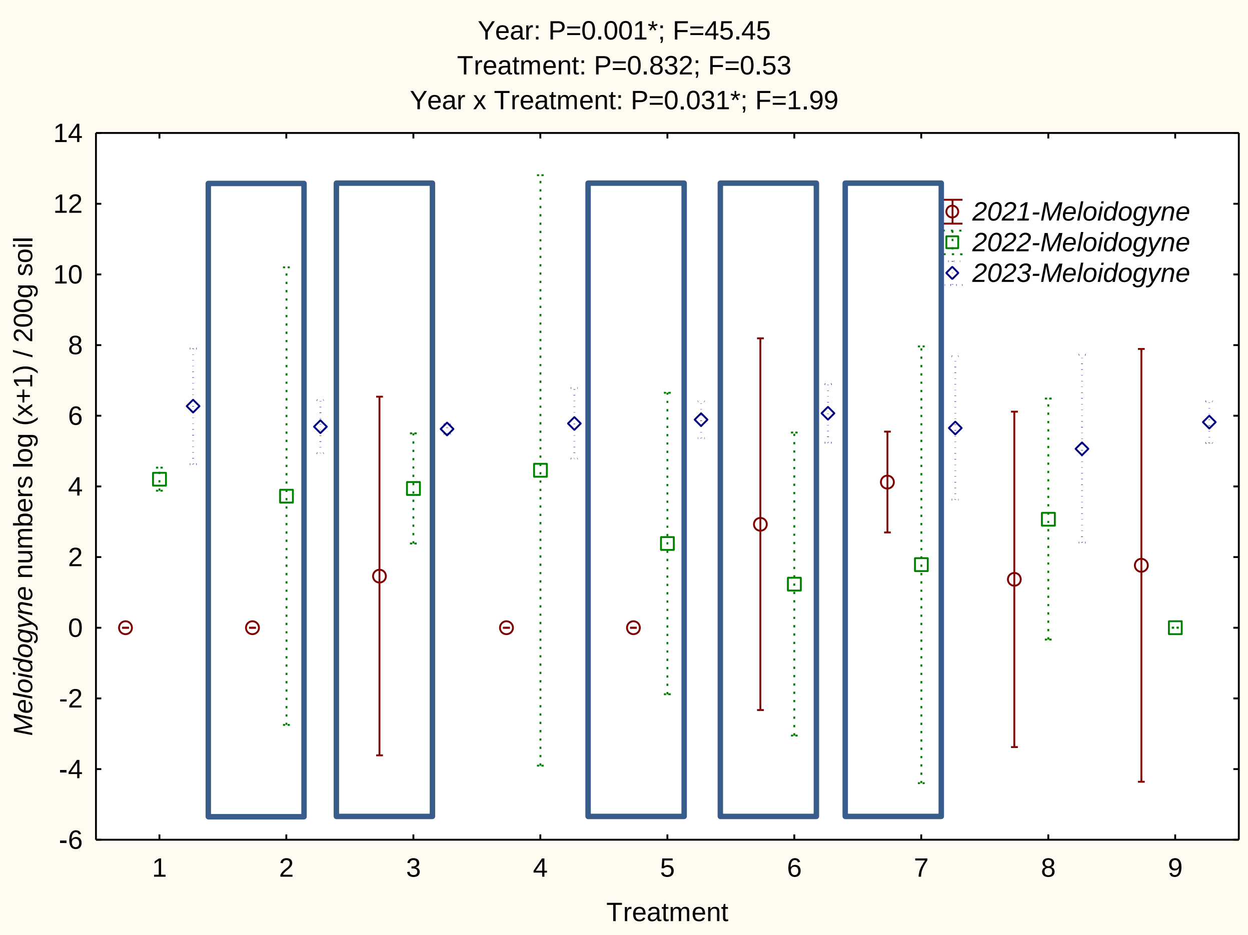


Figure 5. *Meloidogyne* numbers [log(x+1) transformed] per 200 g soil for treatments/cropping sequences evaluated in a crop rotation study at Chrisinasrus (Wesselsbron area, Free State province) during the 2021, 2022 and 2023 growing seasons.

Pratylenchus numbers soil did not differ significantly among treatments (P = 0.151; F = 1.59), but abundance of this genus was significantly different for Treatments over the three years (2021, 2022 and 2023) (P = 0.001*; F = 28.40) (Fig. 6). However, no significant interaction existed for Treatment x Year (P = 0.325; F = 1.16). *Pratylenchus* numbers for Treatment 7 (Maize: Maize-soybean) only were significantly higher in 2023 compared to that of 2021 and 2022.

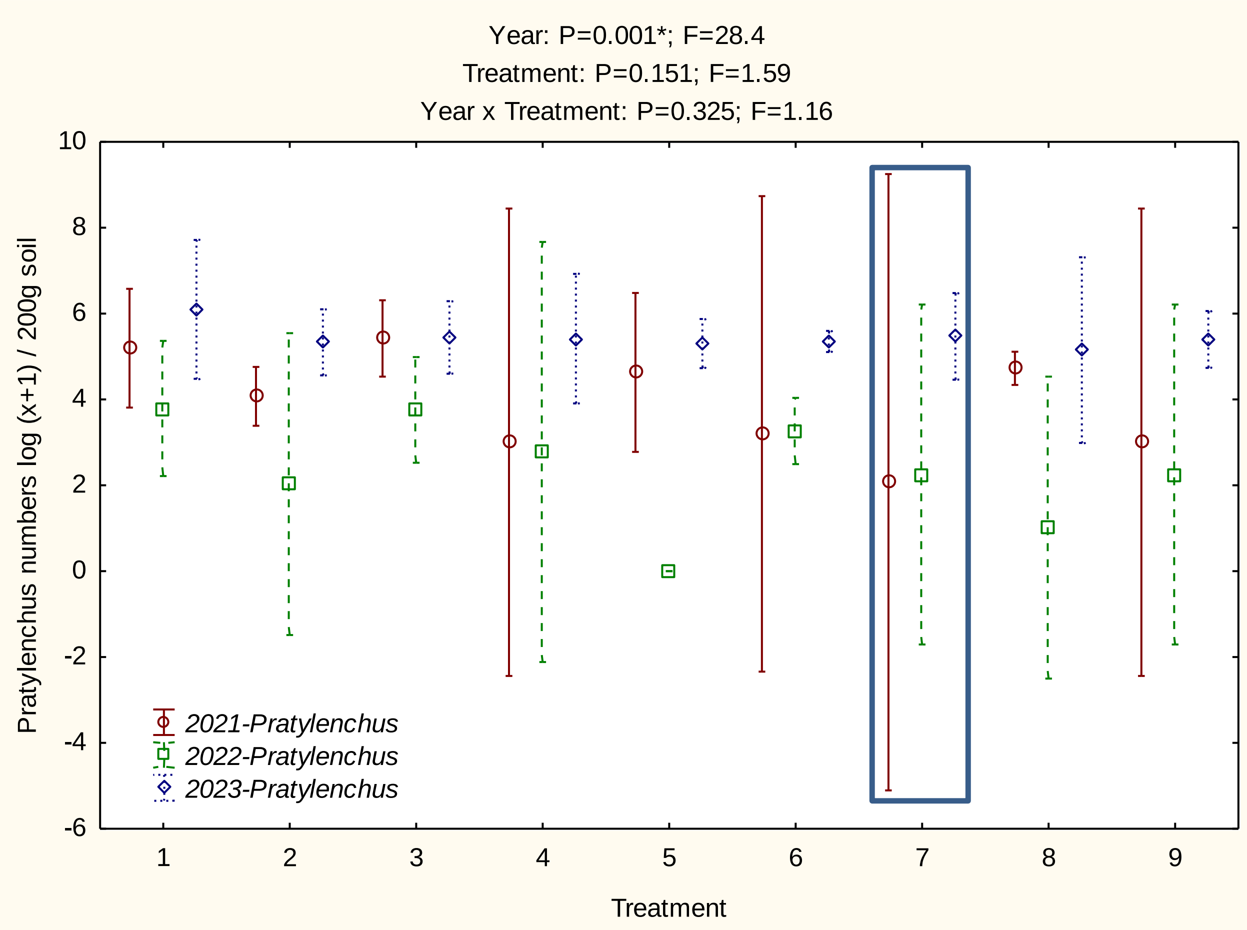


Figure 6. *Pratylenchus* numbers [log(x+1) transformed] per 200 g soil for nine treatments/cropping sequences evaluated in a crop rotation study at Chrisinasrus (Wesselsbron area, Free State province) during the 2021, 2022 and 2023 growing seasons.

Criconematidae numbers in soil (ranging from zero to 1363/200 g soil) did not differ significantly among treatments (P = 0.107; F = 1.75), but differed significantly among the three years (P = 0.001; F = 15.82) with a significant interaction evidenced for Treatment x Year (P = 0.002; F = 2.91) (see Excel file attached as Appendix 1 for raw nematode data). Treatments 1 (Maize: Maize-maize-soybean), 2 (Soybean: Maize-soybean), 6 (Maize: Maize-maize-soybean), 7 (Maize: Maize-soybean) and 9 (Soybean: Maize-maize-soybean) had significantly higher densities for this family during 2023 compared to 2021 and/or 2022.

Trichodoridae numbers (ranging from 357/200 g soil) did not differ significantly among treatments (P = 0.451; F = 0.99), however significant differences were evident for treatments among the three years (P = 0.001; F = 15.64) see Excel file attached as Appendix 1 for raw nematode data). Treatments 1 (Maize: Maize-maize-soybean), 4 (Cover crops: Maize-cover crop-soybean), 5 (Soybean: Maize-cover crop-soybean) and 6 (Maize: Maize-maize-soybean) had significantly higher densities during 2023 compared to 2021 and/or 2023. No significant interaction was evident for Treatment x Year (P = 0.446; F = 1.03).

1.2.2 Beneficial nematodes

Beneficial nematodes from the familes Aphelenchidae, Cephalobidae, Diplogasteridae, Diphterophoridae, Dorylaimidae, Mononchidae, Ostellidae, Plectidae, Prismatolaimidae, Rhabditidae en Tylenchidae were present in soil samples from the different treatments. Cephalobidae en Dorylaimidae in general dominated in abundance (see raw data in Excel sheet attached as Appendix 1).

Community analysis of soil nematodes showed that herbivores (plant-parasitic nematodes) and bacterivores (feeding on bacteria) dominated during the 2023 growing season, which was similar to that of the 2021 and 2022 growing seasons, while omnivores and predators (nematodes feeding on other nematodes and microorganisms), and fungivores constituted the smallest fractions of the nematode communities for 2023 (Fig. 7a & b).

Changes in the nematode community structures were evident among treatments and the three years; for example, herbivore abundance increased substantially for Treatments 1 (Maize: Maize-maize-soybean), 4 (Cover crops: Maize-cover crop-soybean), 7 (Maize: Maize-soybean) and 8 (Maize: Maize-cover crop-soybean) during the 2022 growing season compared to that of 2021 but decreased substantially during the 2023 season to levels comparable to those recorded for 2021 for the respective treatments (Fig. 7a-c).

Treatments 2 (Soybean: Maize-soybean), 3 (Maize: Maize-maize) and 6 (Maize: Maize-maize-soybean) showed increased herbivore abundance for 2023 compared to 2021 and 2022, while Treatments 5 (Soybean: Maize-cover crop-soybean) and 9 (Soybean: Maize-maize-soybean) which had substantially lower herbivore abundance during 2022 compared to 2021, also showed increases in herbivore abundance during 2023 to levels comparable to that of 2021 (Fig. 7a-c).

The biggest shift in bacterivore abundance was evident for Treatment 9 (Soybean: Maize-maize-soybean) during 2022 when the community composition was dominated by bacterivores (Fig. 7a-c).

Shifts in densities of predators, omnivores and fungivores were also evident over the three years, but to a smaller degree than those for herbivores and bacterivores (Fig. 7a-c). Soil analyses showed that Treatments 2 (Soybean: Maize-soybean), and 8 (Maize: Maize-cover crop-soybean) represented the highest densities of omnivores and predators during 2023.

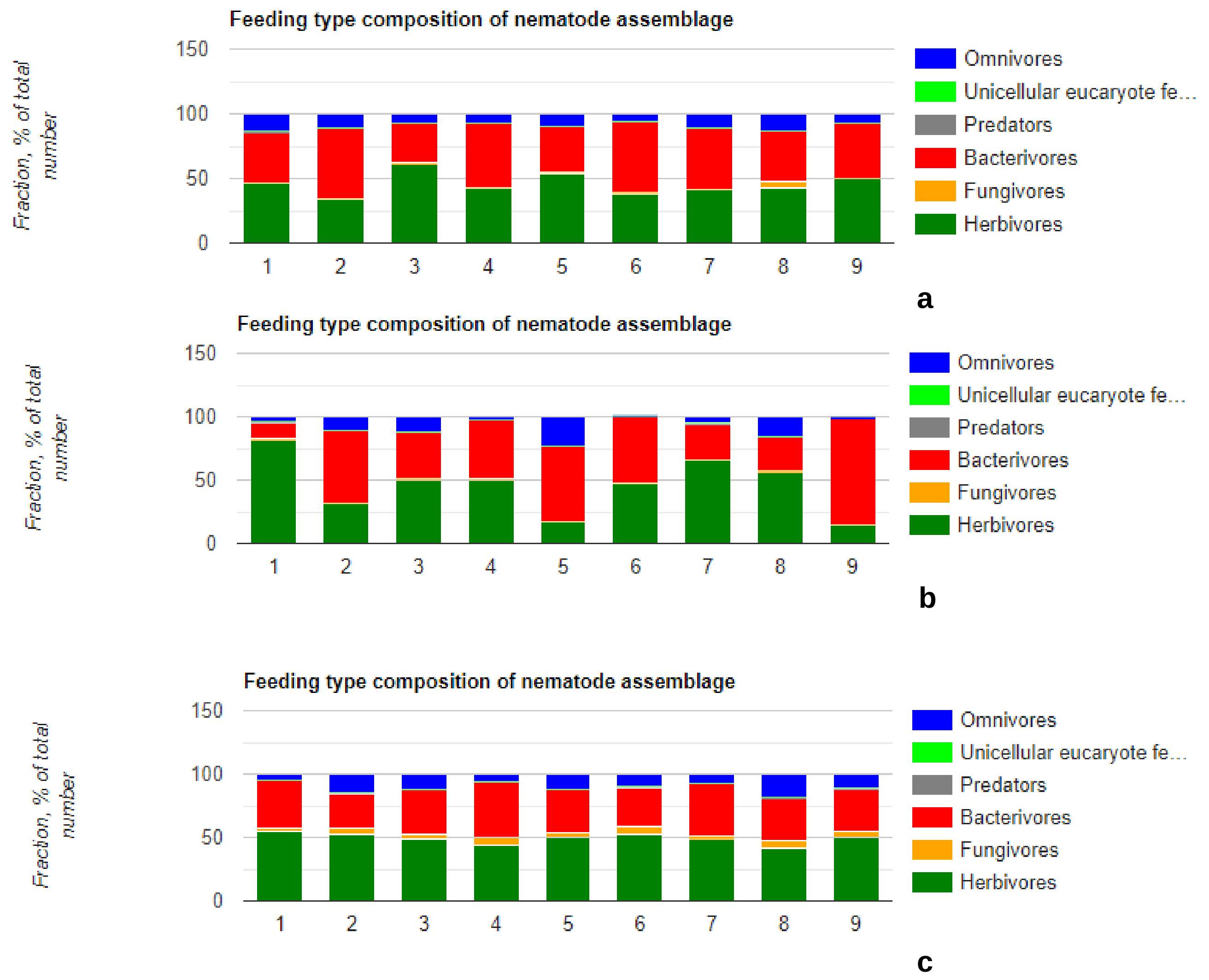


Figure 7a-c. Graphic representations of shifts in the soil nematode community compositions across cropping sequences for the 2021 (a), 2022 (b) and 2023 (c)growing seasons for the different trophic nematode groups identified from soil samples obtained from the Chrisinasrus crop rotation trial site.

Nematode-based indices (NBI) supply valuable information regarding the interpretation of ecosystem health and therefore data for the Maturity Index 2-5 (MI 2-5), Enrichment Index (EI) and Structure Index (SI) calculated for the 9 treatments are referred to and discussed below (Table 3).

Table 3. Mean values (± standard error: SE) for nematode-based indices (Maturity Index 2-5; MI 2-5, Enrichment Index; EI en Structure Index; SI) of treatments/cropping sequences evaluated in a crop rotation study at Chrisinasrus (Wesselsbron area, Free State province) during the 2021, 2022 and 2023 growing seasons.

Treatment	**MI 2-5**			**EI**			**SI**		
	2021	**2022**	**2023**	**2021**	**2022**	**2023**	**2021**	**2022**	**2023**
1	2.57±0.29 aCDEF	2.54±0.40 aCDEF	2.31±0.18 cABCD	0±0 aA	24.84±22.47 abcBCDE	61.22±3.8 aGHI	58.23±20.09 aDEF	54.81±21.92 aDEF	40.33±17.95 bBCDE
2	2.34±0.08 aABCD	2.37±0.12 aABCDE	2.96±0.29 bEF	0+0 aA	41.07±16.09 cEFGH	54.26±7.7 aFGHI	44.47±7.18 aCDEF	46.82±10.31 aDEF	76.58±7.75 aF
3	2.41±0.14 aABCDEF	2.43±0.42 aABCDEF	2.68±0.19 abCDEF	38.5±34.5 aEFG	2.78±4.81 abABC	55.6±10.84 FGHI	50.14±9.87 aDEF	42.99±38.53 aCDEF	66.25±9.27 abEF
4	2.25±0.12 aABCD	2.08±0.13 aAB	2.4±0.16 aABCDE	0±0 aA	1.19±2.06 abA	67.68±3.27 aI	35.61±11.91 aBCDE	12.50±19.34 aABC	48.87±13.81 abDEF
5	2.40±0.32 aABCDE	2.49±0.74 aBCDEF	2.74±0.14 abCDEF	2.4±4.12 aAB	0.0±0 aA	58.76±15.02 FGHI	45.05±24.8 aCDEF	36.65±46.45 aBCDE	68.73±6.31 abEF
6	2.19±0.2 aABC	2.0±0.0 aA	2.65±0.17 abCDEF	2.4±4.12 aAB	0±0 aA	56.5±4.27 aFGHI	25.56±25.02 aABCD	0±0 aA	65.55±9.1 abEF
7	2.34±0.14 aABCD	2.38±0.33 aABCDE	2.42±0.2 aABCDE	0±0 aA	14.81±25.68 abABCD	54.97±20.9 aFGHI	43.97±13.44 aBCD	41.03±35.53 aBCD	50.37±14.96 abDEF
8	2.58±0.02 aCDEF	2.65±0.68 aDEF	2.96±0.26 bF	37.4±34.06 aDEF	26.15±17.07 bcCDE	63.88±3.4 aHI	62.88±0.66 aEF	54.45±34.67 aDEF	76.72±9.25 aF
9	2.28±0.26 aABCD	2.04±0.07 aAB	2.7±0.13 abCDEF	14.0±24.31 aABCD	0±0 aA	59.91±6.79 aFGHI	34.43±30.32 aBCDE	6.84±11.84 aAB	67.38±6.39 abEF
P	*0.337*	*0.527*	***0.004****	*0.071*	***0.021****	*0.765*	*0.398*	*0.198*	***0.007****
F	*1.244*	*0.918*	*4.387*	*2.335*	*3.275*	*0.601*	*1.125*	*1.612*	*4.042*
				Treatment					
P	**0.023***			**0.034***			**0.010***		
F	2.482			2.30			2.86		
				Year					
P	**0.004***			**0.001***			**0.001***		
F	5.994			98.76			11.79		
				Interaction: Treatment x Year					
P	0.556			**0.005***			0.305		
F	0.916			2.54			1.19		

*Means were significant different for treatments according to Fisher's Test (LSD) at P = 0.50.

According to the Factorial ANOVA, significant differences were evident among the treatments for the MI 2-5, with values for this index also being significantly different among the three seasons for Treatments 2 (Soybean: Maize-soybean), 6 (Maize: Maize-maize-soybean) and 9 (Soybean: Maize-maize-soybean) (Table 3). No significant interaction existed for Treatment*Year. Although not significantly different from the other treatments, except from Treatments 1 (Maize: Maize-maize-soybean), Treatment 2 (Soybean: Maize-soybean) and 8 (Maize: Maize-cover crop-soybean) had the had the highest MI 2-5 values (>2.50) for both growing seasons indicating that they are best representing soil ecosystem health (Table 3).

Factorial ANOVA indicated that a significant interaction was evidenced for EI for Treatment*Year, with the treatments differing significantly and values for this index also being significantly different among the three seasons for all treatments (Table 3). The EI values, ranging from medium to high, did not differ significantly among the treatments for 2023 and are indicative of higher densities of bacterivore nematodes being present due to the presence of higher microbial activity in the soil foodweb (Ferris et al., 2001).

For SI, factorial ANOVA indicated that treatments and years differed significantly for Treatments 6 (Maize: Maize-maize-soybean) and 9 (Soybean: Maize-maize-soybean) (Table 3). No significant interaction existed for Treatment x Year. For 2023, Treatment 2 (Soybean: Maize-soybean) had the highest SI value which were significantly different from Treatment 1 but not from the other treatments.

According to the faunal analysis (Sieriebrinnikov et al., 2013) the metabolic footprints of Treatments 2 (Soybean: Maize-soybean) and 8 (Maize: Maize-cover crop-soybean) as well as those of Treatments 3 (Maize: Maize-maize), 5 (Soybean: Maize-cover crop-soybean), 6 (Maize: Maize-maize-soybean) and 9 (Soybean: Maize-maize-soybean) migrated to the maturing and N-enriched quadrant during the third growing season (2023) that this study was conducted – producers should aim to attain this level of soil health using nematodes as bioindicators. Treatments 1 (Maize: Maize-maize-soybean), 4 (Cover crops: Maize-cover crop-soybean) and 7 (Maize: Maize-soybean), however, plotted in the disturbed and N-enriched quadrat indicating a disturbed and bacterial dominated pathway (Ferris et al., 2001) (Fig. 8c). Both EI and SI values for all treatments increased from the 2021 to the 2023 growing season.

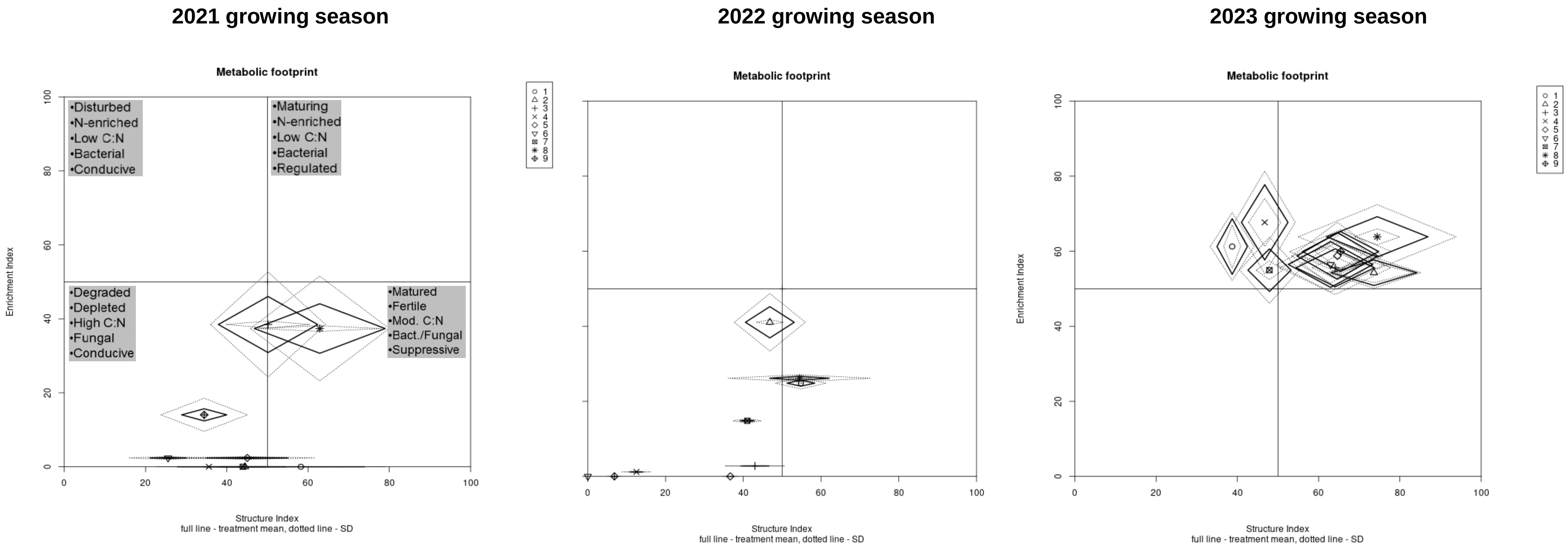


Fig.7. Faunal profiles of soil from, according to the NINJA analysis (Sieriebrienikov et al., 2014) different treatments/cropping sequences indicating the Enricment Indices (EI) en Stucture Indices (SI) represented by beneficial nematodes present at tte Chrisinasrus trial site (Wesselsbron area, Free State province) for growing seasons 2021 (a), 2022 (b) and 2023 (c). The center of the rombus represents the intersection of the EI and SI length of the vertical and horizontal axes correspond with the footprints of enrichment and structure, respectively.

1.3 Discussion and conclusion

Species of the predominant root-knot nematode genus *Meloidogyne* infecting crops at this trial site were identified as *Meloidogyne incognita* and *M. arenaria* occuring as a mixed community. Identification was done using the molecular SCAR-PCR technique (Rashidifard et al., 2019) and complemented by morphological identification of female perineal patterns (Marais et al., 2017). The two endoparasitic genera *Meloidogyne* and *Pratylenchus* as well as ectoparasites belonging to the families Criconematidae and Trichodoridae are the target nematode pests causing nematode infection of crops grown at this trial site.

A considerable challenge experienced with nematode field research is the spot occurrence of these microorganisms in terms of their spatial distribution, which was no exception at this specific trial site (see Table 2 for high levels of variation in raw nematode data per treatment and per replicate). Although log transformation of data has been applied to nematode counts, the high levels of variation in the abundance of nematodes among the three replicates of treatments still pose a challenge to obtain a clear trend of the impact of the treatments/crop sequences on the nematode communities. This must be taken into account when studying this report.

The significant increases in abundance of plant-parasitic nematode eggs of the genera *M. incognita* and *M. arenaria* and *Pratylenchus* sp. in crop roots of Treatments 4 (Cover crops: Maize-cover crop-soybean) and 9 (Soybean: Maize-maize-soybean) in particular, as well as substantial numerical increases for the other treatments over the three years of the study is an indication of the conduciveness of all the cropping sequences in maintaining high nematode pest densities. Severe root-knot nematode galling of soybean (one of the main rotation crops) as well as *Dolichos* and cowpea roots (representing cover crops) confirms the high susceptibility of the crop cultivars used in this study for this nematode pest genus.

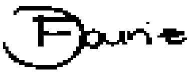
Despite the metabolic footprint of beneficial nematodes for the majority of the treatments/cropping sequences migrating to the 'maturing and N-enriched' quadrat from 2021 to 2023, the plant-parasitic nematodes still dominated and overshadowed the positive contribution by beneficial nematodes. Establishment of structured and complex foodwebs represented by the 'maturing and N-enriched' quadrat results from reduced external inputs, such as practicing no/minimum tilling, minimal use of synthetic fertilizers and pesticides as well as the inclusion of cover crops and/or increasing organic matter in the soil as practiced at this trial site as part of conservation agriculture practices. Nonetheless, although the optimal quadrat with regard to soil health conditions for most of the treatments has been obtained after three years (which is indicative of progressive repair of the foodweb status; Ferris et al., 2001), the adverse impact of plant-parasitic nematode infection is visible as severe galling of soybean, cowpea and *Dolichos* roots as well as by the high nematode pest abundance and should be taken cognisance of.

Therefore, although the soil faunal analysis is a valuable tool, root data for nematodes should always be considered in combination with soil data of which the benefit is demonstrated in the paragraph above. Such an approach ensure that nematode communities, representing both the damaging plant parasites and the beneficial ones, prevailing in the rhizospheres of crop plants, are considered as a whole community impacting on rhizosphere health. Should only soil data for beneficial nematodes be considered, e.g., for this study and especially for the 2023 growing season where the majority of the treatments plotted in the 'maturing and N-enriched' quadrat, the negative impact of the damaging plant-parasitic nematodes reflected by the root data will be overlooked. Action by producers to intervene by applying a strategy or strategies that can mitigate future damage might hence be ignored. In addition, it is suggested that the impact of carbon sequestration and increase in diversity and abundance of beneficial soil-inhabiting fauna and flora will most probably only be experienced/evidenced atfter a prolonged time period of trial implementation.

Recommendations to assist in mitigating nematode damage are:

- cultivars of all crops included in this study be screened for their host suitability to the root-knot nematode species present and cultivars with low susceptibility (representing poor or resistant hosts) be selected for inclusion in future. This is one strategy to effectively reduce the target nematode pest population, which in this case is *Meloidogyne*, and
- use of environmentally friendly products to reduce densities of the predominant nematode pest genera, e.g., VELUM® 1GR which has been registered in 2001 for use on maize and soybean (https://www.cropscience.bayer.africa/za/en-za/products/product-detail-page.html/insecticides/velum_1_gr.html). There is, however, no 'silwer bullet' for reducing high nematode pest densities in the short term, but attempts can be made to use nematicide products with favourable environmental profiles and that have no/limited adverse impacts on non-target organisms. This could be another helphul tool to contribute towards mitigating nematode damage and enable sustainable crop production.

Thank you for supporting our diagnostic laboratory while it was still operative, it is highly appreciated.
Yours faithfully



Extraordinary Professor: Driekie Fourie, Nematologist (Pr.Sci.Nat.; Registr. no: 400196/06)

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APPENDIX 2

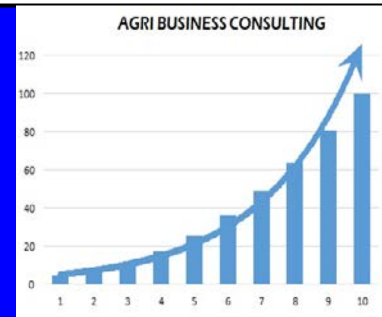
CALCULATION OF TRIAL MARGINS FOR THE 2022 - 2023 PRODUCTION YEAR

NORTHERN FREE STATE CONTROLLED TRAFFIC

Farm Klein Constantia Wesselsbron

Planting date 15 November 2022

CULTIVAR / DKC75-65 BR



	Commodity price			3500	Rand/ton									
	Plot number			1	2	3	4	5	6	7	8	9	10	11
2014_2015			Maize	ROR	Nie-rip	ROR	Nie-rip	TRR	ROR	TRR	ROR	TRR	Nie-rip	ROR
2015_2016 Did not plant drought year			Fallow											
2016_2017			Maize	ROR	Nie-rip	Nie-rip	ROR	ROR	TRR	ROR	TRR	ROR	Nie-rip	TRR
2017_2018			Maize	ROR	ROR	ROR	ROR	ROR	Nie-rip	Nie-rip	Nie-rip	Nie-rip	ROR	ROR
2018_2019			Fallow	ROR	Nie-rip	ROR	Nie-rip	ROR	ROR	ROR	Nie-rip	ROR	Nie-rip	ROR
2019_2020			Maize	ROR	ROR	Nie-rip	Nie-rip	ROR	ROR	ROR	ROR	Nie-rip	Nie-rip	ROR
2020_2021			Maize	ROR	Nie-rip	Nie-rip	Nie-rip	ROR	ROR	ROR	Nie-rip	ROR	ROR	ROR
2021_2022			Maize	ROR	ROR	Nie-rip	Nie-rip	ROR	Nie-rip	ROR	ROR	Nie-rip	Nie-rip	ROR
Production year 2022_2023			**Maize**	ROR	Nie-rip	ROR	Nie-rip	ROR	ROR	ROR	Nie-rip	ROR	ROR	Nie-rip
Trial row width				1.140	1.140	1.140	1.140	1.140	1.140	1.140	1.140	1.140	1.140	1.140
Yield obtained (ton/ha)				6.856	4.019	6.583	4.476	6.355	6.750	5.786	3.185	6.361	6.890	3.788
Gross Production value (R/ha)				23997	14066	23039	15667	22243	23625	20252	11148	22264	24115	13256
A:Specified costs														
Trial seeding rate (seeds/ha)	R/pit		%	27000	27000	27000	27000	27000	27000	27000	27000	27000	27000	27000
Final plant population density (Plants/ha, loss water logging)			#REF!	27000	27000	27000	27000	27000	27000	27000	27000	27000	27000	27000
B: Total Specified Cost R/ha				13955	12883	13168	12934	13899	13943	13836	11781	13900	13959	13614
C: Total fixed cost allocated to enterprise R/ha				2500	2500	2500	2500	2500	2500	2500	2500	2500	2500	2500
Specified Cost per ton R/ton				2035	3206	2000	2890	2187	2066	2391	3699	2185	2026	3595
D: Gross Margin (Surplus/Deficit) R/ha				10042	1182	9871	2733	8343	9682	6416	-634	8,364	10156	-358
E: Operating margin R/ha (D - C)				7542	-1318	7371	233	5843	7182	3916	-3134	5,864	7656	-2858
Gross Margin (Surplus/Deficit) R/ton				1465	294	1500	610	1313	1434	1109	-199	1315	1474	-95
Breakeven Yield ton/ha				3.99	3.68	3.76	3.70	3.97	3.98	3.95	3.37	3.97	3.99	3.89

The very wet season with water logging and water damage occuring on the plots, yield was impacted negatively. With trial planted on the specific type of soils the highest yields and best margins were obtained on the plots that were ripped. The average yield on the ripped plots was 6.512 ton/ha vs the 3.87 ton/ha of the non ripped plots which is 2.64 ton/ha less than the ripped plots. The margin of R10 156/ha or Operating margin of R 7 656/ha and highest yield of 6.89 ton/ha was achieved on plot number 10 where there was not ripped in the 2021/2022 year but ripped in the 2022/2023 year. The second highest margin of R 7 542 /ha and yield of 6.856 ton/ha was obtained on plot number 1 where there has been ripped every year since the start of the trials except the fallow years caused by drought when no action was taken. The biggest deficit of -R 3 134/ha and a yield of only 3.185 ton/ha was obtained on plot number 8 where there was ripped in the 2021/2022 year but was not ripped in the 2022/2023 season. In the 2021/2022 the highest yield of 3.978 ton/ha and an Operating margin of R 136/ha was achieved on plot number 2 where no rip was applied 2020/2021 and ROR was applied 2021/2022. The seven best yields and Operating margins where all achieved on the plots where ROR was applied. The extra cost of ROR is covered by the better average production of 2.64 ton/ha or extra income of R 9 240/ha. If the best margins and yields are taken into account over the period from the 2016/2017 season up and including the 2022/2023 year, it is a fact that the ROR cultivation practice has outperformed the non RIP practice for the specific soils and climatic conditions as can be seen in the table below.

Table showing the cultivation action per year that realised the best yield in ton/ha and best margin in Rand per hectare

Production year	Cultivation Practice	Yield t/ha	Margin R/ha
Production year 2016/2017	ROR	4.21 ton/ha	R 1,249 /ha
Production year 2017/2018	ROR	9.37 ton/ha	R 11,055 /ha
Production year 2018/2019 Fallow due to drought could not plant	-	-	-
Production year 2019/2020	ROR	6.81 ton/ha	R 8,854 /ha
Production year 2020/2021	ROR	7.90 ton/ha	R 13,013 /ha
Production year 2021/2022	ROR	3.98 ton/ha	R 2,636 /ha
Production year 2022/2023	ROR	6.89 ton/ha	R 10,156 /ha

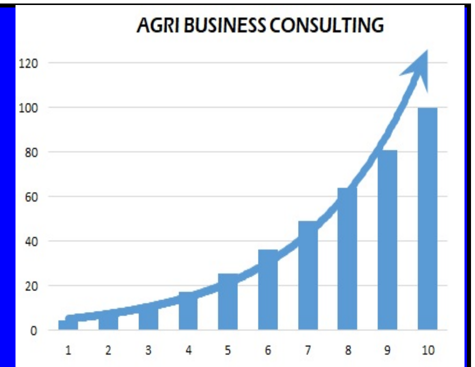
CALCULATION OF TRIAL MARGINS FOR THE 2022 - 2023 PRODUCTION YEAR

Farm: Christinasrust

NORTHERN FREE STATE CONTROLLED TRAFFIC

Planting date: 1 December 2022 **Planting date: 23 November 2022**

CULTIVAR: Maize / DKC77-77 BR **Soya PAN 1507**



Commodity price Maize R 3,500 / ton Soya R 8,200 / ton

		Crop	Maize					Soy beans		
Rotational system followed			M,M	MMS (M2)	MMS (M1)	MS(Maize)	MDS (Maize)	MMS(Soya)	MS (Soya)	MDS(Soya)
Rotational crop 2019/2020			Maize	Soy beans	Maize	Soy beans	Maize	Maize 1	Maize	Cover crop
Rotational crop 2020/2021			Maize	Maize 2	Maize	Maize	Cover crop	Soy beans	Soy beans	Maize
Rotational crop 2021/2022			Maize	Maize 2	Soy beans	Soy beans	Soy beans	Maize 1	Maize	Cover crop
Rotational crop 2022/2023			Maize	Maize 1	Maize 2	Maize	Maize	Soy beans	Soy beans	Soy beans
Trial row width			0.871	0.871	0.871	0.871	0.871	0.871	0.871	0.871
Yield obtained (ton/ha)			6.001	5.594	5.500	6.224	7.547	3.859	3.965	3.828
Gross Production value (R/ha)			21004	19578	19251	21784	26414	31643	32517	31386
A:Specified costs										
Trial seeding rate (seeds/ha)	R/seed	%	30000	30000	30000	30000	30000	300000	300000	300000
Final plant population density (Plants/ha, loss water logging)	**Loss**	**1%**	29700	29700	29700	29700	29700	206896	206896	206896
B: Total Specified Cost R/ha			10383	10362	10357	10394	10464	10098	10103	10096
C: Total fixed cost allocated to enterprise R/ha			2500	2500	2500	2500	2500	2500	2500	2500
Specified Cost per ton R/ton			1730	1852	1883	1670	1387	2617	2548	2638
D: Gross Margin (Surplus/Deficit) R/ha			10621	9217	8894	11390	15950	21545	22413	21290
E: Operating margin R/ha (D - C)			8121	6717	6394	8890	13450	19045	19913	18790
Gross Margin (Surplus/Deficit) R/ton			1770	1648	1617	1830	2113	5583	5652	5562
Breakeven Yield ton/ha			2.97	2.96	2.96	2.97	2.99	1.23	1.23	1.23

The wet season following a good rainfall season the previous year made for challenging production circumstances, with water logging and water damage occurring on some of the plots. The maize cultivar DKC 77-77Br was planted the 1st of December 2022, and the Soya cultivar PAN 1507 was planted the 23rd of November 2022. The cover crop was planted the 23rd of December 2022. The season with its cooler weather appears to have been favourable for the planting of soybeans. The cover crop did not come to its full potential due to its late planting, and the yield of 2.64 ton/ha was cut 91 days after planting. The best Operating Margin of R 19 913/ha was obtained with the Soy beans with a yield of 3.965ton/ha and planted on the plots that had maize in the 2021/2022 year and soy beans the 2020/2021 year. The second best Operating Margin of R19 045/ha was obtained with Soybeans planted on the plot that had Maize the previous season and Soya the 2020/2021 season with an average yield of 3.859 ton/ha. The third best operating margin of R 18 790 /ha was obtained with soy beans following the cover crop the previous year and Maize the 2020/2021 season with a yield of only 3.828 tons/ha. The fourth best operating margin of R 13 450 /ha was obtained with Maize following Soy beans the previous year with cover crop the 2020/2021 year. The lowest average maize yield was obtained with Soy beans the previous year and maize in the 2020/2021 year. (The plots with water logging problems where part of the trial plots with lowest yield and operating margins). With climatic conditions for the specific year the production of soy beans after maize the previous year and soy beans after the cover crop obtained the best operating margins. The average operating margin of the soy beans was more than double that of the maize and is R 10 535/ha better than the operating margin of the maize. The conclusion one can make from the trials in this specific year is that in wet and cool seasons the soy beans outperform the maize, and that rotational cropping has a positive impact on the maize as well as the soy bean yields.