ANNEXURE KK

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FINAL REPORT

Evaluation of suitable conservation tillage methods in crop production systems
M105/11

Project Manager: Dr AA Nel
Co-workers: Mr PA Venter, Mr PR Mogotlwane, Ms MA Mohutsiwa, Mr KA Nkasha

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Abstract

Conservation tillage methods such as reduced and no-till are becoming more relevant in South Africa. These systems are aimed at two highly relevant objectives, namely conservation of soil as a natural resource as well as reduction in fuel and mechanisation costs. No-till has been practised on nearly 100 million ha during 2006 throughout the world. In South Africa the area under no-till is, however, probably insignificant. Other key components of conservation tillage are crop rotation and sound nitrogen fertilisation practices. Many producers probably do not have the capital resources or knowledge to suddenly change from conventional practices to conservation techniques, due to the risks associated with failure. It is therefore important that research institutions evaluate the applicability and adaptability of these practices. The aims of this project were to investigate the response of maize grown under different tillage intensities and rotated with soybean and monocultured as well as fertlised with nitrogen according to two nitrogen procedures. A field trial was conducted on a sandy soil at NAMPO Park near Bothaville in the northern Free State Province. Treatments consisted of two cropping systems (maize in rotation with soybean and monocropped maize), three cultivation intensities (conventional, conventional every alternate season and no-till) and two nitrogen fertilising procedures (conventional and delta yield). A randomised complete block design was used with two replicates. Calculated across seasons for tillage intensities as well as rotations, the mean grain yield of maize was 3701 kg ha^{-1}. The yield of no-till maize was equal or lower (up to 31%) than that of conventionally tilled maize, while the yield of rotated maize was between 14% and 24% higher than that of monocultured maize. Protein and total non-structural carbohydrate content of maize grain were unaffected by treatments. Nitrogen fertilising procedure had no effect on maize yield. However, the estimated N-requirement varied from season to season, with the requirement of the no-till treatment at approximately 50% of the conventionally tilled system. Calculated across seasons the estimated profit of the conventionally tilled maize was 7% higher than that of the no-till maize while the estimated profit of the rotated maize was 2.6 times that of maize in monoculture.

MATERIALS AND METHODS

A field trial was planted during November 2005 at NAMPO Park, 20 km north of Bothaville. Before planting the entire trial area was ploughed after 2 000 kg ha^{-1} calcitic lime was applied. The Avalon soil had an effective depth of 120 cm, with 6% clay in the A horizon (0 - 30 cm depth), 8% clay in the B horizon (30 - 60 cm depth) and contained 25 mg kg^{-1} P, 132 mg kg^{-1} K, 316 mg kg^{-1} Ca and 138 mg kg^{-1} Mg. The estimated yield potential for maize was 3 900 kg ha^{-1} and for soybean 1 800 kg ha^{-1}.

Each of the 48 experiment plots were 14.4 m wide and 40 m long. Treatments applied from the 2006/07 season were:

1. Cropping systems consisted of (a) monocultured maize and (b) maize in an annual rotation with soybean. To account for seasonal effects two plots in each replication were assigned to the maize - soybean rotation where each plot was planted with either maize or soybean.
2. Tillage systems consisted of (a) annual deep ripping (40 cm) for maize and ploughing for soybean (considered as conventional tillage), (b) no-tillage and (c) alternate years of conventional tillage and no-till.
3. N-fertilising procedures for maize consisted of (a) fertilising for a target yield referred to as the conventional system and (b) fertilising according to the Delta-yield procedure as described by Nel and Bloem (2006). As the yield of a zero N-fertilising control is required for the Delta-yield procedure, one quarter of each maize plot received no N fertilisation.

Plots were assigned to the treatment combinations of crop, tillage and N-fertilising systems in a completely randomised block layout with two replicates. The aim of the first year was to establish either a monoculture or rotation effect in the soil of assigned plots, therefor only the N-fertilising procedure could be evaluated.

During September 2006 the maize stubble of the 2005/06 season was shredded with a slasher. Due to a heavy infestation of *Conyza* species in the winter of 2006 all plots were weeded about 80 mm deep with a tine implement. Cultivation of the conventionally tilled plots was done by ripping 35 to 40 cm deep and planting of both maize and soybean crops the next day. Plots assigned to conventional tillage were ripped and plots assigned to soybean were ploughed.

For fertilisation, maize received 200 kg 3:2:1(25%) in 2006/07 and 180 kg ha^{-1} in 2007/08 except for the zero-fertilised part of each plot. Due to a severe drought during 2006/07, no additional fertiliser was applied and consequently the intended treatments

by any treatment in 2006/07 but in 2007/08, the density in the no-till treatment was 26% lower than that of the conventionally cultivated treatment. No meaningfull explanation can be offered for this. One possibility is that the no-till environment for growth and development of germinating seed and seedlings is less favourable than that of conventionally tilled soil. This aspect needs further investigation.

Grain yield

The mean maize grain yield for this season was 4633 kg ha^{-1} and that of the soybean crop only 518 kg ha^{-1}.

Results on yield of maize as affected by tillage and rotation systems are shown in Table 1. The maize yield for 2006/07 was relatively high considering the drought. It was affected by both cropping and tillage system, with no interaction between these factors. The yield of the rotated maize was 24% higher than that of the monoculture maize and the yield of the no-till maize was 31% (1052 kg ha^{-1}) lower than that of the conventionally tilled maize.

In the relatively wet 2007/08 season tillage system had no effect on maize yield while, the yield of rotated maize was 14% higher than that of the monoculture maize. Yield was not affected by an interaction between the systems.

Calculated across seasons maize yield was effected by both cropping and tillage system. Maize grown in rotation with soybean yielded 16% higher than maize grown in monoculture, while the no-till maize yielded 19% less than the conventionally tilled maize.

Table 2 shows the yield of maize that received zero N fertilising as affected by tillage system and crop rotation. In 2006/07 the yield of the zero N-fertilised maize was affected by both tillage system and cropping system, with no interaction between them. The yield of the no-till maize was 29% lower than that of the conventionally tilled maize. The yield of the rotated maize was 43% higher than the yield of the monoculture maize.

Tillage system had no effect on the yield of the zero N-fertilised maize in 2007/08 while the yield of the rotated maize was 19% higher than that of the monoculture maize. Taking both seasons into account, the yield of the no-till maize was 13% lower than that of the conventionally tilled maize. Yield was not effected by interaction between the

Table 2 Grain yield of maize in kg ha^{-1} without N-fertilisation as affected by crop rotation and tillage systems at NAMPO Park in 2006/07 and 2007/08

Tillage system	Cropping system		Mean
	Monocultured	Rotated	
	2006/07		
Conventional	2060	3306	2683[a*]
No-till after conventional	1876	2338	2107[b]
Mean	1968[b]	2822[a]	2395
	2007/08		
Continued conventional	4328	4415	4371[a]
Conventional after no-till	4083	4581	4453[a]
No-till after conventional	3391	4455	3923[a]
No-till second season	3569	4633	4101[a]
Mean	3843[b]	4581[a]	4211
	Mean		
Conventional	3184	3954	3569[a]
No-tillage	2713	3481	3097[b]
Mean	2948[b]	3718[a]	3333

* Means in a row or column for a particular season followed by different letters are significantly different at $p \leq 0.05$.

N-fertilisation rates were applied according to fertilising procedure (conventional or Delta-yield). N-fertilising system had no effect on the yield of maize in 2007/2008. The Delta-yield-no-till-treatment combination, however, received 7 kg N ha^{-1} less than the conventional procedure while the Delta-yield-conventionally-tilled-combination received 8 kg N ha^{-1} more.

The yield of soybean was effected by tillage system in both seasons (Table 3). Yield from the no-till treatment was 54% and 23% lower than that of the conventionally tilled treatment in 2006/07 and 2007/08, respectively. Calculated across seasons the yield of no-tilled soybean was 26% lower than that of conventionally tilled soybean.

Tillage system had no effect on the RUE of the zero N-fertilised maize in 2007/08, while the RUE of the rotated maize was 19% higher than that of the monocultured maize.

Calculated across seasons the RUE of the conventionally tilled maize was 13% higher than that of the no-till maize. RUE was not effected by an interaction between the treatments.

The lower grain yield and RUE of no-till maize is in line with tendencies from other parts of the world. According to the European Commission (2009) there is a transition period of five to seven years after introduction before a conservation agriculture system reaches equilibrium. During this phase yields may be lower than that of conventionally tilled crops. An alternating system of one year of conventional tillage followed by one year of no-till would therefore keep the soil in the transition period not reaching equilibrium and high yields.

The yield increase of 14 and 19% of maize grown in rotation with soybean compared to the yield of monoculture maize, once again confirmed the advantage of crop rotation that was demonstrated in previous projects. Crop rotation is considered one of the cornerstones for success in conservation agriculture, which aims to conserve soil through minimum soil disturbance and a permanent soil cover. For no-till maize production to be successful on this soil type, crop rotation will most likely also be a key factor.

Table 5 Rainfall-use efficiency of maize (zero-nitrogen fertilised) in kg grain ha^{-1} mm^{-1} rain as affected by crop rotation and tillage systems at NAMPO Park in 2006/07 and 2007/08

Tillage system	Cropping system		Mean
	Monocultured	Rotated	
	2006/07		
Conventional	5.35	8.58	6.97[a*]
No-till after conventional	4.87	6.07	5.47[b]
Mean	5.11[b]	7.33[a]	6.22
	2007/08		
Continued conventional	6.47	6.6	6.53[a]
Conventional after no-till	6.1	7.21	6.66[a]
No-till after conventional	5.07	6.66	5.86[a]
No-till second season	5.34	6.93	6.13[a]
Mean	6.21[b]	7.08[a]	6.3
	Mean		
Conventional	5.92	7.73	6.82[a]
No-tillage	5.1	5.54	5.82[b]
Mean	5.51[b]	7.13[a]	6.32

* Means in a row or column for a particular season followed by different letters are significantly different at $p \leq 0.05$.

Estimation of N-fertilisation requirements by means of the Delta-yield procedure

Delta-yield, which is the difference between optimally fertilised maize yield and that of a zero-fertilised control was affected by tillage method in 2006/07 (Table 6). The delta yield of the no-till treatment was only one-third that of the conventionally tilled maize. In 2007/08 delta-yield was effected by a crop system x cultivation system interaction. The delta yield of the no-till rotated maize was negative, while all other treatment combinations had positive values. Calculated across seasons the delta yield of the conventionally tilled treatment was significantly higher than that of the no-tilled treatment.

Table 7 Delta-yield estimated N-fertilisation rates in kg ha^{-1} for conventionally produced and no-till maize at NAMPO Park from 2005/06 to 2007/08

Season	Tillage system	
	Conventional	No-till
2005/2006	62	-
2006/2007	53	27
2007/2008	31	21
Mean	49	25

Maize protein and total non-structural carbohydrates (TNC)

Results on the protein and TNC are available for the 2006/07 season only. The protein content of maize without nitrogen fertilisation is shown in Table 8 and that of maize that was adequately fertilised with nitrogen in Table 9.

The protein content of maize without N fertilisation was effected by crop rotation. Maize preceded by soybean had a higher protein content than monoculture maize. Where the maize received an adequate amount of N its protein content was not affected by cropping system or tillage system. The TNC content of maize was unaffected by any of the treatments and had a mean value of 69.5%.

Compared to the difference in yield caused by crop rotation (14% to 19%), the difference in grain protein content of 5% is relatively small. This confirms the fact that yield quantity is usually affected more by environmental variables (crop rotation in this case) than is grain quality.

maize produced in the various cropping systems and Table 11 the estimated profit.

Table 10 The estimated total direct cost of maize (R ha^{-1}) as affected by crop rotation and tillage systems at NAMPO Park in 2006/07 and 2007/08.

Tillage system	Cropping system		Mean
	Monocultured	Rotated	
	2006/07		
Conventional	5148	5176	5163
No-till after conventional	4756	4761	4759
Mean	4952	4969	4961
	2007/08		
Continued conventional	5586	5595	5591
Conventional after no-till	5562	5579	5571
No-till after conventional	5300	5309	5305
No-till second season	4387	4413	4400
Mean	5209	5224	5217
	Mean		
Conventional	5361	5382	5372
No-tillage	4800	4811	4806
Mean	5081	5097	5089

Calculated across seasons the estimated direct cost of no-till maize was 11% lower than that of the conventionally tilled system due to lower mechanisation costs and the absence of soil cultivation costs.

Estimated profits varied considerably between cropping systems, tillage systems and between the two seasons. In the relatively dry 2006/07 season only the conventionally tilled, rotated maize produced a profit, while maize produced in any other combination of systems showed losses. In 2007/08, despite no significant differences in grain yield, the estimated profit of conventionally tilled maize was 40% (R1248 ha^{-1}) lower than that of no-till maize. Similarly, the estimated profit of the monoculture maize was 35% (R1057 ha^{-1}) lower than that of soybean-rotated maize. Calculated across seasons, the estimated profit of conventionally tilled maize was 7% (R89 ha^{-1}) higher than that of no-till maize. The estimated profit of the rotated maize was 2.6 times that of maize grown

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