CONCLUSIONS

The highlight of this season's results was the outstanding performance of anhydrous ammonia in suppressing root and crown rots and elevating grain yield. The effects of this treatment on root and crown rot incidence were marked and the root and crown rot rating, relative to those of other treatments, improved throughout the 100-day period from planting until the third sampling. The relative yields also did and at harvest this treatment was the only one significantly superior to the control, which it out-yielded by over 1000 kg/ha. On average, those treatments without surface cover (MB, T, MF & SF) were out-yielded by over 18 % (2300 kg/ha). Although differences were evident in terms of root rot ratings, this dramatic separation was not evident in terms of the dominant fungi and nematode counts recorded at the third sampling. This might indicate that the pathogenicity of individual organisms is dependent on the suite of organisms present or simply reflect the fact that unmeasured changes in fungal and nematode pressures occurred between the third sampling and harvest. A clear explanation of the reason is needed. If these benefits of anhydrous ammonia are validated, this form of nitrogen, already extremely popular in the USA and used in many parts of this country, could play a major role in the control of soilborne diseases.

The drastic collapse of the no-cover treatments is currently difficult to explain, but has potentially very important practical implications, especially when no-till is practiced under dryland conditions and no winter crop is grown. The cover left by soyabean is minimal and conditions would be similar to the no-cover plots in this study. Since there was no evidence of wilting during the season, such large yield differentials cannot be ascribed to drought. Surface drying and consequent higher temperatures in the upper root zone may be implicated.

Community level physiological profiles and enzyme activities over time were used successfully to distinguish between groupings of crop and tillage treatments in this study. The biodiversity indices of full-cover treatments were slightly higher than the partial and no-cover treatments during the season. In contrast to the previous season, the MB treatment could not be separated from other treatments based on carbon utilization profiles. The decrease observed in biodiversity in the AN treatment, however did not have a significant impact on the grain yield. Enzyme activities followed the same trend as observed during the previous season. ß-glucosidase activity increased as the season progressed, while urease activity decreased over time.

The influence of AN on the general microbial diversity and particular functional groups should be investigated to include molecular techniques such as PCR-DGGE. It might be of interest to determine which functional microbial groups were affected by the lethal levels of HNO_2 in future studies. No particular correlation could be obtained between microbial diversity and activity, and the tillage and rotation treatments after only a single season. Continuation of this trial would be valuable in determining the impact of these treatments on soil microbial diversity over an extended period.

The very highly significant correlation between crown and root rot severity and the fact that crown rots were only measurable after the second and third sampling is an indication that infection is initiated in the roots and progresses to the crowns. It is probable, therefore, that those root diseases which also cause stalk rots, for example, *F. graminearum,* are primarily soilborne in origin. Since the incidence of *F. graminearum* was significantly correlated with crown and root rot severity, it seems at this stage that *F. graminearum* is an important soilborne pathogen of maize in KZN, but this needs to be confirmed with pathogenicity tests under controlled environmental conditions. There were also useful relationships between sucker counts and crop growth. In this trial, higher sucker counts were clearly related to plant vigour and root health and, since this is a very simple and easily obtained measure, it is something worth pursuing in future studies of this nature.

Although crown and root rot severity were significantly correlated with plant growth from the first to the third sampling time, there were no significant correlations between disease severity and grain yield. As already mentioned in the Results section of this report, other factors such as moisture stress or surface soil temperature seemed to override the effect of disease severity with regard to grain yield, with two of the treatments without stubble cover (MB & T) having yields lower than the control, even though they had significantly less crown and root rot. In the case of MB this was unfortunately at variance with results obtained during the previous unusually wet and cool season, but also suggests that there is possibly a need to delay the third sampling until a stage closer to black layer formation, when carbohydrate reserves in the plant have been drawn down and disease susceptibility is maximized. Root and crown samples collected at the soft dough stage very likely failed to reflect disease incidence during the critical period between then and maturity. This is a methodological issue which needs addressing in future studies of this nature.

The results with regard to the spectrum of potential fungal pathogens and plant parasitic nematodes obtained from diseased crowns and roots, and the combination of fungicides required as seed treatment to improve seedling growth, indicates clearly that crown and root rot of maize is caused by a complex of organisms. The results also showed that there is a succession of these organisms during the season, which agrees with findings of researchers in other countries. Information on the specific role of individual organisms and their succession in maize production will be invaluable in the development of management strategies against soilborne diseases of maize in future.

Fusarium graminearum, an important pathogen of maize was frequently obtained from diseased crowns and roots in this study. This fungus produces mycotoxins, which are harmful to animals and humans. Any measure to reduce the incidences of the fungus and thereby reduce mycotoxin levels can have huge implications. The results of this study confirmed the effect of wheat-maize rotations on the incidences of *F. graminearum*, with higher incidences of the fungus on maize roots following wheat than broadleaf crops such as canola, crambe, and soyabean. Similarly, tillage, which resulted in the incorporation of infected stubble or bare fallow, reduced incidences of the fungus. Since no-till is currently promoted in many maize producing areas, the use of tillage to reduce *F. graminearum* should not be encouraged. Although the alternative winter crops evaluated in this study did not significantly improved yield compared to when wheat was used as a winter crop, these crops reduced incidences of this pathogen. It is also important to determine any other detrimental effects of the other alternative crops, such as increases in plant parasitic nematodes, before any crop can be recommended to replace wheat in the rotation system. Crop rotation seems to be an important component of any strategy to control *F. graminearum*, but it is important that the current study should be repeated before final recommendations with regard to the usefulness of crop rotation can be given.

The results obtained in this study on the incidence of *Trichoderma* spp. on maize roots confirm results obtained during the previous season. They also suggest an important role for *Trichoderma* spp. in the control of soilborne diseases of maize. The significant improvement in plant growth and grain yield of the ECO treatment after the second application of Eco-T, the fact that seedling damping-off was not recorded in the growth room trial on any of the treatments, and the high incidences of *Trichoderma* spp. in the beginning of the season probably suggest a more important role for *Trichoderma* spp. as biocontrol agents of soilborne pathogens of maize than is currently realized. Interestingly, Eco-T resulted in minimal occurrence of *Fusarium oxysporum* on roots at the third sampling. Five *Trichoderma* spp. were obtained from crowns and roots in this study, but Eco-T consists of *T. harzianum* only. It will, therefore, be necessary to elucidate the role of each species as a biocontrol agent or perhaps, even a pathogen, as has been reported by some researchers, before the role of *Trichoderma* spp. as biocontrol agents of the soilborne disease complex in South Africa can be explained.

Fusarium oxysporum was, similar to the previous season, one of the predominant fungi isolated from maize roots. Incidences of this fungus were significantly negatively correlated with incidences of *F. graminearum*, which is regarded as an important pathogen of maize. Furthermore, incidences of *F. oxysporum* were significantly higher on roots from treatments with no stubble cover than those with partial or full cover, but, with the notable exception of the fallow plots, incidences were not correlated with crown and root rot severity. Although this fungus is regarded as a weak pathogen, it is possible that wounding of roots by nematodes can render plants more susceptible to infection by this fungus and it is noteworthy that the fallow plots had particularly high incidences of certain nematodes. It is, therefore, important to study interactions between plant parasitic nematodes and fungal pathogens associated with maize roots in order to understand the root rot complex of maize.

The plant-parasitic nematodes found during this trial will act in a complex, the genera *Scutellonema, Paratrichodorus* and *Longidorus* as ectoparasites, *Meloidogyne* and *Pratylenchus* as endoparasites and *Helicotylenchus* and *Rotylenchulus* as semi-endoparasites. Even though *Criconemoides sphaerocephalus* was found at more than 10 % in the treatments, the population numbers of this nematode were so low that it is doubtful that *C. sphaerocephalus* played any significant role, but any treatment to manage the plant-parasitic nematodes would have to target all these nematodes. If we concentrate on a single genus in, for example, the endoparasitic group, there is always the possibility that the other genera in this group will only move into the empty niche.

The data available on the impact of no-till or conservation tillage on nematodes are inconsistent. Some researchers reported that under no-till the population numbers of plant-parasitic nematodes increase, while others have reported that the population numbers decrease. There is very little South African information about this aspect available. The information obtained during this trail is extremely valuable in helping us to understand the role of nematodes in maize produced under no-till.

Any treatment undertaken to manage the plant-parasitic nematodes would also have to take the spectrum of bacteriophagous, fungiphagous and predacious nematodes into account. The population numbers found during the trial were very low and, as these nematodes form an integral part of the soil fauna, any further depletion of them will most probably increase the effect of the plant-parasitic nematodes.

This study included some of the components that need to be incorporated into an integrated strategy to manage soilborne diseases of maize. The results look very promising with regard to the use of anhydrous ammonia, Eco-T and to a lesser extent, seed treatments and crop rotations. Furthermore, the data reported here, particularly with regard to the plant yields obtained 21, 70 and 100 days after planting, very clearly confirm the fact that soilborne diseases are playing a major yield-determining role in no-till maize production in this country. Further, expanded research efforts in other parts of South Africa are certainly justified.

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