An Interim Report

THE ROLE AND IMPORTANCE OF SOILBORNE DISEASES AND THEIR INTEGRATED MANAGEMENT IN SUSTAINABLE MAIZE PRODUCTION

FACET 1

THE ROLE AND IMPORTANCE OF SOILBORNE DISEASES AND MICROBIAL DIVERSITY AND ACTIVITY IN MAIZE PRODUCTION AS AFFECTED BY CROP ROTATIONS, BIOCONTROL PRODUCTS, CHEMICAL BIOCIDES, SOIL DISTURBANCE AND RESIDUE COVER

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THE RELATIVE IMPORTANCE OF FUNGI FREQUENTLY ASSOCIATED WITH DISEASED MAIZE CROWNS AND ROOTS AS SOILBORNE PATHOGENS OF MAIZE AND ROTATION CROPS, AND THE INTERACTION BETWEEN FUNGAL PATHOGENS AND PARASITIC NEMATODES ON MAIZE

Submitted on behalf of
the No-Till Club of KwaZulu-Natal

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THE ROLE AND IMPORTANCE OF SOILBORNE DISEASES AND THEIR INTEGRATED MANAGEMENT IN SUSTAINABLE MAIZE PRODUCTION

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FACET 1

THE ROLE AND IMPORTANCE OF SOILBORNE DISEASES AND MICROBIAL DIVERSITY AND ACTIVITY IN MAIZE PRODUCTION AS AFFECTED BY CROP ROTATIONS, BIOCONTROL PRODUCTS, CHEMICAL BIOCIDES, SOIL DISTURBANCE AND RESIDUE COVER

ANHYDROUS AMMONIA EFFECTS ON NO-TILL MAIZE YIELD, ROOT ROT AND SOIL HEALTH

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Anhydrous ammonia constitutes over 30% of the agricultural nitrogen market in the USA – some four million tons annually. Due largely to logistical constraints, its share of the local market is considerably less – about 5% – but there are, nevertheless, many ardent users of the product. So, too, are there persons with strong negative sentiments. Claims that it destroys soil life and leads to soil deterioration often appear in the popular press.

This report addresses some of these issues and also provides experimental evidence to suggest that certain benefits of anhydrous ammonia have been underestimated or overlooked. Of particular importance in this regard is the beneficial effect on root rot severity we have recorded in a 5-year maize field study conducted near Winterton.

This study was funded by the Maize Trust, the KZN Department of Agriculture, Omnia Fertilizer, the ARC-PPRI, and Ant and Terry Muirhead of the KZN No-Till Club. It involves

Photo 1: Some of the people involved from the farm and co-operating institutions and disciplines.

Photo 2: A maize fallow plot surrounded by alternative winter crops.

researchers with skills in plant pathology, nematology, microbiology, soil science and agronomy and is a good example of institutional and disciplinary co-operation (**Photo 1**). The overall objective of the experiment was to identify strategies to lessen the impact of soilborne diseases in no-till wheat/maize systems and the comparison of anhydrous ammonia with LAN was just one of several treatments compared – alternative winter rotations (**Photo 2**), biocontrol agents, tillage, and level of soil cover.

Photo 3: Preparing to inject anhydrous ammonia.

The soil was a Hutton sandy clay (45% clay), with a KCl pH of 4.8 and had previously been under no-till maize and soybean for 10 years. Adequate levels of P, K, S, Zn and B were ensured and all plots received the same level of N (200 kg/ha), either as anhydrous ammonia injected two or three days prior to planting (**Photo 3**) or as LAN applied immediately after planting. The anhydrous gas was applied to a depth of 15–20 cm in rows 45 cm apart, while the LAN was broadcast by hand. The maize cultivar used was PHI 32D96B and was planted at a population of approximately 54 000 per ha.

DATA COLLECTED

Each season (2006/2007 to 2010/2011), plant mass was determined three weeks after planting, near flowering, and during the hard-dough stage of grain development. At the same time, root and rhizosphere soil samples were collected for root rot assessments and fungal identification, nematode counts and classifications, and soil microbial characterisation. Inter-row soil samples were drawn and chemically analysed early in the season and leaf samples were collected for analysis at flowering. Earthworm counts and infiltration rate determinations were conducted periodically.

The treatments compared in this article are shown in **Table 1**. The maize fallow treatment was not planted to a winter crop, but received the same winter irrigation as the other plots, while in treatments other than the control wheat/maize treatment, wheat straw was cut and removed to facilitate imposition of the strategies concerned (**Photo 3**). The methyl bromide treatment was purely to provide an experimental baseline.

WHAT DID ANHYDROUS AMMONIA DO?

Table 1 provides what are considered to be the major beneficial effects of anhydrous ammonia recorded in this study. No effects on topsoil chemical properties were measurable and neither were there any meaningful effects on nematodes or soil microbial properties. Clearly, however, there were dramatic effects on grain yield and significant effects on root rot severity and leaf manganese (Mn) content. It is important to note that leaf N content was at no stage significantly affected and any possibility of N availability having played a role is improbable. This implies that suppression of root rot severity was brought about by enhanced Mn availability.

Table 1. Anhydrous ammonia effects on yield, root rot ratings at the hard-dough stage and leaf manganese content at flowering (5 year averages).

Treatment①	**Yield (kg/ha)**	**Root rot rating②**	**Leaf manganese content (mg/kg)**
Wheat / maize + anhydrous (wheat straw removed)	15320	2.57	116
Wheat / maize ripped as for anhydrous, but without gas (wheat straw removed)	14200	2.92	79
Wheat / maize + methyl bromide (wheat straw removed)	13650	2.74	80
Wheat / maize control (wheat straw not removed	13600	3.19	72
Maize fallow (no wheat planted)	12860	3.16	73
LSD (0.05)	933	0.34	23

① All plots received the same level of N.

② 0 = Healthy roots, 1 = >0–25% root rot, 2= >25–50% root rot, 3 = >50–75% root rot and 4 = >75–100% root rot.

Manganese is known to have powerful fungicidal properties and has long been used in foliar fungicides, but soil applications are largely ineffective, because of the rapid conversion of Mn to forms unavailable to plants. This suggests that enhanced Mn uptake resulted from the presence of high concentrations of ammonium at the root surface. Ammonium uptake results in release of acidity by roots and this would cause unavailable soil Mn to become soluble – the reverse of the effect just described. We are unaware of such an association having been made with anhydrous ammonia use. While there is an abundance of literature indicating that ammonium fertilizers can suppress the incidence of several plant diseases, this is usually ascribed to the toxicity of the ammonium ion or to products formed during the conversion of ammonium to nitrate. Our evidence suggests that rhizosphere acidification is a more probable cause and that the magnitude of the effect would depend on soil pH, another factor recognised as having an influence on many diseases. This means that the favourable effects measured in this research might not be duplicated on all soils.

It is not suggested that enhanced Mn uptake is the sole reason for the yield increase due to anhydrous ammonia. The increase that resulted from ripping without gas, although, on average, only statistically significant when compared to the maize fallow treatment, in two high rainfall seasons (2007/2008 and 2010/2011) also proved significantly superior to the wheat/maize control and methyl bromide fumigation. There is, thus, evidence of a positive trend, which cannot be ignored. The anomalously low yield of the methyl bromide treatment, which had a root rot rating essentially the same as that of the anhydrous ammonia treatment, also seems to be related to the substantially reduced rate of water infiltration, as does the disappointingly low yield of the maize/fallow treatment (**Tables 1 & 2**).

Now to the possible negative effects of anhydrous ammonia that are so frequently referred to in the popular press and, considering the long-term magnitude of anhydrous use in the USA, are somewhat surprising. Apart from the fact that intensive soil microbial investigations conducted in this study failed to identify any such effects, earthworm counts, a widely accepted measure of soil health, clearly showed that anhydrous gas *per se* had no worse an effect than the ripping action of the anhydrous applicator (**Table 2**). The significantly higher worm count in the wheat/maize control treatment was undoubtedly the result of a far greater stubble load on these plots, while thorough tillage required for methyl bromide fumigation would not be expected to sustain earthworm populations as high as those in treatments where straw was removed, but the residue remaining was not incorporated (**Photo 3**). Similarly, since no winter cover was generated in the maize/fallow treatment, the stubble load was relatively low (**Photo 2**). The reduced infiltration rates in these two treatments are almost certainly related to reduced earthworm-created porosity.

Table 2. **Earthworm counts and infiltration rates averaged over three assessments during the 2010/2011 season.**

Treatment	Worm count (no. / m^2)	Infiltration rate (min./20L)
Wheat / maize + anhydrous	36	5.4
Wheat / maize ripped – anhydrous	36	7.5
Wheat / maize + methyl bromide	19	31.5
Wheat / maize control	58	12.9
Maize fallow	25	60.0
LSD (0.05)	23	34

SUMMARY

- Anhydrous ammonia is not only an effective source of N. It has important fungicidal properties in soils such as that used in this investigation and, in addition, the ripping action associated with its application markedly increases the rate of water infiltration.
- In this study, it proved to be the best strategy tested for soil-borne disease control and performed as well as prohibitively expensive soil fumigation with methyl bromide.
- On average, the annual yield benefit over the wheat/maize control exceeded 1700 kg/ha and that over the maize/fallow treatment was over 2400 kg/ha.
- Importantly, our findings indicate that anhydrous ammonia does no more damage to soil health than simply ripping without gas, an action also performed by many modern no-till planters.

FACET 4

THE RELATIVE IMPORTANCE OF FUNGI FREQUENTLY ASSOCIATED WITH DISEASED MAIZE CROWNS AND ROOTS AS SOILBORNE PATHOGENS OF MAIZE AND ROTATION CROPS, AND THE INTERACTION BETWEEN FUNGAL PATHOGENS AND PARASITIC NEMATODES ON MAIZE

PATHOGENICITY AND CROSS-PATHOGENICITY TRIALS

EXECUTIVE SUMMARY

In KwaZulu-Natal, soilborne diseases can significantly depress maize yields in irrigated systems where wheat follows no-till maize. To determine the relative importance of the soilborne fungi involved, pathogenicity tests were conducted during 2010 with isolates obtained from diseased maize crowns and roots. More than 75 fungal species were tested, and the most important species were reported as *Fusarium boothii*, *Fusarium graminearum*, *Phialophora zeicola*, *Phaeocytostroma ambiguum* and *Stenocarpella maydis*. Many of the fungi tested, such as the pathogenic *Pythium* and *Rhizoctonia* spp., were new pathogen reports for maize in South Africa. In order to compare our results with those of local and overseas researchers, it is important to repeat the pathogenicity and virulence tests. Since maize in KZN is often double cropped with wheat in winter and rotated with soybean in summer, it is important to evaluate the pathogenicity and virulence of the important soilborne pathogens of maize on soybean, as well as on crops, such as black oat, canola, stooling rye that may replace wheat as a winter crop. The main aim of Facet 4 of the project "The role and importance of soilborne diseases and their integrated management in sustainable maize production" is to determine the relative importance of the soilborne pathogens associated with diseased crowns and roots of maize and to determine the susceptibility of soybean and winter crops (black oat, canola, stooling rye, and wheat) in order to select the best crops for summer and winter rotation with maize that will reduce disease pressure from soilborne pathogens. Two glasshouse trials were conducted to confirm the 2010 results obtained on the pathogenicity of soilborne pathogens on maize and to conduct cross-pathogenicity tests on summer and winter crops that may be rotated with maize. In the first trial, representative isolates of *F. boothii* (2 isolates), *F. graminearum* (5 isolates), *P. ambiguum* (5 isolates), *P. zeicola* (5 isolates) and *S. maydis* (5 isolates) were tested. In the second trial eight *Pythium* spp. [*P. acanthicum* (1 isolate), *P. aristosporum* (3 isolates), *P. arrhenomanes* (2 isolates), *P. periilum* (4 isolates), *P. irregulare* (9 isolates), *P. rostratifingens* (1 isolate), *P. spinosum* (4 isolates) and *P. ultimum* (1 isolate)] were evaluated for pathogenicity and cross-pathogenicity. In the first trial, canola was not susceptible to any of the test pathogens. *Fusarium boothii* significantly reduced survival and growth of maize and stooling rye and increased root rot severity compared to the controls. This fungus also caused root rot of soybean. *Fusarium graminearum* significantly reduced survival and growth and caused root rot of black oat, maize, stooling rye and wheat, and also reduced survival and caused root rot on soybean. *Phaeocytostroma ambiguum*, *P. zeicola* and *S. maydis* caused a very low level of root rot on soybean, stooling rye and wheat, but did not significantly reduce survival and growth. Results showed that black oat, stooling rye, wheat and most probably soybean can be important alternative hosts of either *F. boothii* or *F. graminearum* or both in rotation systems (double cropping) with maize. In the second trial, *P. ultimum* was the most virulent species on all test crop plants. Canola, soybean and stooling rye were most susceptible to injury by *P. irregulare*, *P. rostratum*, *P. spinosum* and *P. ultimum*, but these fungi also significantly reduced growth of maize, black oat and wheat. *Pythium arrhenomanes* significantly reduced growth and increased root rot severity of maize compared to the control. All the crops were susceptible to *P. irregulare*, which is the most common and one of the most virulent *Pythium* spp. associated with no-till maize in KwaZulu-Natal. These results highlight the importance of pathogenicity and cross-pathogenicity tests in order to select suitable rotation crops. The cross-pathogenicity trials will be repeated and similar tests will be done with the remainder of the pathogens that were selected as new records and potentially important soilborne pathogens of maize. The data obtained with these tests provide extremely important information with regards to the development of an integrated management strategy for control of soilborne diseases of no-till maize in KwaZulu-Natal and possibly elsewhere.

INTRODUCTION

Soilborne diseases have been shown to markedly depress maize yields in maize-wheat double cropping systems in KwaZulu-Natal. In trials conducted near Winterton since 2006, more than 75 fungal species have been isolated from diseased maize crowns and roots. In order to determine the relative importance of these fungi, pathogenicity trials were conducted with 420 isolates (representing all fungi obtained from diseased maize crowns and roots) under controlled glasshouse conditions during 2010.

The results of these trials showed that a large number of fungi isolated from diseased maize crowns and roots caused crown and root rot and reduced survival and growth of maize plants. Fungi that significantly reduced survival of seedlings compared with the control were *Fusarium avenaceum* (78 % survival), *F. graminearum* species complex (68 %), *F. pseudograminearum* (87 %), *Trichoderma asperellum* (86 %), *T. dorotheae* (87 %), *Pythium spinosum* (85 %), *P. ultimum* (77 %), *Rhizoctonia solani* AG-2-2 (83 %), and Unidentified 6 (87 %). The highest mean root rot ratings were recorded for *F. graminearum* species complex (2.47), *F. avenaceum* (1.34), *P. abiguum* (1.88), *Phialophora* spp. (1.33), *Pyrenochaeta terrestris* (1.27), *R. solani* AG-2-2 (2.19), *Stenocarpella maydis* (2.24) and Unidentified 1 (1.57), Unidentified 3 (1.33) and Unidentified 4 (1.06). Fungi that caused significant crown rot compared to the control were *F. graminearum* species complex (68 *%), S. maydis* (56 %), *R. solani* AG-2-2 (52 %), *F. avenaceum (*48 %), Unidentified 5 (33 %), Unidentified 4 (18 %), *P. ambiguum* (36 %), *Phialophora* spp. (16 %), *P. terrestris* (10 %), *Bipolaris* spp. (7 %), *Macrophomina phaseolina* (6 %), Unidentified 3 (6 %), *F. subglutinans* (6 %) and *F. proliferatum* (6 %). Fungi that significantly reduced growth were *Apergillus* spp., *F. avenaceum, F. graminearum,P. ambiguum, Phialophora* spp. *P. aristosporum, P. arrhenomanes, P. periilum, P. rostratifinges, R. solani* AG-2-2, *S. maydis,* Unidentified 1, Unidentified 3 and Unidentified 5. All the *Trichoderma* spp. except for *T. asperellum* significantly improved growth compared to the control. Of the fungi most frequently isolated from diseased maize in our trial conducted for Facet 1, *F. boothii*, *F. graminearum*, *Phialophora zeicola, P. ambiguum* and *S. maydis* proved to be the most aggressive pathogens on maize seedlings, and the pathogenic *Pythium* and *Rhizoctonia* spp. are new pathogen records for South Africa. Isolates within the different fungal groups often differed significantly with regard to their ability to reduce survival and growth and to cause crown and root rot. Results also showed that crown and root rot of maize are caused by a complex of pathogens. This pathogenicity study is to date the most comprehensive study of this nature on soilborne diseases of maize in South Africa.

In order to compare our results with those of other researchers locally and in other countries, the identity of all fungi used in these tests was molecularly confirmed. It is, however, important that the pathogenicity tests with the most aggressive pathogens as well as newly recorded pathogens for South Africa be repeated and that cross-pathogenicity with these pathogens should be performed on potential summer and winter rotation crops that were included in the field trials at Winterton. These are the main aims of Facet 4 of the project “The role and importance of soilborne diseases and their integrated management in sustainable maize production”. This project was initiated in 2006 with the ultimate goal to develop an integrated management strategy, that will include the incorporation of a winter crop that is not susceptible to soilborne pathogens of maize, application of straw cover to reduce plant stress and render plants less susceptible to soilborne pathogens, application of anhydrous ammonia to reduce inoculum of soilborne pathogens, seed treatment and cultivar tolerance/resistance, for the control of soilborne diseases of no-till maize in KwaZulu-Natal. Aspects with regard to application of anhydrous ammonia and straw cover, as well as the effect of alternate winter crops on soilborne diseases were studied under field conditions, but research on the relative importance of the pathogens and susceptibility of winter crops to maize pathogens is still in progress. The effect of seed treatments and cultivar reaction to the most important pathogens will also have to be addressed in future.

MATERIALS AND METHODS

Two trials were conducted to repeat pathogenicity of soilborne pathogens on maize, and to test cross-pathogenicity on black oats, canola, soybean, stooling rye and wheat. In the first trial representative isolates of *F. boothii* (2 isolates), *F. graminearum* (5 isolates), *P. ambiguum* (5 isolates), *P.zeicola* (5 isolates) and *S.maydis* (5 isolates) were tested. In the second trial eight *Pythium* spp. [*P. acanthicum* (1 isolate), *P. aristosporum* (3 isolates), *P. arrhenomanes* (2 isolates), *P. periilum* (4 isolates), *P. irregulare* (9 isolates), *P. rostratifingens* (1isolate), *P. spinosum* (4 isolates) and *P. ultimum* (1 isolate)] were evaluated for pathogenicity and cross-pathogenicity on the same crops.

A pasteurised potting mix consisting of maize soil, river sand and coarse perlite (1:1:1) was used in the pathogenicity tests. Trials were conducted under glasshouse conditions at 28 °C day and 18 °C night temperatures.

An inoculation technique using sand-bran as a medium to grow the respective fungi for inoculum production was adopted. The growth medium was inoculated with the sand-bran one day before planting the crops. The number of seeds planted per pot was 10 for maize, 20 for soybean and 50 for the winter crops. Pots were watered on alternative days and plants evaluated for crown and root rot 3 (maize and soybean) and 2 (other crops) weeks after inoculation. Root rot severity was rated as follows: 0 = roots healthy, 1 = >0 – 25% root rot, 2 = >25 – 50% root rot, 3 = >50 – 75% root rot, and 4 = >75 – 100% root rot. The number of plants that survived and growth were also measured 3 weeks after planting maize and soybean (summer crops) and 2 weeks after planting winter crops.

The trials were randomised block designs and data were analysed using ANOVA and the Student – at least significant difference at 5% significance level was calculated to compare means.

RESULTS AND DISCUSSION

Results on the effect of the fungi evaluated in trial 1 on survival of seedlings, root rot severity and growth are given in **Table 1**.

Table 1. Effect of soilborne pathogens of maize on survival, growth and root rot severity of black oat, canola, maize, soybean, stooling rye and wheat after inoculation under glasshouse conditions.

Crop	Fungus	Survival (%)	Plant length (mm)	Root rot severity
Black oat	**Control**	98.0	196.7	0.0
	F. boothii	95.0	183.2	0.1
	F. graminearum	73.1	174.4	0.5
	P. ambiguum	97.1	194.6	0.1
	P. zeicola	97.5	188.2	0.0
	S. maydis	97.5	195.5	0.1
Canola	**Control**	94.7	59.4	0.0
	F. boothii	92.3	58.9	0.2
	F. graminearum	93.1	59.1	0.2
	P. ambiguum	93.6	55.6	0.1
	P. zeicola	93.2	62.4	0.2
	S. maydis	93.6	59.8	0.0
Maize	**Control**	100.0	382.7	0.3
	F. boothii	71.7	288.6	2.3
	F. graminearum	47.3	291.2	1.9
	P. ambiguum	93.3	371.7	0.9
	P. zeicola	95.3	367.7	1.0
	S. maydis	92.0	344.6	1.3
Soybean	**Control**	85.0	287.9	0.3
	F. boothii	82.5	286.3	0.6
	F. graminearum	76.7	267.1	0.7
	P. ambiguum	82.5	288.5	0.4
	P. zeicola	83.7	288.6	0.4
	S. maydis	80.7	291.4	0.4
Stooling rye	**Control**	73.3	199.4	0.2
	F. boothii	55.3	178.9	1.3
	F. graminearum	28.0	146.4	2.1
	P. ambiguum	72.3	200.3	0.7

Crop	Fungus	Survival (%)	Plant length (mm)	Root rot severity
	P. zeicola	71.7	194.2	0.6
	S. maydis	71.6	190.7	0.9
Wheat	**Control**	98.0	233.8	0.0
	F. boothii	93.7	226.6	0.7
	F. graminearum	90.1	212.5	0.9
	P. ambiguum	95.2	231.1	0.4
	P. zeicola	93.5	226.3	0.4
	S. maydis	95.3	221.7	0.5
LSD (P = 0.05)		**7.042**	**14.314**	**0.225**

Canola was not susceptible to any of the test pathogens. *Fusarium boothii* significantly reduced survival and growth of maize and stooling rye and increased root rot severity compared to the controls. This fungus also caused root rot of soybean. *Fusarium graminearum* significantly reduced survival and growth and caused root rot of black oat, maize, stooling rye and wheat, and also reduced survival and caused root rot on soybean. *Phaeocytostroma ambiguum*, *P. zeicola* and *S. maydis* caused a very low level of root rot on soybean, stooling rye and wheat, but did not significantly reduce survival and growth. Results showed that black oat, stooling rye, wheat and most probably soybean can be important alternative hosts of *F. boothii* and *F. graminearum* in rotation systems (double cropping) with maize, but these results will be confirmed in a repeat trial currently being conducted under glasshouse conditions.

Results of the effect of *Pythium* spp. associated with diseased crowns and roots of maize on survival, root rot severity and growth of seedlings of alternative crops are given in **Table 2**.

Table 2. **Effect of *Pythium* species associated with diseased maize crowns and roots on survival, growth and root rot severity of black oat, canola, maize, soybean, stooling rye and wheat after inoculation under glasshouse conditions.**

Crop	Fungus	Survival (%)	Plant length (mm)	Root rot severity
Black oat	**Control**	98.0	140.0	0.0
	P. acanthicum	99.3	146.6	0.0
	P. aristosporum	97.2	143.0	0.2
	P. arrhenomanes	99.3	144.0	0.3
	P. periilum	98.7	145.3	0.5
	P. irregulare	88.0	125.2	0.6
	P. rostratifingens	92.0	132.5	0.2
	P. spinosum	88.5	129.4	0.2
	P. ultimum	74.7	115.5	0.6

Crop	**Fungus**	**Survival (%)**	**Plant length (mm)**	**Root rot severity**
Canola	**Control**	92.0	62.0	0.0
	P. acanthicum	96.0	26.6	0.0
	P. aristosporum	95.5	27.2	0.2
	P. arrhenomanes	94.7	45.1	0.1
	P. periilum	95.0	42.8	0.2
	P. irregulare	48.0	21.1	1.1
	P. rostratifingens	36.0	17.3	1.2
	P. spinosum	66.7	26.6	1.2
	P. ultimum	14.0	11.8	2.0
Maize	**Control**	96.7	327.7	0.0
	P. acanthicum	93.3	326.5	0.2
	P. aristosporum	94.2	325.1	0.2
	P. arrhenomanes	90.0	298.4	1.0
	P. periilum	93.3	322.2	0.7
	P. irregulare	96.3	295.8	0.7
	P. rostratifingens	90.0	278.6	0.5
	P. spinosum	91.0	310.9	0.8
	P. ultimum	80.0	283.3	0.7
Soybean	**Control**	88.3	172.2	0.0
	P. acanthicum	91.7	178.2	0.4
	P. aristosporum	85.3	171.0	0.4
	P. arrhenomanes	88.3	177.4	0.5
	P. periilum	87.5	172.3	0.6
	P. irregulare	71.3	104.4	1.9
	P. rostratifingens	78.3	127.4	2.0
	P. spinosum	57.9	105.9	1.7
	P. ultimum	53.3	65.5	2.0
Stooling rye	**Control**	85.3	134.5	0.0
	P. acanthicum	76.7	131.8	0.2
	P. aristosporum	80.3	130.2	0.2
	P. arrhenomanes	83.7	138.0	0.3
	P. periilum	80.2	131.0	0.5
	P. irregulare	56.0	114.5	0.7
	P. rostratifingens	51.3	121.5	0.1
	P. spinosum	46.0	108.2	1.0
	P. ultimum	29.3	85.4	1.7
Wheat	**Control**	96.7	133.5	0.0
	P. acanthicum	88.7	130.4	0.4
	P. aristosporum	92.3	133.1	0.7
	P. arrhenomanes	95.3	132.6	0.6
	P. periilum	92.2	128.7	0.7
	P. irregulare	90.2	124.6	0.9

Crop	Fungus	Survival (%)	Plant length (mm)	Root rot severity
	P. rostratifingens	94.0	122.6	0.6
	P. spinosum	88.3	125.1	0.7
	P. ultimum	84.7	110.9	1.1
LSD (P= 0.05)		**9.770**	**12.955**	**0.251**

Pythium ultimum was the most virulent species on all test crop plants. Canola, soybean and stooling rye were most susceptible to injury by *P. irregulare*, *P. rostratum*, *P. spinosum* and *P. ultimum*, but these fungi also significantly reduced growth of black oat, maize, and wheat. *Pythium arrhenomanes* significantly reduced growth and increased root rot severity of maize compared to the control. All the crops were susceptible to *P. irregulare*, which is the most common and one of the most virulent *Pythium* spp. associated with no-till maize in KwaZulu-Natal. These results highlight the importance of pathogenicity and cross-pathogenicity tests in order to select suitable rotation crops.

The cross-pathogenicity trials will be repeated and similar tests will be done with the remainder of the pathogens that were selected as new records and potentially important soilborne pathogens of maize. The data obtained with these tests provide extremely important information with regards to the development of an integrated management strategy for control of soilborne diseases of no-till maize in KwaZulu-Natal.

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