Host suitability of selected South African maize genotypes to the root-knot nematode species Meloidogyne incognita race 2 and Meloidogyne javanica: A preliminary study

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Thirty-one commercial maize (Zea mays L.) hybrids and open-pollinated varieties (OPV's) were screened in separate greenhouse trials with a resistant inbred line MP712W as reference genotype for host suitability to Meloidogyne incognita race 2 and Meloidogyne javanica. Approximately 10 000 eggs and second-stage juveniles (J2) of the appropriate root-knot nematode species were inoculated on roots of each maize seedling 10 days after plant emergence. The numbers of eggs and J2 per root system were counted, while it was also calculated g^{-1} root. In addition, percentage resistance in relation to the most susceptible genotype and nematode reproduction factors (Rf) were calculated for the maize genotypes screened. Substantial variation existed among the maize hybrids and OPV's with regard to the nematode parameters evaluated. A number of genotypes could be regarded as highly resistant to M. incognita race 2 based on the fact that they supported less than 10% of the population of this root-knot nematode species, compared to that supported by the most susceptible genotype. Several hybrids and OPV's were identified with Rf values less than one for M. incognita race 2 and M. javanica respectively, indicating antibiosis resistance to these parasites. Screenings of maize genotypes in this study have provided a clear indication of the genetic variability within the maize genome, also with regard to susceptibility of the crop to root-knot nematodes. This substantiates the fact that maize could not be regarded as a non-host to root-knot nematodes on a generic basis, particularly in terms of commercial hybrids. It is suggested that commercial maize hybrids are screened on a continuous basis against root-knot nematodes, which would facilitate selection of hybrids that are less susceptible to both nematode species but that would perform optimally in soils conducive to root-knot-nematode infestation.

Keywords: Hybrids, open-pollinated varieties, resistance, root-knot nematodes, Zea mays

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Introduction

Maize (Zea mays L.) is an important cereal crop for human consumption in many parts of the world, with global production exceeding 600 million tonnes (mt) in recent years (FAO, 2007). Approximately 60% of the world's maize is produced in developing countries (Mc Donald & Nicol, 2005), with 14.8 mt having been produced in southern Africa during 2006 (FAO, 2007). Maize is the most important agricultural crop by far in South Africa. Annual production is highly variable due to periodic droughts but other abiotic and biotic constraints could also have localised or more extensive effects on the crop (Mc Donald & Nicol, 2005).

Several authors have indicated that plant-parasitic nematodes are of great economic importance in maize production since they cause significant yield losses worldwide (De Waele & Jordaan, 1988; Riggs & Niblack, 1993; Mc Donald & Nicol, 2005). From a global perspective the predominant plant-parasitic nematode genera that infect maize are Meloidogyne spp. (root-knot nematodes), Pratylenchus spp. (root-lesion nematodes and Heterodera spp. (cyst nematodes) (Riggs & Niblack, 1993; Mc Donald & Nicol, 2005). M. incognita race 2 and M. javanica are the most common and predominant Meloidogyne spp. in the western maize production areas of South Africa (Riekert, 1996). These two species are, therefore, regarded as having the greatest damage potential on maize in local maize-production regions due to their high population levels, which often result in yield losses (Riekert, 1996).

Although a variety of chemical, cultural and biological strategies exist for the control of nematodes (Kerry, 1987; Stirling, 1991; Mc Donald & Nicol, 2005), host-plant resistance offers one of the few really cost-effective option to producers (De Brito & Antonio, 1989; Cook & Starr, 2006). Under conditions of severe nematode infection and/or inadequate levels of resistance, host plant resistance could still serve to complement other control strategies.

South Africa has a well-developed and highly competitive maize seed trade and foreign as well as locally adapted germplasm is continuously introduced into a market with an extensive choice regarding maize hybrids and open-pollinated varieties (OPV's). National cultivar trials conducted by the ARC-GCI and co-funded by the Maize Trust are conducted annually in the different maize production areas. Results are used to prepare cultivar performance databases for recommendation of the most suitable hybrid or variety. Apart from yield, other characteristics are included (with the exception of disease and pest resistance) in the performance database.

The objective of this study was to screen some popular maize genotypes with a known resistant standard for their host suitability to the most common root-knot nematodes that occur in local maize-producing areas, viz. M. incognita race 2 and M. javanica, respectively. This way the possible range of resistance in commercial maize to these nematodes could be determined.

Material and methods

Two trials, one for M. javanica and the other for M. incognita

race 2, were conducted in separate greenhouses. An ambient temperature range of 19-20°C (minimum) and 25-27°C (maximum) with a 14:10 LD photoperiod was maintained in the relevant greenhouses for the duration of both trials.The trials were laid out as randomised-complete block designs with six replicates per entry (hybrid, variety or inbred line). Plastic pots with a capacity of 4 000cm^{-3} were filled with a methyl-bromide fumigated (1 162 g as 2 m^{-3}soil) and steam-pasteurised sandy-loam soil (3.9% clay, 93.6% sand, 1.9% silt and 0.6% organic-matter contents). The soil pH (H_2O) was 6.55. Nutrients were added according to the results of a soil nutrient analysis.

Thirty-one local genotypes consisting of commercial maize hybrids and OPV's were screened for host suitability to local populations of M. incognita race 2 and M. javanica in the two independent trials. The previously tested, foreign inbred line MP712W was used as the resistant standard (Aung et al., 1990; Windham & Williams, 1994). Two seeds of each maize genotype were planted per pot and seedlings were thinned by hand to one per pot, five days after emergence. Pots were watered with municipal tap water three times a week by filling the saucer of each pot. No water was supplied from above, i.e. directly onto the soil in which the seedlings were planted. Maize seedlings were each inoculated 10 days after emergence with approximately10 000 root-knot nematode eggs and second-stage juveniles (J2) of the respective nematode species or race on roots exposed around the stems of each seedling. Root-knot nematode inoculum for both trials was obtained from infected roots of tomato (cv. Rodade), which were grown for 60 days in soil infested with pure cultures of the respective species in 25 000 cm^{-3} capacity plastic pots in separate greenhouses. The M. incognita race 2 population was originally obtained from infected sunflower roots sampled in the Wesselsbron area (Free State Province) during the 2005 growing season. On the other hand the M. javanica population was originally obtained from infected potato tubers sampled in the Christiana area (North-West Province) during 2005.

After inoculation the roots were covered with soil from the same source from which the pots were filled. Both trials were run for 56 days after nematode inoculation, allowing for completion of at least one nematode generation (Milne & Du Plessis, 1964; 1973; Kleynhans, 1991; Fourie, 2005).

At trial termination the maize plants were cut off at ground level and the aboveground material was discarded. The root systems were removed from the pots, carefully washed, dried with paper towel and weighed. Root-knot nematode eggs and J2 were extracted from every root system using the adapted NaOCl method of Riekert (1995). The numbers of eggs and J2 were counted in a De Grisse dish with a dissection microscope. The number of eggs and J2 g^{-1} root was also calculated. Resistance percentage (number of eggs and J2 per root system of each genotype evaluated ÷ number of eggs and J2 per root system obtained for the most susceptible genotype x 100) and reproduction factors [Rf = final egg and J2 numbers (Pf) ÷ inoculated egg and J2 number (Pi)] were used as the criteria to screen for nematode resistance in maize genotypes. These parameters proved to be discriminant tools for identification of root-knot-nematode-resistant sources in different of crops (Windham & Williams, 1988; Fourie et al., 2001; Hussey & Janssen, 2002; Fourie et al., 2005; Cook & Starr, 2006). Nematode data were subjected to an analysis of variance (Statgraphics Plus 5 for Windows). Treatment means were separated using the Tukey test (P 0.05).

Results and discussion

None of the 31 genotypes screened were immune to the root-knot nematodes used in this study (Tables 1 & 2). However, eight of the genotypes, excluding the resistant standard, could be classified as highly resistant to M. incognita race 2 since they maintained less than 10% of the nematode population that was maintained by the most susceptible genotype, PAN6146 (Table 1). None of the genotypes could be classified as highly resistant to M. javanica since all, except the resistant standard MP712W, maintained more than 10% of the average nematode population that occurred on the most susceptible genotype, LS8511 (Table 2).

Nine maize hybrids and seven OPV's could be classified resistant to M. incognita race 2 since they had Rf values less than 1 (Table 1). The same applied to 13 maize hybrids and seven OPV's evaluated against M. javanica (Table 2). All OPV's screened against both nematodes showed resistance (Tables 1 & 2). This is of particular importance because these genotypes are mostly grown by resource-poor farmers since the OPV seed prices are substantially lower than those of hybrids. Seed from one or more OPV crops can also be retained by producers to be planted during the next season.

Substantial variation existed with regard to root-knot nematode population growth, expressed as Rf values among the maize genotypes screened against M. incognita race 2 as well as M. javanica (Tables 1 & 2). Some, such as DKC80-10 and AFG4410, proved highly susceptible to both nematode species, while others, such as DKC78-15B, PHB3203 and DKC61-25B, are resistant to one nematode species but not to the other. This could be problematic as M. incognita and M. javanica often occur in mixed populations in crop fields (Kleynhans, 1991; Luc et al., 2005), particularly in local maize fields (Riekert, 1996; Riekert & Henshaw, 1998). In addition, hybrids resistant to one of these species but susceptible to the other can stimulate one of these root-knot nematode species to dominate in a particular field. This way it might adversely affect successive crops because producers often do not know this when planning for the successive season. Hybrids such as DKC80-10, AFG4410, PHB32A05B and others were highly to moderately susceptible to both nematode species based on Rf values (Tables 1 & 2).

The numbers of eggs and J2 of both nematode species got alarmingly high in roots of some hybrids at 56 DAI, even when compared to other traditionally more susceptible crops (Fourie et al., 1999; Fourie et al., 2001). When these hybrids are grown, whether in monocropping or in rotation systems with other root-knot-nematode-susceptible crops, the nematode damage may be cumulative in successive growing seasons. This could be prevented by selecting hybrids that are less susceptible to both nematode species but which would perform equally to susceptible hybrids when the latter are grown in the absence of root-knot nematodes. Therefore it is suggested that commercial maize hybrids are screened on a continuous basis against root-knot nematodes, as is done with local soybean cultivars (Erasmus & Fourie, 2009).

Table 1 Population status of Meloidogyne incognita race 2 on 31 maize genotypes 56 days after inoculation (DAI) with 10 000 eggs and J2 in a greenhouse trial.

Genotype	No. of eggs & J2 root system^{-1}	No. of eggs & J2 g^{-1} root	[1]Resistance %	[2]Rf value
PAN6146	19 818 j	137 def	100	1.98
DKC80-10	19 079 ij	135 def	96	1.90
PHB3203	18 924 ij	184 f	95	1.89
AFG4410	16 898 hij	129 cdef	85	1.68
AFG4520	15 640 ghij	139 def	79	1.56
DKC61-24	15 090 fghij	132 def	76	1.50
DKC80-12B	14 570 efghij	316 g	74	1.45
DKC61-25B	14 159 efghij	128 cdef	71	1.41
PHB32A05B	14 003 efghij	167 ef	71	1.40
PAN6479	13 787 efghij	83 abcdef	70	1.37
LS8511	13 073 efghi	87 abcdef	66	1.30
PHB30D05	12 013 defgh	79 abcdef	61	1.20
CRN3505	11 861 defgh	93 abcdef	60	1.18
PAN6966	10 237 cdefg	79 abcdef	52	1.02
CRN5549	10 056 cdefg	89 abcdef	51	1.00
LS8507	8 799 cdef	55 abcde	44	0.87
PAN6053	8 758 cdef	51 abcde	44	0.87
PAN6777	8 065 bcde	44 abcd	41	0.80
QS7707	6 525 abcd	46 abcd	33	0.65
ZM523	4 950 abc	34 abcd	25	0.49
PAN6126	4 721 abc	50 abcd	24	0.47
PAN6549	1.951 ab	13 ab	10	0.19
AFRIC1	1 988 ab	11 a	10	0.19
SAM1101	1 780 ab	14 abc	9	0.17
OBATAMPA	1 395 a	40 abcd	7	0.13
PANTHERA	1 074 a	11 a	5	0.10
DKC78-15B	691 a	4 a	3	0.06
PAN67	750 a	7 a	4	0.07
QPM-SR	312 a	3 a	2	0.03
PAN6114	183 a	3 a	1	0.01
QS-OBA	60 a	1 a	0	0.006
[3]MP712W	31 a	1 a	0	0.003
P value	0.0000	0.0001		0.0000
F ratio	8.0395	2.8241		8.0395
SE	601	8.22		0.06

Means in the same column followed by the same letter do not differ significantly at P≤0.05 according to the Tukey test; [1]Resistance % = [number of egg and J2 per root system of each genotype evaluated/number of eggs and J2numbers/root system of the most susceptible hybrid (PAN6146) x 100]; [2]Rf = final egg and J2 numbers (Pf)/initial egg and J2 numbers (Pi); [3]Resistant standard.

Table 2 Population status of Meloidogyne javanica on 31 maize genotypes measured 56 days after inoculation (DAI) with 10 000 eggs and J2 in a greenhouse trial.

Genotype	No. of eggs & J2 root system^{-1}	No. of eggs & J2 g^{-1} root	[1]Resistance%	[2]Rf value
LS8511	29 967 j	382 cdefghi	100	2.99
DKC80-10	21 792 j	656 i	73	2.17
AFG4410	21 742 j	470 fghi	73	2.17
CRN5549	18 658 ij	436 efghi	62	1.86
AFG4520	17 958 ij	489 ghi	60	1.79
CRN3505	16 908 hij	507 ghi	56	1.69
PHB32A05B	15 967 ghij	531 hi	53	1.59
DKC80-12B	15 883 fghij	356 bcdefghi	53	1.58
DKC78-15B	14 300 efghij	407 defgh	48	1.43
PAN6777	11 892 defghi	208 abcde	40	1.18
PAN6966	11 725 cdefghi	221 abcde	39	1.17
PAN6479	9 283 bcdefgh	212 abcde	31	0.92
PANTHERA	8 858 bcdefg	234 abcdef	30	0.88
PAN6549	8 600 abcdefg	230 abcdef	29	0.86
PAN6146	8 392 abcdefg	280 abcdefg	28	0.83
PHB30D05	8 317 abcdefg	195 abcde	28	0.83
DKC61-24	8 300 abcdefg	220 abcde	28	0.83
QS7707	8 217 abcdefg	214 abcde	27	0.82
LS8507	8 075 abcdef	169 abcd	27	0.80
PHB3203	7 708 abcde	184 abcd	26	0.77
DKC61-25B	6 833 abcde	126 ab	23	0.68
PAN67	6 017 abcd	144 abc	20	0.60
PAN6126	5 667 abcd	166 abcd	19	0.56
AFRIC1	5 350 abcd	151 abc	18	0.53
ZM523	4.583 abcd	101 a	15	0.45
QPM-SR	4 167 abcd	84 a	14	0.41
QS-OBA	4 083 abcd	116 ab	14	0.40
PAN6114	4 000 abc	108 a	13	0.40
OBATAMPA	3 808 ab	97 a	13	0.38
SAM1101	3 633 ab	112 ab	12	0.36
PAN6053	3 308 ab	58 a	11	0.33
[3]MP712W	825 a	66 a	3	0.08
P value	0.0000	0.0000		0.0000
F ratio	4.6449	3.1923		4.6449
SE	627	18		0.06

Means in the same column followed by the same letter do not differ significantly at P≤0.05 according to the Tukey test; [1]Resistance % = [number of egg and J2 per root system of each genotype evaluated/number of eggs and J2 numbers/root system of the most susceptible hybrid (LS8511) x 100]; [2]Rf = final egg and J2 numbers (Pf)/initial egg and J2 numbers (Pi); [3]Resistant standard.

Resistance is in practice a relative concept, with various levels of resistance being identified within a continuum of host-nematode interactions by comparing genotypes to each other (Hussey & Janssen, 2002). When genotypes are classified according to their relative resistance to the most susceptible genotype in a batch, the higher susceptibility of the most susceptible genotype will facilitate identification of more resistant genotypes based on the criteria used in this study (Roberts, 1992; Hussey & Janssen, 2002; Cook & Starr, 2006). Reproduction factors are useful to calculate because it is an accurate indication of the ability of the nematode to develop and reproduce on a particular genotype. Low Rf values may indicate antibiosis resistance since this mechanism of resistance refers to all adverse effects exerted by the host plant on the biology, survival, development and reproduction of a pathogen (Painter, 1951; Horber, 1980).

That there are maize hybrids and OPV's with resistance to root-knot nematodes has been reported by a number of authors (Baldwin & Barker, 1970; Windham & Williams, 1988; De Brito & Antonio, 1989; Aung et al., 1990; Windham & Williams, 1994; Mc Donald & Nicol, 2005). The inbred line MP712W, which is resistant to USA populations of M. javanica and M. incognita (Aung et al., 1990; Windham & Williams, 1994) has constantly proved to have superior resistance to local populations of both these species (Fourie & Mc Donald, 2003). For this reason the line could be used to introgress higher levels of resistance to local resistant sources by crossing it with well-adapted maize genotypes. Combining ability of MP712W with locally adapted hybrids and OPV's will be the decisive factor to successfully breed for acceptable yields when resistance is transferred in this way (Mc Donald & Nicol, 2005).

Screenings of maize genotypes in this study have provided a clear indication of the genetic variability within the South African maize germplasm and confirm reports worldwide in this regard for foreign maize germplasm (Davis et al., 1999; Chandler & Brendel, 2002), with regard to susceptibility of the crop to root-knot nematodes. This substantiates the fact that maize could not be regarded as a poor or non-host to root-knot nematodes on a generic basis, particularly in terms of commercial hybrids. These screenings also provided for the identification of useful sources of resistance to M. incognita race 2 and M. javanica, which could be utilised in breeding programmes.

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