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Potential of Sequential Cropping in the Management of Root-Knot Nematodes in Okra

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Abstract: The response of different crops to a mixed population of root-knot nematodes, *Meloidogyne javanica* and *M. incognita* and their potential as suppressants in sequential cropping systems was evaluated in greenhouse and field experiments. Crops rated as resistant were five maize cultivars, four sorghum cultivars, two millet varieties, guwar and two pigeonpea cultivars which had galling indices ranging between 1.4-3.6. cowpea cv. K80 was rated as moderately resistant with a galling index of 4 while greengram and cowpea cv. KKI were rated as susceptible with galling indices ranging from 5.6 to 7.4. Four crops namely sweetcorn, babycorn, maize cv. Pioneer (Ph3253) and guwar were selected after the greenhouse tests for field trials, based on their poor host status to root-knot nematodes as well as relative acceptability to vegetable growers. These crops were then incorporated into a rotation program with okra. Initial and final J_2 numbers in the field were determined before planting and at the end of the season, respectively. Okra was then sown in the plots previously grown with the selected nematode suppressive crops and the nematode numbers determined mid and end of the season. A 44 and 21% decline in nematode numbers was recorded in plots under guwar or sweetcorn and babycorn, respectively. In contrast, a 441% increase in nematode numbers was recorded in plots under continuous crop of okra. The galling index on a crop of okra that followed sweetcorn was 3.3 compared to 8.6 in the control which was continuously under okra, resulting in an increase in yield within a range of 60-92%. This underscores the potential of rotating highly susceptible crops with poor hosts in the management of root-knot nematodes.

Key words: *Meloidogyne* sp. maize, sorghum, galling index, resistant, rotation, eggmass index, susceptible

INTRODUCTION

Okra (*Abelmoschus esculentus* Moench.) is one of the warm season crops that is grown in the tropical and sub-tropical regions of the world (Rashid *et al*., 2002). The crop is a leading Asian vegetable exported from Kenya and the third most important foreign exchange earner after frenchbeans and snowpeas. Small-hold tropical farmers grow okra for export under contract production arrangements or for local consumption (Zareen *et al*., 2001).

Okra is known to be highly susceptible to root-knot nematodes and infected plants are stunted, exhibiting signs of nutrient deficiency and characteristic large swellings on both primary and secondary roots (Thies *et al*., 2004; Sikora and Fernandez, 2005). The crop has been shown to suffer more than 90% yield loss when grown in fields infested with 3-4 *M. incognita* juveniles per gram of soil (Zareen *et al*., 2001). A number of strategies including chemical nematicides, fallowing, cover copping, crop rotation, biological control, host resistance and organic soil amendments developed for management of root-knot nematodes are restricted in adoption due to the major limitations associated with them (Mostafa, 2000). Nematode control by use of cover crops is uncertain because knowledge of nematode genera present and susceptibility of potential cover crops is largely unknown (Abbasi *et al*., 2005). A cultural practice such as fallowing is restricted in adoption mainly due to scarcity of arable land and loss of production during the fallowing while flooding is restricted due to topography and scarcity of water resources (Sikora *et al*., 2005). Although biological control is a viable alternative to pesticides, difficulties in mass production, imbalance in biodiversity and unaffordability by smallholder farmers limit its adoption (Kiewnick and Sikora, 2004; Tiyagi and Shamim, 2004). According to Walker (2004), chemical nematicides are not only too expensive, they are currently restricted in use since most of the potent nematicides are being phased out due to environmental and health concerns.

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Crop rotation is a classical cultural approach that has enormous potential as a sustainable strategy in the management of plant parasitic nematodes (Ball-Coelho *et al*., 2003). Incorporation of crops that are poor hosts, trap or antagonistic to nematodes in a rotation program have been shown to reduce the initial nematode population thus allowing the subsequent crop to establish before nematode populations build-up to economic threshold levels (Oka and Yermiyahu, 2002; Wang *et al*., 2003). Potential rotation crops must however, be tested under local nematode populations before their adoption is recommended (Kratochvil *et al*., 2004.). Although sequential cropping offers an exciting opportunity for nematode management, the crops selected must also have a ready market to be accepted by growers. This study was undertaken with the aim of identifying crops that can be grown in rotations with okra to suppress build-up of root-knot nematodes.

MATERIALS AND METHODS

Greenhouse and field experiments were carried out in the period between August 2004 and April 2005 at the Kibwezi Irrigation Project in Kenya. The greenhouse experiment was undertaken to evaluate the potential of 21 selected crops including cultivars of sweetcorn, babycorn, maize and guwar among others, for nematode suppressiveness with okra as the control. Potting medium was made by mixing volcanic ash and top forest soil after sterilizing, at the ratio 1:3. Pre-plant fertilizer (DAP) was added to the pots at the rate of 5 g per pot. The pots were irrigated and sown with four seeds of each crop and thinning done after germination to leave two seedlings per pot. Treatments were arranged in a completely randomized design with five replications.

Eggs for inoculum were extracted from infected okra roots using NaOCl as described in Vaast *et al.* (1998). The potting medium was infested with nematodes 10 days after emergence of the seedlings, at the rate of 4000 eggs/juveniles per pot. This experiment was terminated after 60 days and repeated once. Damage assessment (galling index) and reproductive potential (egg masses stained with Phloxine B) were assessed using a scale of 1-9 where 1 = no galls eggs masses; 2 = 1-5 galls/egg masses; 3 = 6-10 galls/egg masses; 4 = 11-20 galls/egg masses; 6 = 31-50 galls/egg masses; 7 = 51-70 galls/egg masses; 8 = 71-100 galls/egg masses; 9>100 galls/egg masses (Sharma, 2001). Second stage juveniles were extracted from 200 cm^3 soil using modified the Baermann funnel technique as described by Hooper *et al.* (2005).

Based on the results from the greenhouse experiment, four crops namely sweetcorn, babycorn, maize cv pioneer and guwar were selected for further evaluation in the field. Selection was based on their potential in nematode suppression as well as their relatively higher market value which is a stimulus to adoption by small-hold farmers. A field that was naturally infested with *M. incognita* and *M. javanica* in the ration 3:1 was used. The crops were planted in 6×6 m plots arranged in a randomized complete block design with 4 replications. Plots planted with okra were included as controls. Initial (P_i) nematode numbers in the soil were determined by taking 5 samples from each plot and extracting the second stage juveniles (J_2) using the modified Baermann funnel technique. Data on galling index, eggmass index and final juvenile population (P_f) were recorded at 8 weeks after planting.

To evaluate the effects of rotating okra with selected nematode suppressive crops, okra was grown in the 6×6 m plots previously sown with the nematode suppressive crops in the field. The P_i and P_f *Meloidogyne* J_2 numbers were determined at the beginning and the end of the season. Damage by root-knot nematode on okra was assessed at the end of the season as described above. Each of the experiments was repeated once.

RESULTS

Reaction of different crops to *Meloidogyne* sp. under greenhouse conditions: Significant ($p<0.05$) differences in J_2 numbers, galling and eggmass indices were observed among the crops tested (Table 1). Galling was highest (7.4) on plots planted with okra (control) followed by greengrams cv. KS20 (6.0). Cowpea cv. KKI, cowpea cv. K80 and greengram cv. Ranress had galling indices of 5.6, 4.0 and 5.2 were rated as moderately resistant. The least susceptible (resistant) crops were sorghum, millet, guwar, sweetcorn, babycorn and maize cultivars Pioneer (Ph 3253), DLCI, DHO1 and Katumani with galling indices ranging from of 1.2-1.8. The eggmass indices followed a similar trend among the crops tested. Similarly, okra cultivars harboured the highest nematode numbers (690-740) compared to all other treatments. Cultivars of maize, sorghum, millet and pigeonpea had nematode numbers in the range 240-150 in their soils and were rated resistant. Cowpea cv. KK1 and both cultivars of greengrams which had higher nematode numbers and were rated as susceptible.

The reaction of the 4 selected crops to root-knot nematodes under field conditions was variable (Table 2). The highest galling index (8.2) was recorded in okra (control) while the least (1.2) was observed in guwar followed by sweetcorn (1.5). With the exception of okra

Table 1: Reaction of different crops to root-knot nematodes under greenhouse conditions

Crop, variety and species	Use	Galling index I	Galling index II	Eggmass index I	Eggmass index II	J_2/200 cm^3 I	J_2/200 cm^3 II	Reaction
Maize-Katumani (*Zea mays*)	Cereal	1.4	1.2	2.8	3.4	193	239	Res.
Maize-DLCI (*Zea mays*)	Cereal	1.6	1.4	3.0	2.8	148	214	Res.
Maize-DH01 (*Zea mays*)	Cereal	1.4	1.6	2.2	2.6	144	176	Res.
Maize-Pioneer (Ph3253) (*Zea mays*)	Cereal	1.6	1.4	1.6	2.6	186	164	Res.
Maize-Sweetcorn (*Zea mays saccharala*)	Veg.	1.6	1.8	1.8	1.6	204	205	Res.
Maize-Babycorn (*Zea mays scarni*)	Veg.	1.4	1.4	3.8	2.2	222	173	Res.
Sorghum-Serena (*Sorghum bicolor*)	Cereal	2.0	1.8	2.0	2.0	155	146	Res.
Sorghum-Seredo (*S. bicolor*)	Cereal	1.6	1.8	2.0	1.8	161	166	Res.
Sorghum-Kari mtama 1 (*S. bicolor*)	Cereal	2.0	1.6	2.2	2.0	147	147	Res.
Sorghum-Gadam (*S. bicolor*)	Cereal	1.8	1.6	2.4	1.8	167	222	Res.
Millet-ICMV221 (*Pennisetum glacum*)	Cereal	1.8	2.0	3.6	2.2	203	171	Res.
Millet-KATPM 1 (*P. glacum*)	Pulse/veg.	2.4	2.2	3.0	2.6	183	179	Res.
Pigeonpea-Land race (*Cajanas cajan*)	Pulse/veg.	1.2	1.6	2.6	2.6	218	161	Res.
Pigeonpea-ICPL 870/9 (*C. cajan*)	Pulse/veg.	1.6	1.4	3.2	2.4	237	165	Res.
Guwar-Pusa Naubahar (*Cyamopsis tetragonoloba*)	Veg.	1.4	1.4	2.6	2.2	218	227	Res.
Cowpea-K80-(*Vigna unguiculata*)	Pulse/veg.	4.0	4.2	5.4	5.8	406	429	M.Res.
Cowpea-KK1-(*Vigna unguicuilanta*)	Pulse/veg.	5.6	5.8	6.2	7.8	900	560	Sus.
Greengram-Ranres-(*Vigna aurens*)	Pulse/veg	5.6	5.2	5.2	6.2	237	660	Sus.
Greengram-KS20 (*Vigna aurens*)	Pulse/veg	6.2	5.8	4.0	6.0	144	563	Sus.
Okra-Pusa sawani (*Hibiscus esculentus*)	Veg.	7.4	6.4	8.2	8.6	697	699	Sus.
Okra-India (*H. esculentus*)	Veg.	7.2	7.4	8.6	8.4	774	740	Sus.
LSD (p = 0.05)		1.6	1.0	1.5	1.2	219.5	124.0	

Res: Resistant, M.Res: Moderately resistant, Sus: Susceptible, Veg: Vegetable, I: Season one, II: Season two

Table 2: Reaction of selected nematode suppressive crops to root-knot nematodes under field conditions

Treatments	Galling index I	Galling index II	P_i/200 cm^3 I	P_i/200 cm^3 II	P_f/200 cm^3 I	P_f/200 cm^3 II	P_f/P_i I	P_f/P_i II	% change in nematode population I	% change in nematode population II
Sweetcorn	1.6	1.50	270.0	268.0	180.0	109.0	0.67	0.41	-33.0	-59.0
Guwar	1.3	1.20	334.0	358.0	185.0	195.0	0.55	0.54	-44.0	-45.0
Pioneer (3253)	1.7	1.80	309.0	329.0	234.0	205.0	0.75	0.62	-24.0	-39.0
Babycorn	1.5	1.60	249.0	346.0	196.0	265.0	0.79	0.77	-21.0	-23.0
Okra (control)	8.2	8.10	234.0	236.0	464.0	464.0	1.98	1.96	+98.0	+83.0
LSD (p = 0.05)	0.4	0.39	78.7	86.4	70.9	69.7	0.12	0.10	12.4	14.0

P_i: Initial juvenile population at the beginning of the season, P_f: Final juvenile population at the end of the season, I: Season one, II: Season two

Table 3: Response of okra in plots previously sowed with selected nematode suppressive crops

Treatments (Previous crop)	Galling index I	Galling index II	P_i/200 cm^3 I	P_i/200 cm^3 II	P_f/200 cm^3 I	P_f/200 cm^3 II	P_f/P_i I	P_f/P_i II	% change in nematode population I	% change in nematode population II	Yield (t ha^{-1}) I	Yield (t ha^{-1}) II
Babycorn	4.20	4.00	134.0	191.0	200.0	248.0	1.490	1.20	+33.00	+29.80	4.40	4.80
Guwar	3.80	3.60	162.0	130.0	178.0	145.0	1.090	1.10	+9.80	+11.50	4.80	5.30
Sweetcorn	3.50	3.00	158.0	210.0	162.0	170.0	1.020	0.84	+2.70	-15.00	4.0	5.00
Pioneer	4.50	4.20	210.0	179.0	235.0	208.0	1.110	1.16	+11.00	+16.00	4.50	5.20
Control (Okra)	8.60	8.50	178.0	225.0	939.0	1150.0	5.200	5.10	+427.00	+411.00	2.50	3.00
LSD (p = 0.05)	0.68	0.64	47.6	52.3	96.8	108.4	0.270	0.25	27.30	27.20	1.10	1.20

P_i: Initial juvenile population at the beginning of the season, P_f: Final juvenile population at the end of the season, I: Season one, II: Season two

where a 98% increase in nematode numbers was recorded, decline in nematode numbers was observed in the rest of the treatments. A 44% decline in nematode numbers was recorded in plots under guwar and sweetcorn while the least decline (22%) was in plots grown with babycorn.

Damage to roots of okra and nematode numbers in the soil was also significantly variable when okra was planted in plots previously under different suppressive crops (Table 3). The highest damage was recorded in plots under continuous okra, while the least damage was in plots where guwar preceded okra. Nematode numbers were increased in all the plots regardless of the previous crop. A 400% increase in nematode numbers was recorded in plots continuously under okra followed by those under babycorn (30%). Nematode build-up in plots under guwar, sweetcorn and Pioneer was between 10 and 16%. Okra yield was significantly higher in plots where the crop was grown in rotation with other crops, compared to the control.

DISCUSSION

This study has established that some crops have great potential of suppressing root-knot nematodes when incorporated in rotational cycles with susceptible crops like okra. Suppression of root-knot nematode by sorghum, millet and guwar is a finding which is in agreement with earlier studies (Morris and Walker, 2002; Wang *et al*., 2002, 2003). The reproductive potential of the nematodes was suppressed by sorghum and millet shown in earlier findings by Wang *et al.* (2004). This could be due to glycosides found in the vacuole which are a precursor for hydrogen cyanide that is toxic to nematodes. Nematode suppression could also be attributed to production of a compound like dhurrin which has been detected in Sudan grass, a wild grass closely related to sorghum (Wider and Abawi, 2000). Dhurrin has been shown to breakdown upon decomposition in the soil to produce hydrogen cyanide (Sikora *et al*., 2005).

Nematode decline under maize suggest that it is a poor host of root-knot nematodes making it an acceptable crop which can be rotated with okra (Kimenju *et al*., 1999). Root-knot nematodes suppression by sweetcorn and babycorn offers an interesting opportunity for their incorporation into rotation programs with okra. The crops have been frequently incorporated into rotation programs partly because of their high value and a ready export market. Among other advantages, the crops mature relatively fast (75 days for sweetcorn and 90 days for babycorn) thus providing a high turnover within a short period of time. These attributes have made the crops popular with farmers as rotation alternatives to the highly susceptible vegetable like tomato, eggplant and okra (Kratochvil *et al*., 2004; Siddiqui *et al*., 2006).

Nematode suppression by guwar (*Cyanamopsis tetragonoloba*) a legume commonly known as cluster bean, is an interesting finding considering that soil fertility is a major issue under intensive cultivation. Being a legume, the crop fixes nitrogen into the soil that can be utilized by subsequent crops (Chitwood, 2002; Siddiqui *et al*., 2001). According to Siddiqui *et al*. (2006), nutrient abundance stimulates overall plant growth of the subsequent plants after guwar by making them grow rapidly and escape the nematode damage. The build-up of root-knot nematodes in okra that was planted immediately after selected suppressive crops might be an indicator that one season rotation with a suppressive crop is not an adequate period to sustainably reduce nematode numbers to allow for economic growing of subsequent nematode susceptible crops. Cowpea (K80) another legume, also rated as moderately resistant is an important grain, vegetable and hay crop in many tropical and subtropical countries (Budh and Baheti, 2003). In addition, cowpea is an excellent candidate for rotation in tropical regions against nematodes due to its adaptation to sandy soils and tolerance to heat (Westphal and Scott Jr., 2005). According to Roberts *et al.* (2005), cowpea genotypes that are resistance to root-knot nematodes maintain low numbers thus facilitating escape of subsequent susceptible crops from severe damage. Indeed, some cultivars of cowpea have been recommended as viable alternatives to chemical N fertilizer and have been successfully used to integrate nematode and nitrogen management in tropical regions (Sikora and Fernandez, 2005). The differential susceptibility of cowpea cultivars in this study provide an opportunity to study the modes of action of cowpea on plant parasitic nematodes suppression and to differentiate nematode suppressive effect from green manure effect performed by cowpea (Wang *et al*., 2003). However, being of a relatively low market value, cowpea is restricted in acceptability by growers.

In conclusion, sequential cropping using suppressive crops that have been tested for host status under local nematode populations before adoptions is a viable approach in the management of plant parasitic nematodes. This study recommends that integrated approaches to root-knot nematodes management be further developed such as resistant crop varieties combined with sequential cropping. Integrated approaches are more likely to be adopted by small-holder farmers due to the multiple benefits associated with them.

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