RUFORUM Working Document Series (ISSN 1607-9345) No. 14 (1): 771-777.
Available from http://repository.ruforum.org

Research Application Summary

Efficacy of soil solarization and selected organic amendments for the control of root-knot nematodes in African nightshades

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Abstract

Root-knot nematodes (RKN) (*Meloidogyne* spp.) causes up to 80 % yield losses in infected vegetables. The efficacy of solarizing soils amended with or without selected organic amendments for the control of the RKN on African nightshade (AFNS) *Solanum villosum* was evaluated in field experiment at Ng'enyilel, Uasin Gishu County, Kenya. Solarizing soils amended with cattle manure, pymarc and *T. diversifolia* organic materials resulted into higher shoot height and biomass in *S. villosum*. *Tithonia diversifolia* was the best amendment, followed by cattle manure and pymarc in improving plant growth. In addition, nematode populations were reduced greatly in solarized amended soils compared to non-solarized soils. Solarized soils amended with cattle manure (Cm), *Tithonia diversifolia* (Td) and pymarc (Pm) reduced RKN population and damage significantly compared with non-solarized and non-amended controls. Solarization improved the efficacy of organic amendments against RKN on *S. villosum* with the highest percentage J2 control being obtained by cattle manure (84.3 %) followed by pymarc (57.22 %), *T. diversifolia* (10.83 %) and unamended controls (3.6 %). Reproduction was lower on Cm, Pm and Td amended soils while galling index ranged from 0.7 to 2.2 in solarized soils compared to 1.4 – 5.0 in non-solarized soils. Solarized soils had higher soil temperature relative to non-solarized soils. Solarizing soils amended with organic materials is an ideal integrated pest management strategy for combating RKN infecting AFNS. Soil solarization combined with *T. diversifolia* compost, cattle manure and pymarc amendments could be used for RKN management and improving soil fertility for production of AFNS.

Key words: Amendment, *Meloidogyne* spp., pymarc, *Solanum villosum*, solarization, *Tithonia diversifolia*

Résumé

Les nématodes à galles (RKN) (*Meloidogyne* spp.) provoque jusqu'à 80% des pertes de rendement dans les légumes infectés. L'efficacité de la solarisation des sols amendés avec ou sans amendements organiques sélectionnés, pour le contrôle de la RKN sur morelle africaine (SAAN) Solanum villosum a été évaluée dans l'expérience sur le terrain au Ng'enyilel, Uasin Gishu County, Kenya. Solarisation des sols amendés avec du fumier de bétail, pymarc et T. diversifolia matières organiques a entraîné à la hausse la hauteur des pousses et la biomasse dans S. villosum. Tournesol mexicain était le meilleur amendement, suivie par le fumier de bovins et pymarc dans l'amélioration de la croissance des plantes. En outre, les populations de nématodes ont été réduites considérablement dans les sols amendés solarisées par rapport aux sols non-solarisées. sols Solarized amendés avec du fumier de bovins (Cm), Tournesol mexicain (Td) et pymarc (Pm) a réduit la population RKN et des dommages considérablement par rapport aux contrôles non-solarisée et non modifiées. Solarisation amélioré l'efficacité des amendements organiques contre RKN sur S. villosum avec le plus grand contrôle de J2 de pourcentage étant obtenu par le fumier de bovins (84,3%), suivie par pymarc (57,22%), T. diversifolia (10,83%) et les contrôles non modifiées (3,6%). Reproduction était inférieure à Cm, Pm et Td modifiés sols tandis que l'indice grippage variait de 0,7 à 2,2 dans les sols solarisées comparativement à 1,4 à 5,0 dans les sols non-solarisées sols. Solarized avaient plus la température du sol comparativement aux sols non-solarisées. Solarisation des sols amendés avec des matières organiques est une stratégie de gestion des ravageurs idéale intégrée de lutte contre la RKN SAAN infectant. La solarisation du sol combiné avec T. diversifolia compost, fumier de bovins et pymarc amendements pourraient être utilisés pour la gestion des RKN et l'amélioration de la fertilité des sols pour la production de SAAN.

Mots clés: Amendement, *Meloidogyne* spp., pymarc, *Solanum villosum*, solarisation, *Tithonia diversifolia*

Background and Literature summary

African nightshades (AFNS) are rich in health promoting compounds, combat micronutrient deficiencies and malnutrition, and contribute to food security and income generation among the smallholder farmers in Kenya and Africa at large (Ministry of Agriculture, 2010). However, production of AFNS is constrained by a myriad of challenges including its vulnerability to viral, fungal, bacterial and root-knot nematodes (RKN) diseases. The RKN (*Meloidogyne* spp) is more challenging to control because they inhabit the soil and their symptoms are usually mistaken for water or mineral deficiency. Moreover, they have a wide host range of over 5500 plant species including AFNS (Nchore *et al.*, 2013). *Meloidogyne* species are among the top five major plant pathogens and are ranked first in the world among the ten nematode genera considered as important pathogens (Mukhtar *et al.*, 2013) hence a serious threat to AFNS production. They cause serious damage to AFNS impacting both the quantity and quality of marketable yields. In Kenya, the RKN problem was reported on African nightshades with GI and reproduction above 3 and 46 % respectively on *S. nigrum* and *S. villosum* (Nchore *et al.*, 2013). Eco-friendly management of RKN is a serious challenge for farmers. Crop rotation and nematicides are not always viable control options for these destructive pests. Chemical nematicides are both unaffordable to small scale farmers and also unavailable in the market due to their toxic nature and threat to the ecosystem (Wachira *et al.*, 2009). Efficacy of organic amendments in controlling RKN in AFNS has been reported, however, enhancement of organic materials through solarization to improve their efficacy on the management of RKN in Kenya has not been exploited. Besides, fields in Western Kenya are fallowed for six months from October to March during the dry season and thus these conditions are ideal for soil solarization. This study sought to assess the effect of solarizing soils amended with organic materials on RKN damage on AFNS under the field conditions.

Study description

This study was conducted to integrate solarization with *T. diversifolia*, cattle manure and pymarc during the hot and dry months (October 2014 – March 2015) in a farmer's field previously reported with RKN infection in Ng'enyilel, Uasin Gishu County (00^o 34' 03N and 034^o 57' 53E at 1806 m a.s.l). A total of 48 plots each measuring 15.36 m^2 with a 1 m guard row between the plots, replicated three times (16 plots per block) in RCBD were prepared. The experimental design was a 2 × 2 × 4 factorial, with two solarization treatments (solarized or control), nematode (with or without) and four soil amendment (cattle manure, pymarc, *Tithonia diversifolia* and unamended control) treatments. The plots were amended at the rates of 4 t ha^{-1} for *T. diversifolia* and 5 t ha^{-1} for pymarc and cattle manure respectively and immediately the field was watered to 20 cm soil depth. The treatments were watered to 20 cm depth and covered with a single layer of 25-ìm thick, clear, low-density polythene mulch for solarization. Edges of the polythene mulch were buried into a trench around the treated plots to prevent wind from blowing or tearing it. Of all the treatments, one set was covered with clear transparent polythene mulch while the other set was not covered and was therefore unsolarized. Non-amended plots without polythene mulch served as absolute controls. The polythene mulch was left for five weeks allowing the soil to heat to the greatest depth possible. The soil temperature of the solarized plots was recorded at depths of 5 and 15 cm at an interval of five days using soil thermometer. At the end of five weeks, the polythene mulch was removed and the soil was allowed to dry to workable texture. Immediately after terminating solarization, samples (500 g) of treated soil were obtained from 5 cm and 15 cm depths from ten points on each treated plot. Shallow cultivation was done to prevent bringing up pathogens from the lower levels of the soil. The percentage nematode control for each treatment at 5 cm and 15 cm was calculated as follows;

$$\text{Percentage control} = 100 - \frac{\text{(J2 population on solarized plot)}}{\text{(J2 population on unsolarized plot)}} \times 100$$

Three seeds of *Solanum villosum* were planted and covered lightly with soil at a depth of 1 cm per depression in ten rows at spacing of 15 cm x 30 cm. Two weeks after germination, the seedlings were thinned to one seedling per depression with each row having six seedlings. Data on plant height, dry shoot weight and fresh root biomass and disease parameters were collected 60 days after terminating solarization. The root systems of AFNS were harvested at the end of the experiment, washed separately and dabbed dry with a tissue paper to assess galling index (GI) on a scale of 0-10 rating chart by Bridge and Page (1980) where; 0 = no galls, 5 = 50 % of the roots infected and 10 = entire root system galled and plants usually dead; egg-mass index (EMI) as described by Holbrook *et al.* (1983) and scored using a 0-5 egg-mass rating index according to Quesenberry *et al*. (1989) where; 0= no egg-masses; 1= 1-2; 2= 3-10; 3= 11-30; 4= 31-100 and 5= > 100 egg-masses per root system. The J2 population was established from both roots and soil.

Five hundred grams (500 g) soil sub-samples and each organic material were taken to the Kenya Agricultural and Livestock Research Organization (KARLO) National Agricultural Research Laboratories (NARL) Kenya, for physicochemical and mineral content analysis.

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The galling index (GI) and egg-mass index (EMI) differed significantly ($P < 0.05$) between the treatments (Table 1). The GI and EMI was lower on solarized soils amended with Cm, Td, Pm and unamended control compared with non-solarized soils (Table 1). Solarization and amendment effect on GI and EMI was significant ($P < 0.05$) although the interaction effect of solarization × amendment on both GI and EMI was not significant. Solarizing soils amended with cattle manure, pymarc and *T. diversifolia* organic materials resulted to higher shoot biomass in *S. villosum*. Pymarc had the highest increase in dry shoot weight (71.57% and 49.82%), followed by those amended with cattle manure (55.57% and 39.33%), *Tithonia* (40.13% and 31.66%) and the unamended control (15.81% and 9.28%) on both soils with or without nematodes, respectively. In addition, solarization improved the efficacy of organic amendments against RKN on *S. villosum* with solarized plots treated with Cm recording the

Table 1. Effect of solarization on galling and egg-mass index on *S. villosum*

Amendments	Treatments	Galling index[y]	Egg-mass index[z]
Cattle manure (Cm)	Solarized	0.7c[x]	2.0cd
	Non-solarized	2.9ab	3.3ab
Tithonia compost (Td)	Solarized	1.8bc	1.3d
	Non-solarized	2.5b	2.3bc
Pymarc (Pm)	Solarized	1.3bc	2.0cd
	Non-solarized	1.4bc	2.3bc
Control	Solarized	2.2bc	4.7a
	Non-solarized	5.0a	5.0a
P-value		0.0175	0.0001
LSD		0.2921	0.1381

[x] Data are means of three replications. Means on the same column followed by similar letter(s) are not significantly different at P e" 0.05 according to LSD test.
[y] Galling index scale of 0-10 where 0 = no galls, 5 = 50% of the roots infected and 10 = entire root system galled and plants usually dead (Bridge and Page, 1980).
[z] Egg-mass index on a 0-5 scale where; 0 = no egg-masses; 1 = 1-2; 2 = 3-10; 3 = 11-30; 4 = 31-100 and 5 = > 100 egg-masses per root system (Quesenberry *et al*., 1989)

highest nematode control (84.3 % and 68.4 %), followed by those amended with Pm (57.22 % and 73.6 %) and Td (10.83 % and 40.43 %) at 5 cm and 15 cm depths respectively compared with unamended control (3.6 % and 32.65 % respectively).

Treatments did not differ significantly ($P > 0.05$) on their effect on RKN reproduction factor (Rf). Soils amended with Cm, Td and Pm had lower Rf that did not differ significantly from the controls. In addition, solarized soils with or without amendments had lower Rf compared with non-solarized soils although there was no significant difference established. The various treatments differed significantly ($P < 0.05$) on their effect on dry shoot weight (Fig. 1). Plants grown on solarized amended soils had significantly ($P < 0.05$) heavier dry shoots compared with those grown on non-solarized amended soils except for soils amended with *T. diversifolia* compost and unamended controls that did not differ significantly (Fig. 1).

Plants grown on nematode infested soils recorded lower dry shoot weight compared to those grown on non-infested soils. Significantly ($P < 0.05$) lower dry shoot weights were recorded on plants grown on RKN infested soils amended with cattle manure on both solarized and non-solarized soils as well as on solarized soil amended with pymarc compared to their controls (Fig.1). All the other treatments did not differ significantly ($P > 0.05$) from their controls.Solarization improved soil pH, phosphorus, potassium, calcium, magnesium, copper and iron compared with non-solarized soil. In addition, solarized soils had narrower C: N ratio compared to non-solarized soils. The results also revealed that the concentration of the total nitrogen and total organic carbon in solarized soils was lower than that of non-solarized soils.

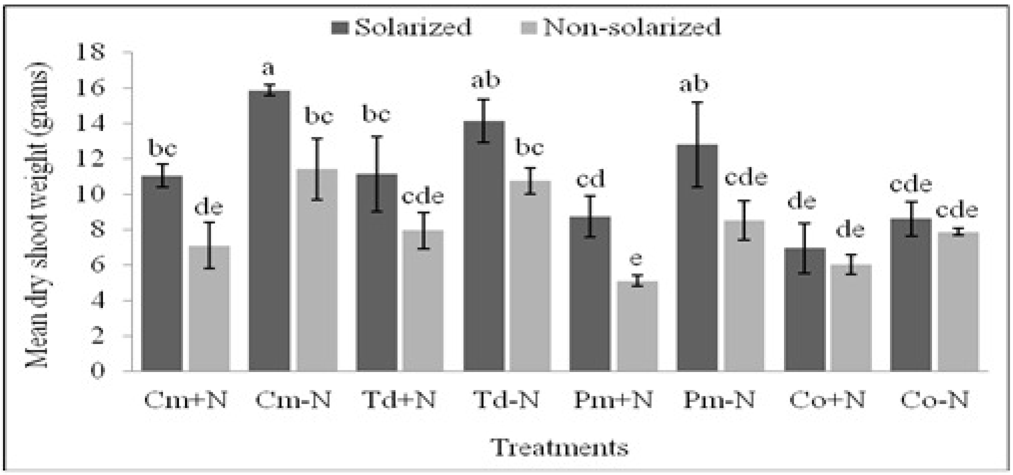

Figure 1. Effect of solarization on dry shoot weight of *Solanum villosum*. Data are means of three replications. Means with the same letter (s) are not significantly different at P e" 0.05 with LSD test. Cm - cattle manure, Td - *Tithonia diversifolia*, Pm - pyrethrum marc, Co - control, +N - with root-knot nematodes and -N - without root-knot nematodes

Discussion

Solarized soils amended with cattle manure, pymarc and *Tithonia diversifolia* organic materials have a potential as an alternative means of ridding the soils of root-knot nematodes. Solarized soils amended with cattle manure and pymarc had the highest nematode control at 5 cm and 15 cm soil depths compared with the control while *T. diversifolia* had the least nematode control. Solarization suppressed RKN damage (GI and EMI) as shown in Table 1, population and reproduction. The GI was significantly suppressed on solarized cattle manure and unamended control compared to non-solarized soils (Table 1). The J2 populations were suppressed more significantly in solarized soils than in the non-solarized soils. Moreover, J2 suppression was higher at 5 cm soil depth in solarized soils than non-solarized soils. The mechanisms of suppression are not fully understood, although suppression of RKN by cattle manure, *Tithonia* and pymarc could be attributed to high pH, organic carbon, nitrogen content, low phosphorus levels, narrow C: N ratio, high lignin and polyphenols that are nematicidal as well as humic and fulvic acids which influences chemical properties of the soil (Jama *et al*., 2000; Reddy, 2013). Besides, solarization stimulates the release of collagenase and chitinase enzymes that acts on the cuticle of nematodes and their eggs (Reddy, 2013). Nematode antagonists like *Bacillus* species, *Flavobacterium balustinum*, various *Pseudomonas* species and several fungi (*Streptomyces*, *Penicillin*, *Trichoderma* and *Gliocladium verens*) have been reported to be abundant in decomposed organic materials (Jenking and Jain, 2010).

Suppression of RKN on solarized soils could also be attributed to high temperature during solarization. Heat retained within the polythene mulch together with that generated by the decomposing cattle manure, pymarc and *Tithonia* might have increased the temperature compared to the non-solarized and non-amended soils. High temperature coupled with low C: N ratio is attributed to accelerating decomposition of organic matter in the solarized soil leading to the production of ammonium and volatile compounds that are trapped between the soil surface and the plastic film thus inhibiting RKN metabolism (Ros *et al*., 2008). Additionally, plant growth was better on solarized soils than on non-solarized soils. This might be due to increased breakdown of organic materials in the soil that might have resulted in the release of soluble nutrients for plant growth (Reddy, 2013). Solarizing soils amended with organic materials improves release of essential nutrients, microflora beneficial to plant growth and antagonistic organisms to RKN (Abada *et al*., 2014). Studies by Ahmed *et al*. (1996) reported that soil solarization improved breakdown of organic materials releasing essential nutrients like calcium (Ca^{+2}), magnesium (Mg^{+2}), potassium (K^{+}) making them more available to the plants leading to higher growth. However, the mechanism of control needs to be evaluated for informed decisions. There is need to combine soil solarization with *T. diversifolia* compost, cattle manure and pymarc amendments for RKN management and production of AFNS. Further studies should be carried out on different edaphic and climatic conditions to ascertain the efficacy of solarization on organic amended soils against root-knot nematodes.

Acknowledgement

The authors acknowledge HORTINLEA project for funding this study. In addition we thank the farmers from Uasin Gishu County for allowing us to conduct the field trial in their farm, and Kenyatta University for providing us with space to carry out the laboratory assays.

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