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Research Paper

Organic farming provides improved management of plant parasitic nematodes in maize and bean cropping systems

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ABSTRACT

Intensification of agriculture, combined with poor agronomic practices have increased the incidence of plant parasitic nematodes (PPN) and other soil pathogens in East Africa, which consequently affects crop productivity in small holder farms. The objective of the study was to assess the effectiveness of farming systems in management of PPN and to recommend the best practice to farmers. Therefore, two field trials were established, one in farmer fields and one on-station, using maize (*Zea mays* L.), intercropped with beans (*Phaseolus vulgaris* L.) and in rotation with beans as a sole crop. Organic farming (that received compost, *Tithonia diversifolia* and neem cake (*Azadirachta indica*)) was compared to conventional farming (that received fertilizer and nematicide), farmer practice (that received manure, *Tithonia diversifolia* and wood ash), and a farm with no input application (control). After three years of continuous cultivation, twelve genera of PPN were recovered from soil and/or root samples from the trials. Under inter- and sole-cropping at both sites, the abundance of PPN including *Pratylenchus* and *Meloidogyne* were significantly reduced in the organic system compared to the conventional, farmer practices and control. Organic farming was effective in reducing the genera of PPN below the control for a longer period (4 months) compared to conventional farming and farmer practice (2 months). The findings demonstrated the potential of organic farming in the suppression of PPN at the farmer level. Policy development and extension services can therefore consider organic farming as an alternative method in managing soil-borne nematodes in small holder farms in sub-Saharan Africa. However, further studies are required on other crops, in dry areas and the period to top-dress with organic amendments to assure effective suppression of PPN in organic farming.

1. Introduction

Maize (*Zea mays* L.) and common beans (*Phaseolus vulgaris* L.) are considered the most important food crop and legume in Kenya (Nyongesa et al., 2004; MoA, 2013). Since its introduction to East Africa in the sixteenth century (McCann, 2005), maize has become the dominant crop in Kenya, grown primarily by small-holder farmers over approximately 1.6 million ha annually (Kamidi et al., 1999). Similarly, beans are the most important legumes grown in Kenya on more than 700,000 ha (MoA, 2013) and play a major role in food security. As with all important crops, their production is limited by various biotic and abiotic constraints, including plant parasitic nematodes (PPN) (Kimenju et al., 1999; Widmer and Abawi, 2000; Karanja et al., 2002; Nyongesa et al., 2004; Agrios, 2005; McDonald and Nicol, 2005; Luc et al., 2005; Sikora et al., 2005; Wachira et al., 2009; Hockland et al., 2012).

With regard to food security, PPN are an important consideration, especially in the tropics and sub-tropics, where PPN short generation times lead to rapid population build-up all-year round, which substantially affects crop production (Agrios, 2005; Perry and Moens, 2013). In Kenya and its sub-region, intensification of agriculture, combined with poor agronomic practices such as lack of crop rotation, improper fertilizer application (soil nutrient analysis) and inconsistent irrigation have led to an increase in PPN and other soil pathogens (Wachira et al., 2009), especially root knot nematodes (*Meloidogyne* spp.) and lesion nematodes (*Pratylenchus* spp.) which are among the most damaging PPN and reported to be associated with monoculture cropping systems (Kimenju et al., 2008).

Traditionally, management of nematodes has relied on synthetic

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chemical nematicides. These nematicides have proven unreliable for small-holder systems as they are often unaffordable and unavailable to farmers (Agyarko and Asante, 2005; Renco and Kovacik, 2012). Furthermore, due to the increasing attention to environmental safety, most nematicides have been withdrawn from markets or their use severely restricted (Chen and Ferris, 2004; Renco and Kovacik, 2012). Mineral fertilizers alone or in combination with manure can also be used in controlling PPN (Okada and Harada, 2007; Oka, 2010; Hamida et al., 2015). However, continuous use of these fertilizers can result in decreasing soil pH (Adamtey et al., 2016), consequently affecting crop growth and yields (Zhong et al., 2010); and if not well managed can pose a potential threat to the environment (Scow et al., 1994). Other management techniques, such as solarization, flooding, use of resistant cultivars and use of cover crops have been practiced but have their individual limitations. For example, solarization is expensive, can be technically challenging for farmers, and negatively impacts on the beneficial soil micro-organisms (Gaur and Perry, 1991; Kaskavalci, 2007). Flooding is not suitable for all locations and is dependent on the type of crop and nematode species (Sikora et al., 2005); resistant cultivars are often highly specific to nematode species and are not readily available to farmers in developing countries (Roberts, 1992; Bridge, 1996; Sikora et al., 2005; Hockland et al., 2012); and cover crops that are considered most effective such as rattlebox (*Crotalaria spectabilis*) and castor (*Ricinus communis*) may be toxic to livestock and are mostly species specific (McSorley, 1999).

The use of organic amendments as a potential alternative to nematode management presents a promising option (Sharma, 2001; Devi and Hassan, 2002; Stephan et al., 2002; Summers, 2011; Stirling et al., 2011; Renco and Kovacik, 2012; Olabiyi and Oladeji, 2014). Briar et al. (2016) confirmed that amending soil with green or organic manure and crop residues in a field, would significantly suppress PPN populations. Several studies indicate a reduction of PPN abundance and damage following addition of organic amendments (Sasanelli et al., 2006; D'Addabbo et al., 2011; Renčo et al., 2011). Possible mechanism for this reduction could be attributed to toxic compounds released during decomposition or increase in PPN antagonists (McSorley, 2011; Briar et al., 2016). In contrast, Sharma et al. (2000) reported that organic amendments were not effective in that they resulted in build-up of the nematodes. Another study by Kimpinski et al. (2003) showed that populations of *Pratylenchus* spp. and *Meloidogyne* spp. did not respond to organic soil amendments over long-term studies.

There is limited information in sub-Saharan Africa on organic management techniques and situations that effectively lead to the suppression of PPN, which are economical and can easily be adopted by most farmers. To address this, the Research Institute of Organic Agriculture (FiBL) and partners in Kenya are using different farming systems within the framework of the "Farming systems comparison trials in the tropics" (SysCom; www.systems-comparison.fibl.org) to address the obstacles (including soil-borne nematodes) that confront organic crop production in small-holder farms. The hypothesis for the study was that organic farming is more effective than conventional farming in suppressing PPN. Therefore, the specific objectives of this study were to assess the effects of organic and conventional farming, and farmer practice on the relative abundance and variations of PPN genera, population of PPN and the dynamics of PPN genera over time.

2. Materials and methods

2.1. Site description

The study was conducted at Chuka in Tharaka Nithi County, Kenya (Longitude 037° 38.792′ and Latitude 00° 20.864′). The area is situated in the agro-ecological zone 2 (AEZ 2) of the upper midland 2 (UM 2) located in the mid-altitude (1458 m above sea level). It receives a mean annual rainfall of 2000 mm in two seasons a year (long rains from March to June and short rains from October to December) with temperatures at site ranging between 19.2–20.6 °C (Fig. 1). The soils at the study site are classified as humic nitisols (IUSS Working Group WRB, 2006; Wagate et al., 2010). The percentage proportion of sand, silt and clay in the study area is 9.4, 16.6 and 74.0% respectively (Adamtey et al., 2016). Table 1 shows the initial chemical characteristics of the soils at the study site to a depth of 20 cm.

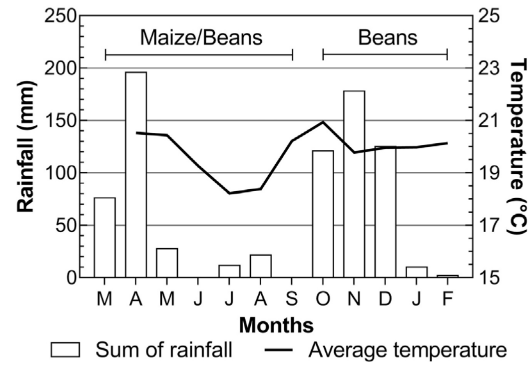

Fig. 1. Mean temperature and rainfall data for the study site during the growing period of the trial, from March 2015 to February 2016, at Chuka in the Central Highlands of Kenya.

Table 1
Initial soil chemical characteristics of the study area at Chuka in the Central Highlands of Kenya.

Parameter	On-farm	On-station
pH	5.82 ± 0.19	5.18 ± 0.05
EC(S) (μS/cm)	80.00 ± 8.03	99.00 ± 0.58
C.E.C (meq/100 g)	16.74 ± 0.86	16.10 ± 0.03
SOC (%)	23.6 ± 0.80	23.2 ± 0.90
N total (%)	2.3 ± 0.10	2.4 ± 0.70
P (Olsen) (mg/kg)	29.48 ± 5.16	29.48 ± 5.16
K (Cmolc kg^{-1})	0.90 ± 0.16	0.31 ± 0.02
Ca (Cmolc kg^{-1})	8.59 ± 1.09	5.85 ± 0.26
Mg (Cmolc kg^{-1})	2.58 ± 0.25	2.25 ± 0.16
Na (Cmolc kg^{-1})	0.25 ± 0.03	0.19 ± 0.01

Key to Parameters: EC – Electrical conductivity, C.E.C – cation exchange capacity, SOC – Soil Organic Carbon, N – Nitrogen, P – Phosphorus, K – Potassium, Ca – Calcium, Mg – Magnesium, Na – Sodium; μS – micro siemens, meq - milliequivalent, ppm – parts per million.

Annual crops such as maize (*Zea mays*), beans (*Phaseolus vulgaris* L.), potatoes (*Solanum tuberosum* L.), sweet potatoes (*Ipomoea batatas* L.), sorghum (*Sorghum bicolor* L.) and vegetables are predominantly grown by small holder farmers on 0.5–1 ha at Chuka (Adamtey et al., 2016). Perennial crops like bananas (*Musa* spp. L.), avocado (*Persea americana* M.), passion fruits (*Passiflora* spp.), pineapples (*Ananas comosus*), sugarcane (*Saccharum officinarum* L.); and cash crops like tea (*Camellia sinensis* L.) and coffee (*Coffea* spp.) are also normally grown alongside dairy farming as a source of income for smallholder farmers (Adamtey et al., 2016).

2.2. Field experimental design and treatments (farming systems)

The study was conducted over two cropping seasons in 2015 and 2016 in two ongoing trials (on-farm and on-station) established in March 2013. The on-farm trial (Type 2 experimental design; designed by the researcher, managed by the farmer) consisted of four farmers, each serving as a replicate or a block and located in close proximity to each other. Farmers were selected based on severity of soil-borne diseases in the study area, following a group discussion and interactions with researchers and Ministry of Agriculture extension agents. Four farming systems were being compared: farmer practice, organic, conventional and non-amended control, represented the treatments based upon the amendments that each practice received (Table 2).

The on-station trial (Type 1 experimental design; designed and