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Research Paper

Integrated soil fertility management reduces termite damage to crops on degraded soils in western Ethiopia

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A B S T R A C T

Crop damage by termite is known to be severe in degraded soils. However, the role of organic inputs in reducing crop damage by termite has not been systematically studied in Ethiopia. Therefore, the objectives of this study were to quantify (i) the influence of integrated use of manure and NP fertilizer on termite damage and pod yields of hot pepper (*Capsicum frutescence* L.), (ii) the optimum rate of manure and NP fertilizer for hot pepper production for the study area, and (iii) the association between different rates of nitrogen (N) fertilizer and plant damage by termite. Two separate experiments were conducted for three consecutive seasons on degraded soils that were hotspots of termite activity. The treatments in experiment 1 consisted of different rates of well-composted manure applied in combination with NP fertilizer, whereas experiment 2 consisted of different rates of N fertilizer with basal application of 44 kg P ha^{-1}. In experiment 1, the combined application of manure and NP fertilizer significantly ($P < 0.05$) reduced plant damage but increased pod yields compared with the control treatment and the recommended NP fertilizer. Plant damage by termites decreased from 29% in the first season to 11% in the third season, while pod yield increased from 378 kg ha^{-1} in the first season to 2339 kg ha^{-1} in the third season. The results of the repeated measures data analysis also indicated significant ($P < 0.0001$) differences among the seasons in plant damage by termite and pod yield. In experiment 2, continuous application of the different rates of N fertilizer did not significantly reduced plant damage by termite while the N effect lacked consistency on pod yield. However, the application of N at rates ≥75 and > 100 kg ha^{-1} increased termite damages to hot pepper in the first and second seasons, respectively. Overall, the application of one-fourth of the recommended NP fertilizer (25/11 kg N/P ha^{-1}) along with 10 t manure ha^{-1} was found to be optimum for hot pepper production for the study area and similar agroecosystem. Therefore, we recommend adoption of the integrated use of manure and NP fertilizer to prevent soil degradation and reduce termite damage in western Ethiopia.

1. Introduction

Soil degradation due to continued use of land for agriculture without external inputs and soil conservation practices has caused enormous socioeconomic and environmental problems in many countries in sub-Saharan Africa (SSA) (Nkonya et al., 2016). The loss of vegetative cover and decline in soil organic matter (SOM) levels is now recognized as the root causes of soil degradation (FAO and ITPS, 2015). Loss of SOM does not only threaten productivity, but it also affects overall soil health which is a key indicator of the state of natural capital (Montanarella et al., 2015). Rapid population growth, cultivation on steep slopes, clearing of vegetation and overgrazing are the main factors that accelerate soil degradation (Tamene and Vlek, 2008; Wood, 1991). Despite increased use of technology packages such as improved crop varieties and chemical fertilizers in SSA, these alone, have not been able to sustain crop productivity (Tully et al., 2015).

Crop damaged by pests, especially by termites, has been recognized as one of the important problems in crop production in SSA (Sileshi et al., 2009). However, not all termites are pests. Based on their feeding habits, termites can be grouped into three broad categories: (1) those feeding on plant materials (live, freshly dead, and dead materials at various stages of decomposition) and soil rich in organic matter, (2) humivorous termites feeding on humus, and (3) those that feed on fungi (Rosengaus et al., 2011; Wood, 1996). Although there are over 660 known species of termite in SSA, only about 20% are important crop pests (Sileshi et al., 2009, 2010). Most of these termites play a beneficial role, especially in carbon and nutrient cycling (Ali et al., 2013; Sileshi et al., 2009, 2010). The most notorious crop pests belong to the

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family Termitidae and subfamily Macrotermitinae (Fungus-growing termites) consisting of over 165 African species (Sileshi et al., 2010). *Odontotermes, Macrotermes* and *Pseudacanthotermes* species build large above ground mounds and exhibit a wide range of feeding habits. *Microtermes*, *Allodontotermes*, *Ancistrotermes* and *Synacanthotermes* build subterranean nests without any surface structure indicating the presence of a colony in the soil. Members of these genera feed mainly on wood, litter, dung and occasionally damage trees and crops. However, *Microtermes* is the most economically important genus in Africa as it consists of serious pests of crop plants, trees, wood and lawn (see Sileshi et al., 2010 for details).

The severity of termite problems is higher in degraded soils in some parts of SSA. Typical examples are the "Cattle Corridor" of Uganda (Sileshi et al., 2009) and rangelands of western Ethiopia (Wood, 1991) where overgrazing by livestock has exacerbated termite damage. In western Ethiopia, termites have a long history of serious damage to annual and perennial crops and pasture. The first report of a serious termite outbreak dates back to 1938 in Kiltu Kara and Mendi in Wollega where farmers were forced to abandon their farms (Wood, 1991). By the early 1980s, the termite problem was said to have worsened and in 1983, the Ethiopian Ministry of Agriculture launched a campaign to poison termite mounds in Menesibu and Jarso districts of Wollega. Over 600,000 *Macrotermes* mounds were poisoned with 12,000 kg of Aldrin at the cost of over 200,000 man-days (Wood, 1991). Despite all the control efforts, the termite problem was still a major concern of farmers by 1986. It became evident later that the problematic termites were not the mound-building *Macrotermes* but one or more of the subterranean species belonging to the genera *Microtermes* (Wood, 1991). The primary cause of the termite problem was also found to be overgrazed (Wood, 1991). Foraging termites removed the remaining grass from overgrazed rangelands in the dry season, leaving the soil bare and susceptible to erosion (Wood, 1991). Although the ecological benefits of termites have been well accepted and termite activity is encouraged in many cropping systems (e.g. Ali et al., 2013; Kaiser et al., 2017), eradication of termite has been accepted as a norm in Ethiopia for decades (Wood, 1991). Physical, biological and chemical controls of termites have been practiced for decades in western Oromia; unfortunately, none of these practices have been successful in reducing crop damage by termites.

Pepper (*Capsicum frutescence* L.) is one of the most important spice and cash crop in Africa (Sileshi et al., 2011). Termite damage on hot pepper is more severe on poor soils in Ethiopia (Gauchan et al., 1998; Sisay et al., 2008). However, the high rates of inorganic NP fertilizers (110–150 kg N ha^{-1} + 44 kg P ha^{-1}) recommended by researchers (Tesfaw et al., 2013; Mebratu et al., 2014) has not solved the termite problem. On the other hand, little damage is often observed on crops grown in homesteads with high SOM and water holding capacity. This indicates that management practices that improve SOM could alleviate the termite problem on hot pepper. Crops are more severely attacked by termite under low soil fertility and water stress conditions than under optimal conditions (Van den Berg and Riekert, 2003). Recent studies also indicate that improvements in SOM and soil water retention play an important role in reducing termite damage to crops (Sileshi and Mafongoya, 2003; Sileshi et al., 2005). In that sense, integrated soil fertility management (ISFM) as defined in Vanlauwe et al. (2015) could pave the way for providing a lasting solution to termite problems associated with degraded soils.

Recent studies have shown that ISFM can increase the growth and fruit yield of pepper (*Capsicum annum* L.) cultivars in Malawi (Sileshi et al., 2011). However, there is no empirical information on the effect of ISFM on termite damage and the productivity of hot pepper in Ethiopia. Therefore, the objectives of this study were to quantify (i) the influence of integrated use of manure and NP fertilizer on termite damage and pod yields of hot pepper (*Capsicum frutescence* L.), (ii) the optimum rate of manure and NP fertilizer for hot pepper production for the study area and similar agroecosystem, and (iii) the association between different rates of nitrogen (N) fertilizer and plant damage by termites. The key hypotheses tested were: (i) combined application of composted manure and NP fertilizer reduces termite damage on degraded soils, (ii) combined application of 10 t ha^{-1} of manure along with one-fourth of the recommended NP fertilizer provides higher pod yield than the sole application of the recommended NP fertilizer, and (iii) increasing the rate of N fertilizer does not necessarily increase pod yields or reduce plant damage by termite.

2. Materials and methods

2.1. Site characterization

The study was conducted at the Bako Agricultural Research Center located in the East Wollega Zone in Oromia National Regional State, western Ethiopia. The area is situated 260 km west of Addis Ababa at 9°6′N and 37°9′E. It has an altitude of 1650 m above sea level in a sub-humid climate with a unimodal rainfall pattern. The average annual rainfall (1961–2014) is 1265 mm, whereas the minimum, maximum and average air temperatures are 14.4, 28.5 and 20.9 °C, respectively. The rainy season extends from April to December and maximum rainfall is received in June-August. The rainfall amount and distribution during the study period were recorded at a meteorological station located at about 500 m from the experimental fields (Fig. 1). The soil type of the study area is Nitisol with sandy clay texture, acidic reaction, low soil organic carbon (SOC), total N and available P (Negassa and Gebrekidan, 2004; Table 1).

2.2. Experimental design

Two sets of experiments were set up to test the research hypotheses. The experiments were run for three consecutive years (1997–1999) hereafter referred to as season 1, season 2 and season 3, respectively.

In order to address objectives 1 and 2, and hypotheses 1 and 2, experiment 1 was set up. Experiment 1 consisted of 0/0, 25/11 and 50/22 kg N/P ha^{-1} fertilizer with a factorial combination of 0, 10, 20 and 30 t ha^{-1} compost manure. The recommended rate of N/P fertilizer (100/44 kg ha^{-1}) was included as an additional treatment for comparison with the different combinations of manure and N/P rates. However, the recommended rate was not part of the factorial combination. Accordingly, the 13 treatments (3 × 4factorial + recommended N/P fertilizer) were laid out in a randomized complete block design with three replications. The hot pepper variety Bako local was used as the test crop. The plot size of each treatment was 4.2 m × −3 m (12.6 m^2) and each plot contained 60 hot pepper plants with inter row and intra row spacing of 70 cm and 30 cm, respectively,

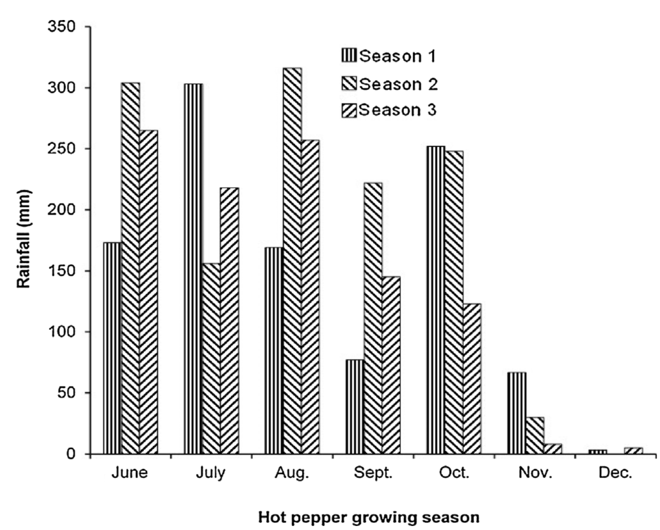

Fig. 1. Rainfall distribution during the hot pepper growing seasons.