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Impacts and Management of Termites (Isoptera: Termitidae) among Smallholder Farmers In East Africa

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Author's contribution

The sole author designed, analyzed, interpreted and prepared the manuscript.

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ABSTRACT

- Effective termite management strategies should involve at least one of the following:
  - Provision of adequate food to deter termites from attacking crops.
  - Enhancing multiplication and proliferation of natural enemies (e.g. nematodes, fungus, bacteria, virus, ants, frogs, beetles and spiders).
  - Reduce vulnerability of crops through improved crop nutrition and water supply for vigorous growth.
  - Integration of termite-repelling crops and plants in the farms.
  - Killing of termites e.g. use of termicide, physical destruction of the mound, killing of the queen.
- In areas regularly affected by termites, scouting and control should be incorporated as regular components of seasonal crop production trainings.
- Particular emphasis should be given to non-chemical practices which have significant co-benefits such as enhanced soil health.
- Effective and long-lasting control is based on combination of chemical and non-chemical practices – dig out mounds, kill the queen then spray with termicide. For fields which experience

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termite attacks every season, farmers should dress seed with termicide before planting. These chemicals should be used judiciously to reduce negative impact to the environment and health risks to the farmers.

Keywords: Crop yield loss; chemical control of termite; integrated pest management; non-chemical control; termite management.

1. INTRODUCTION

Agriculture is an important sector that provides 60% of all jobs to the African population – the current population growth rate is 2.6% - that accounts for 17% of the total global population [1]. Despite the faster population growth rate, the food production has remained low and more than 60% increase over the next 15 years would be required to sustain the population [2]. Poor crop performance in the region is linked to biotic and abiotic constraints such as soil infertility, weed infestation, soil acidity, insect pest attack, disease infestation, poor seed system and drought [3-6]. Drought alone is predicted to reduce crop productivity by 50% by 2020 [7]- the effect of drought is diverse as it also aggravates the impacts of other constraints such as insect pests and diseases attacks.

Crop pests can be broadly grouped as above ground and below ground pest. Together with disease occurrences, pests account for about 49% of crop yield losses recorded in Africa – the highest loss globally [8]. Among below ground pests, termites are increasingly becoming important with various countries reporting significant yield losses on food crops. For instance, termites have been reported to cause maize yield losses in affected fields of 10-30% in Kenya, Uganda and Tanzania, and above 50% in Ethiopia and Nigeria [9,10]. This could be attributed to several factors including climate change currently turning most of the agricultural lands into desert like environments that are suitable for termite colonization.

2. RESEARCH OBJECTIVE

The focus of this work is on termites as an important below ground pest having both negative and positive impacts on crop production, depending on the population and species of the pest. With the current effect of climate change, the general negative impacts of pests (e.g. termites) on crops is on the rise as the crops become water stressed and unable to withstand attacks. In fact, during my visits to various farms in Tanzania, Ethiopia and Zambia, farmers reported increased termite occurrences with yield loss ranging from 10-20% on cereals such as maize, sorghum, wheat and rice,. This prompted the need to research on and compile the impacts of this pest on agricultural productivity in the region heavily dependent on crop production as source of food and income. This work also proposes various management strategies that can be adopted for various crops across the region. For every management strategies, a snapshot into possible adoption concerns have also been included. I believe that clear understanding of these strategies is important in making better management decisions by farmers.

3. DATA SOURCING

The data used here were majorly secondary sourced from various scientific publications and recognized research institutions websites. Some of the key search phrases used to locate the resources were; “impact of termites in the ecosystem”, “factors influencing termite attack”, “types of termites attacking crops in East Africa”, “crop yield loss due to termite attack”, termites attack on tree”, “cultural management practices for termites”, “biological management of termites”, and “chemical control of termites”. The sourced materials were then downloaded, read and cited as a best practice. Also, based on my extensive travel and focus group discussions with farmers across Africa, some few primary data (unpublished) were incorporated.

4. RESULTS AND DISCUSSION

Termites are one of the social insects living in colonies with caste system - queen (mainly to lay eggs), soldiers (mainly for the security of colony in case of attack) and workers (feeding termite soldiers, aiding queen in movement and offer some level of security when colony is under attack). Out of these categories, the reproductive queens and kings stayed in the nest. There are over 3000 species of termites globally with about 1000 found in Africa [11,12]. In Africa, the common species are *Macrotermes* spp., *Coptotermes* spp., *Ancistrotermes* spp., *Nasutitermes* spp. and *Odontotermes spp.* [13].

Based on past research, termites are estimated to form 40-65% of the overall soil macrofaunal biomass [14]. This percentage could be subjective, lower and likely to vary depending on habitat as influenced by other components of the system. Primarily, the diet of termites consists of wood, however, they have diversified their feeding to include several kinds of organic matter such as decayed wood, litter, grasses, lichens, soil organic matter, and fungi that members of the subfamily *Macrotermitinae* cultivate in their nests [15].

4.1 Impacts of Termite Activities on Crop Production

Termites fill many ecological functions in the tropical ecosystem. In general, the role of termites could be grouped into key categories; soil fertilization, bioturbation and soil formation, decomposition of organic matter and vegetation growth and diversity [16-18]. Termites have a strong influence on their habitat, modifying the topography, soil structural and chemical properties, and plant growth rates. During feeding and formation of mounds (that involves bringing of soil from great depths onto the soil surface), termites are also involved in the release of soil nutrients for plant use. For instance, researchers have reported high content of Ca, Na, P, K, Cu nutrients and organic matter from termite mounds compared to the surrounding soil layer [19-22]. Also, termites are heavily involved in churning of soil and creation of several tunnels leading to improved soil structure, aeration and water infiltration [23]. Such increased levels of nutrients, soil organic matter, and soil aeration water infiltration consequently resulting in improved yields of crops [24,25]. Other cultural benefits are summarized by Huis under a research work entitled 'Cultural significance of termites in sub-Saharan Africa' [26].

However despite the above benefits, some species of termites – especially *Coptotermes spp., Nasutitermes* spp*., Odontotermes* spp*., Ancistrotermes* spp., *Macrotermes* spp., most of which are found in Africa region - have detrimental effects on crop production specifically attributed to their feeding habits on both food crops and trees. For instance, termites have been reported to cause maize yield losses of 10-30% in Kenya, Uganda and Tanzania, and >50% in Ethiopia and Nigeria in the affected fields [27, 28]. Sekamatte, [29] reported yield loss of between 50 and 100% on both crops and trees in Uganda. These figures are more of estimates as precise losses are difficult to determine and vary by termite species, crop type, soil type, and fertility status and prevailing weather conditions. The attacks usually begin from the roots and then spread to upper part of the plants. On living plants, the attacks begin from older plant bark after which the underlying tissues are exposed and eaten up which gradually result to ultimate death of the plant.

4.2 Integrated Termite Management

This section looks into various strategies – broadly categorized as chemical and non-chemical practices – that have been proposed, either proven scientifically or believed to and reported by farmers, to help in the managing termite populations and activities on their farms.

4.2.1 Scouting and monitoring of termites

Scouting and monitoring are important steps towards termite management. There are several technologies that could be used to monitor termite activities – some of which are very expensive and sophisticated and would require technical knowledge to carry out – such as use of baits [30,31] and Green Eye Termite Detector (GETD) [32]. These technologies do not easily fit under resource constrained smallholder farmers in Sub-Sahara Africa, hence not considered here. In this context, scouting and monitoring of termite would involve a regular crop inspections to assess crop health and estimate termite pest levels and activities to facilitate timely intervention where needed by the farmer. For better scouting, it is recommended for farmers to follow a zig-zag transect method (Fig. 1). This process should be done once during adequate rainfall and twice during low rainfall periods per every two weeks (Fig. 2). This is because termite attacks are more prevalent and cause greater losses during relatively drier periods. This was, however, not observed during my field visits-farmers were observed to randomly and inconsistently scout for the presence of termites.

To differentiate crops attacked by termites from those attacked by other pests, look for wilting and/or fallen crops in the field. At the base of affected plant stems/roots, check for the presence of termite feeding activities (like clearly gnawed cuts of the stalks/roots (Fig. 2G) that could be accompanied with a sheet/heap of soil at the base (Fig. 2H) and/or live termites on the plant base (Fig. 2D).

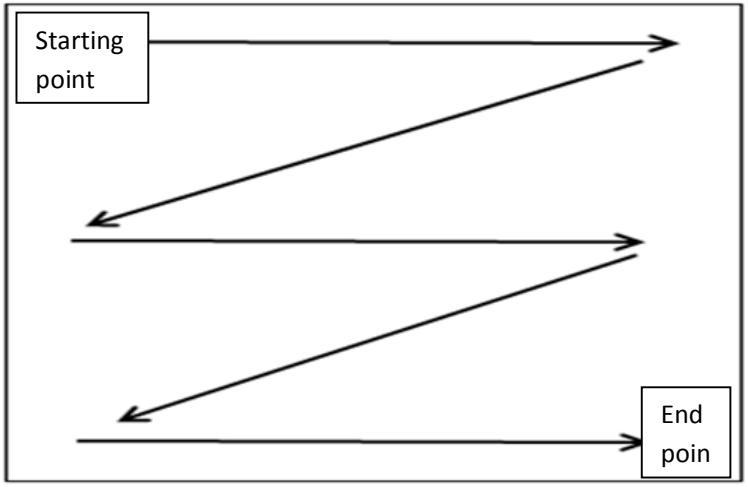

Fig. 1. An illustration of zig-zag transects scouting method

Table 1. Key agronomic practices and interventions for management of termites

Practices	Rational	Reported impact	Adoption challenges
a) Non-chemical termite management strategies ● The category entails mainly cultural and agronomic practices			
Select tolerant varieties	● In general, termite tolerance trait could be found in a) indigenous/locally adapted plants and b) hybrids bred for termite tolerance. ● Farmers to adopt LAC 23 and NERICA 5 and 14 upland rice varieties which have shown moderate tolerance. ● Currently, no hybrid maize variety is tolerant to termite in East Africa.	Reduction in termite attack by ~90% above control (IDSA 6) [33].	● Currently exists only for few crops such as groundnut and upland rice.
Use higher seeding rate	● Farmers to adopt slightly high seeding rate (more than 1 plant per hill) for the affected sites [34]. This increases chances of maintaining optimum density in case one is destroyed.	No clear impact data available.	● Increased seed costs. ● Possible plant competition for growth factors e.g. water, nutrients and light.

Practices	Rational	Reported impact	Adoption challenges
Improve crop nutrition	● Crop nutrition could be looked at in terms of organic and inorganic fertilizer application. These materials improve crop health which then grow and mature faster while tolerating termite attack. However, Sileshi et al. [35] found higher damage due to fertilizer application compared to other practices. ● Use of manure has other additional benefits like improved soil structure and pH for better crop performance. ● Farmers to adopt improved plant nutrition through application of adequate and balanced nutrients based on soil analysis report, manure application and regular irrigation.	About 30% reduction in termite population and 40% yield increase due to manuring in maize [36].	● Low availability of manure. ● Bulkiness of manure. ● Lack of mechanized system would also mean high labor demand during application of manure.
Apply mulch	● Mulching/ crop residue retention provides extra food that diverts the attention of termite from feeding on grown crops. Other benefits include increased soil fertility, soil water conservation and suppression of weeds. ● Farmers to bring in and spread organic materials (any available quantity) between planting row. Under sole maize crop, farmers to cut off and spread tassels along the rows at grain filling/doughing stage to provide food to termite as the crops mature and get harvested.	Increased mulching / residue retention results (indirectly) in reduced lodging due to termite damage [37].	● Low crop residue supply due to other competitive use of materials like thatching, source of fuel and animal among farmers. ● Possibility of termites persisting and increasing in population in a particular place due to free food.
Intercrop or rotate with legumes	● Legumes drop their leaves early enough to provide this extra food. ● Farmers to adopt maize-soybean/ groundnut intercrop/rotation or practice mulching [38, 39].	Maize yield increase of 12% with soybean and 6% with groundnut has [40].	● Small land sizes that cannot support effective rotation e.g. in Rwanda and Burundi. ● Restricting government policies on intercropping.
Agroforestry/mix planting	● Maize-trees (e.g. *Gliricidia, Ricinus communis, Tephrosia vogelii, Pterocarpus angolensis* etc.) system. These plants have termite repellant characteristics leading to low attack on maize when planted together [41, 42]. The system has additional soil health and crop protection benefits like improved fertility and control of other pest. ● Farmers to adopt these trees under agroforestry system.	No valuable data as researchers have mixed reaction [43].	● Small land sizes may limit available space for trees. ● Not always effective when the tree are not having termite repellent characteristics.
Ploughing, digging out of mounds and Killing of queen	● It is effective in the mound-building termite. ● It works to reduce termite multiplication through killing of queen and exposure of the whole colony to predators. ● Ploughing also destroy their nests and tunnels.	About 50% reduction in population within 5-8 weeks of killing the queen and 100%	● Labor intensive. ● Limited to mound-building termite types only. ● Possible colony rejuvenation

Practices	Rational	Reported impact	Adoption challenges
	● Farmers to dig out mounds and kill queens in the nearby colonies early in the season before planting.	reduction in populations within 2-4 weeks if queen is killed and termicide is also applied [44].	since they could substitute their queen.
b) Chemical management strategy			
● Farmers should always wear protective gear (waterproof apron, rubber gloves, gumboots and breathing masks) whenever dealing with any of these chemicals and avoid any product which is listed within World Health Organization (WHO) Class II category. ● The use of termicides should be with; a) under emergency cases and/ or when the termite population has reached economic injury level - when 5-10 plants are destroyed in an acre [45] and b) in cases where other control methods have failed to be effective. ● For more information on dilution and application rates, always; a) follow the product label; b) check with agro-chemical distributor or dealer; and c) seek advice from professionally recognized agricultural extension based in the region.			
Wood ash	● Suitable for small plots and around the bases of trees. Also, provide nutrients like K and Ca to crops. However, care must be taken to avoid heavy application that could cause runoff since wood ash makes soil to be hydrophobic. ● Farmers to apply ash around trees and nursery beds to repel surface termites. ● Wood ash could be replaced immediately whenever washed off by rain or under observed increased activities of termite [46].	18-52% reduction in termite population within 5 months of application [47].	● Inadequate home-base supply for use on large plots (> 0.5 acre). ● No clear application rates. ● High labor demand under large acreage of crops. ● Less effective under heavy attack. ● Can easily be washed away under heavy rains.
Plant extracts	● Several plant species have shown termiticidal or repellent effect e.g. neem, *Lantana camara*, pawpaw, *Acacia nilotica,* blackjack, tea, mexican marigold, teak, cashew, garlic etc. ● Farmers to make and spray these plant concoctions (boil 1-2 kg of leaves/barks/seeds in 5L of water [48] and apply till uniform wetting is achieved) or buy the commercial versions available and apply at recommended rates.	About 87% yield increase above control due to neem oil seed extract application in NERICA rice [49].	● Difficult to determine effective concentration and application rates. ● Large quantities is required. ● Short protection period. ● Dry spell reduce availability of these herbs for use when termites commonly attack. ● Commercial products are expensive.
Spraying with Bio-termicide	● Involves the use of preparations from natural enemies like insect-attacking nematodes, fungi (*Beauveria bassiana*) and two species of	Up to 100% mortality of worker termites within 6	● Short storage period. ● Complex in training and would

Practices	Rational	Reported impact	Adoption challenges
	Metarhizium [50]. ● The preparations/products are commercially available e.g. Kalichaka [51], Bio-Blast, BotaniGard and Naturali for farmers to buy and apply on their farms.	days; 80% reduction in maize lodging; 70% yield increase with *M. anisopliea* application [52, 53].	require specialized storage like coolants. ● Increased cost of production since most of them are more expensive than synthetic chemicals.
Dressing and treating seeds with termicides	● This is the coating of seeds with termicides to offer systemic control. It also protects crops against other soil borne pests. ● Purchase of pre-dressed seeds would be the best, if available. Otherwise farmers could consider home dressing of seeds using: Fipronil @ 4 mL/kg of seed [54]; Dursban/ Ruban/Durmet 20 EC (chlorpyriphos) @ 4 mL/ kg seed; Thiodan 35 EC (endosulfan) @ 7 mL/kg; Regent 5% SC (fipronil) @ 6 mL/kg seed.	Yield increase by ~128% in wheat and ~56% in rice compared to control [55,56].	● Complex in training farmers to dress their own seeds. ● High health risk during home-base dressing process. ● Dressing could be costly and labour intensive when handling large quantities of seeds.
Using termite baits/barriers	● These materials kill termites upon feeding on them or attract predators that then feed on and kill termites. Some of the predators include ants, ground beetles, spiders, bats, birds, frogs etc. ● Farmers to burry either Bio Blast or hexaflumuron baits in areas with persistent termite activities. ● Farmers could also add sugar/protein based baits e.g. molasses and fish meal around plant bases/rows / mounds to attract predators.	About 80% reductions in lodging and 30-60% yield increase in maize due to use of bait [57].	● Slow control action. ● Require much labor and time. ● Rely more on probability for termites to infect the colony.
Spray fields and crops with synthetic termicides	● This involves spraying the farm/ crops/ buildings/ structures with termicide solutions. ● Under emergency and heavy termite attack, farmers to use either lufenuron, diflubenzuron, hexaflumuron, hydramethylnon, noviflumuron and imidacloprid based termicides for control.	Up to 100% destruction of colony; 67-98% reduction in maize lodging; and ~30% yield increase above control in maize [58, 59].	● High health risk. ● Have negative impact to the environment – pollution and possible death of other important soil organisms.

(A) Termite mound in a mixed cropped farm in Kenya. The mounds could be as high as 5 m and wide as 30 m depending on the type of termite. ***Source:*** *Infonet*

(B) The picture shows entrance to termites nest. The entrances are usually many in number per mound and vary in diameter. They provide important route during chemical control. ***Source:*** *Infonet*

(C) This is an illustration of soil-covered tunnels built by termites on a mango tree. In most cases - depending on the species - termites attracted to and start feeding on the dead tree barks and dried stems. ***Source:*** *Infonet*

(D) This is a presentation of various stages of termite - from eggs to flying swarm. Watch for any of the stages during scouting and monitoring activity. ***Source:*** *Termite website*

(E) This is an illustration of soil cover tunnels built by termites around dead plant materials as they feed on them on the field. Destroy these tunnels before spraying. ***Source:*** *Warren, 2016*

(F) This is a picture illustrating lodged maize plants due to termite attack. The attack is high when the maize plants have developed stalks. ***Source:*** *ChaitanyaJoshi, 2018*

(G) Photo showing maize plant attacked and eaten by termites at the base. Note the eating characteristics. ***Source:*** *www.chem.unep.ch*. ***Photo by*** *Maniania*

(H) Photo showing sorghum plant attacked by the termites. Note the cut region, eating characteristics and heap of soil cover tunnel around the base. ***Source:*** *www.runetwork.org*

(I) This is a picture showing maize cobs attacked by termites. ***Source:*** *www.chem.unep.ch*. ***Photo by*** *Maniania*

Fig. 2. Picture illustrations of termite activities to keep an eye on during scouting and monitoring - they include mounds, lodged plants and trees, termite tunnels, sheet of soil cover on tree branches and crop residues on the soil surface. These signs should be checked within and the surrounding of the farms

4.2.2 Termite management options

This subsection summarizes key agronomic practices and interventions for termite control within an integrated pest management strategy framework. The agricultural extension agents and farmers should choose method(s) to adapt adopt based on the seriousness of the adoption challenges and any other past experiences with the technology. Use of synthetic chemicals should be considered as last option under emergency and in situations where no other option is available.

5. CONCLUSION

Termites have both positive and negative impacts on agricultural land depending on the species of termite present, population level and type of crop grown. From this research, adoption of mulching, cereal-legume intercrop, agro-forestry, crop rotation and cultivation of termite tolerant varieties could ensure sustainable management of termites and healthy environment if chosen and adopted well. Use of termicides provides a faster and efficient way of containing the negative impact of termites as soon as the damage threshold is realized. Application of non-chemical strategies should be given first priority and only use synthetic chemicals under emergency or in situations where other strategies have proved inefficient.

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COMPETING INTERESTS

Author has declared that no competing interests exist.

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