PREVALENCE AND EFFECTIVENESS OF PLANTING TIME AND IMIDACLOPRID TREATED SAWDUST IN CONTROL OF TERMITES IN MAIZE IN EASTERN UGANDA

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DECLARATION

I, Najjoma Dennis hereby declare that the work compiled in this report is my own effort and it has never been submitted to any University for any academic award.

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APPROVAL

This work is submitted to Directorate of Research and Graduate Training of Kyambogo University with our approval as supervisors.

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DEDICATION

Dedicated to my parents; Ms. Naigobe Esther (RIP) and Mr. Musalwa Balaam. I will forever treasure your parental love, care, support and everything!

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ACRONYMS

CVI	-	Content Validity Index
FAO	-	Food and Agriculture Organization
IM	-	Imidacloprid
IPM	-	Integrated Pest Management
SD	-	Sawdust
Sp	-	Species
UBOS	-	Uganda Bureau of Statistics
WAP	-	Weeks After Planting

ABSTRACT

Termites are among the most devastating maize pests globally. Quite a lot of research has been conducted on termites in Uganda but information on the incidence of termites and environmentally friendly control measures is scanty, especially in eastern Uganda. Accordingly, the farmers are reported to use several chemical and cultural methods for managing termites, most of them not very sustainable and quite expensive in the long run. Therefore, this study was conducted with two key objectives, i) to ascertain the prevalence and diversity of termites in eastern Uganda and, ii) determine the effect of integrating planting time and treated wood sawdust in control of termites. Termite prevalence was determined by collecting data using a questionnaire and interview from 272 respondents in the nine districts in Eastern Uganda.For objective two, three experiments were laid out at Ikulwe Satellite Station in Mayuge District in a Randomized Complete Block Design (RCBD) with four treatments, namely (i) Wood sawdust treated with imidacloprid (IM+WSD), (ii) Wood Sawdust only (WSD), (iii) Imidacloprid only (IM) and (iv) the Control (no treatment). The data was collected on the number of lodged plants, termite number and grain yield, among other parameters. Data was subjected to analysis of variance using Genstat (15th Edition) statistical software. Results showed that the highest (95.5%) termite prevalence was in Kapchorwa and the lowest in Pallisa and Bugiri, each recording 44.2%. The dominant (65.5%) termite species was *Macrotermes bellcosus.* Imidacloprid treated wood sawdust and early planting significantly ($P<0.05$) reduced termite's infestation. Imidacloprid treated wood sawdust had generally low termite population (442 and 759 termites/ha) compared to the control (2154 and 2840 termites/ha) under early and late planting, respectively. Low number of damaged cobs and high yield was recorded under early planting and treated saw dust. It can be concluded that use of treated sawdust as bait to control termite damage and early planting of maize will increase grain yield. However, there is need for additional studies in different agro-ecological zones to validate the results on use of treated wood sawdust and early planting.

CHAPTER ONE: INTRODUCTION

1.1 Background to the study

Maize (*Zea mays* L.) is amongst the most significant global food crops, together with wheat and rice offer 30% of the food calories to over 4.5 billion (Shiferaw *et al.,* 2011).In 2017, maize production in the world was estimated at 1,134 million tons implying production was growing at an average annual rate of 3.46% (KNOEMA, 2017). Africa produces about one-third of the global white maize crop (Nuss and Tanumihardjo, 2010). The increasing global production of maize is attributed to nutritional and economic relevance since it contains 10% protein, 72% starch, and 4% fat and supplies 365 Kcal/100j of energy (Nuss and Tanumihardjo, 2010). According to Ranum *et al.* (2014), the daily energy intake from maize estimated at consumption can be as high as 328 grams. In fact, it forms 50% of diet of one billion people across Latin America, South Asia and sub-Saharan Africa. Besides, maize is also used as animal feed and production of biofuels in Africa (Ranum *et al.*, 2014).

In Uganda, maize is among the top three crops in terms of area planted and production volume, after cassava and plantains banana (UBOS, 2015, 2020). According to UBOS (2020), maize production in Uganda was 3.4 million metric tonnes (MT).Maize in Uganda is predominantly produced in four regions by smallholders. Breakdown of the sub-regions production shows North Buganda with 837,700 MT, South Buganda (295484MT), Bunyoro (656,300 MT), Busoga (320,300 MT), Bukedi (167918MT), Elgon (133148MT), Teso (76890MT), Karamoja (134685MT), Lango (273054MT), Acholi (55,300 MT), West Nile (55, 315MT), Tooro (271,038MT), Ankole (113,521MT), and Kigezi (26,300 MT) (UBOS, 2020).

Maize contributes to the livelihoods of over 3.6 million households (UBOS, 2020) where over 70% of maize produced is consumed as food (FINTRAC, 2011). "Additional uses of maize comprise of preparing local drinks such as Kwete, Malwa, and Waragi (FEWSNET, 2017).

The yields of maize vary across Uganda's agro-ecological zones. Maize yield in Uganda is< 1000-3000 kg/ha which is low compared to the expected potential yield between 3000-7000 kg/ha when agrotechnical inputs like improved varieties, fertilizers are used (Mugisha*et al.,* 2011). Other factors that contribute to low yield include soil infertility, unreliable rainfall, disease and pests.

Maize is attacked by several types of pests, including the stalk borers and army worms, termites among others. Termites are one of the most damaging insects of maize (Abonyo et al., 2015; Ahmed *et al.,* 2016; Javed et al., 2021).Termites destroy the vegetation exposing the soil to the elements of erosion (Tasisa and Gobena, 2013) hence indirectly affecting maize production. In Uganda, termites reduce crop productivity causing enormous yield losses up to 100% (Sekamate et al., 2001; Apori *et al.,* 2020). Termite effect is visible during dry seasons. This implies that with the increased dry seasons associated with effects of climate change, farmers are bound to continue incurring yield losses due to termites, hence their livelihoods significantly affected (Sekamate *et al.*, 2003).

The intricacy of termite challenge rationalizes the application of several control strategies in an integrated approach since no sole control approach is adequately effective against termites. For example, in some places, destruction of mounds and termite queen killing are solely used hence continued termite problem because of lack of a holistic approach. Besides, chemical insecticides, the most preferred method has detrimental environmental impacts and effect non-target beneficial organisms (Yadav et al., 2015; Demissie *et al.,* 2019). Additionally, studies show that cultural practices like intercropping maize with soybean, early planting reduce termite effect though their effect is low hence require to be applied in combination with other methods (Demissie *et al.,* 2019). More so, intercropping and cover cropping decreases the population of termites by increasing the population of predatory ants (Ahmad et al., 2015; Carmona *et al.,* 2022). However, intercropping and crop rotation are ineffective in small-scale areas despite being good practices (Ahmad et al., 2015). On the otherhand, planting time is among the key valuable strategies used to minimise the effects of crop pests (Krell et al., 2005). However, the effectiveness of planting time varies depending on the pest type and other agronomic factors (Halerimana *et al.,* 2022).

1.2 Statement of the problem

Damage imposed by termites affects food security and income of smallholder farmers (Maayiem et al., 2012; Legesse *et al.,* 2013; Apori *et al.,* 2020). According to Demissie *et al.* (2019), above 50% of maize termite damage in Africa is reported in countries like Uganda, Nigeria and Ethiopia. This reduces the quantity of maize produced resulting into famine and poverty (Abraham *et al.,* 1995; Legesse *et al.,* 2013). In Uganda, the diversity and severity of damage by termites differ by agro-ecological zones since these zones have different soil and vegetation characteristics (Apori *et al.,* 2020), and consequently management techniques also vary. The use of chemicals is a common method of controlling termites on maize in the field (Iqbal and Saeed, 2013; Paul *et al.,* 2018); though it is discouraged due to human health concerns and environmental pollution. Besides, other cultural practices such as intercropping, mulching, early planting and manuring have been reported to reduce termite damage (Ahmad et al., 2015; Demissie *et al.* 2019). Mulching with dead plant material in the field keeps crops less exposed to termites since termites are attracted to feed on substitute food source (Ahmad *et al.,* 2015) though there is a likelihood of an increase in termite population because of excess availability of food (Nyagumbo *et al.*, 2015). Building from the concept of mulching, sawdust is one of the common wood materials in Uganda that could easily be used to bait termites in the field. Its efficacy when treated with chemicals like imidacloprid (the commonly used chemical to control termites) in combination with early planting is unknown; whether they will produce additive or synergistic effect. It's upon this background that this study was conducted.

1.3 Objectives of the study

The general objective was to determine occurrence, termite diversity, and effectiveness of time of planting and imidacloprid treated sawdust in reducing termite damage on maize crop. Specific objectives were to:

i. Assess the prevalence of termites, their diversity and cultural practices that influence their occurrence in maize fields in eastern Uganda.
ii. Determine the effect of planting time and imidacloprid treated sawdust in control of termites on maize.

1.4 Hypotheses

i. There is low prevalence and diversity of termites in maize fields in eastern Uganda

ii. Planting time and imidacloprid treated sawdust has no effect of the prevalence and diversity of termites in maize fields in Eastern Uganda

1.5 Significance of the study

i. The information generated from this study will be used as a basis for further research on termite control in maize fields by researchers in Uganda.

ii. It is envisaged that the results of this study will be published and be used for awareness creation among extension workers and farming communities on the economic values of using wood sawdust and its integration with a chemical pesticide to control termites in maize fields.

iii. The results will inform policy makers and extension personnel on the usefulness of wood sawdust in control of termites

1.6 Scope of the study

The study was conducted at Ikulwe satellite research station farm in three seasons. First Season was conducted in of 2017, second and third seasons were conducted in 2018 to evaluate effectiveness of time of planting and baiting in reducing termite damage on maize crop.

CHAPTER TWO: LITERATURE REVIEW

2.1 Biology and behavior of termites

Termites are insects that belong to the class Isoptera comprising of 2,500 species. However, about 300 species are regarded as pests (Kumar *et al.*, 2013). Termite colonies have different types of termites differing in age. Both supplementary and primary reproductive adults termites occur in colonies (Ahmad *et al.*, 2008), The queen and king primary are the reproducers and founders of the nest and colony. The king copulates and fertilizes the queen by insemination. The queen stores the sperm in the spermathecae after the copulation and uses them to sire the unfertilized eggs. The adults mate only once. The main role for a queen is to produce eggs as she lays more than 3000 eggs per day, gradually enlarging her body, especially the abdomen, to accommodate the eggs (Khan and Ahmed, 2018). The incubation period may be prolonged for50–60 days. After incubation, the nymphs hatch out in the form of neonates. Neonates undergo a number of mountings before becoming adults as summarized in figure 1a.

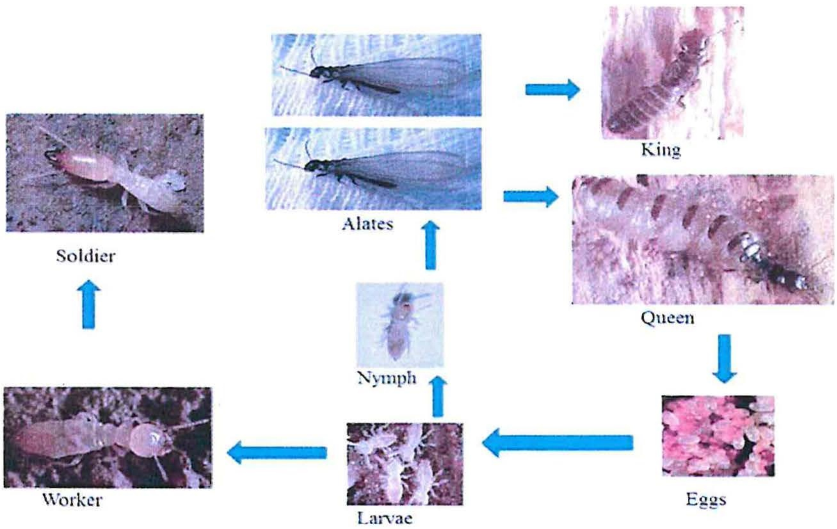


Figure **1**a: Life stages and castes of *Reticulitermes sp.*

Source: Khan and Ahmed (2018)

Termites have a caste system resulting into different colonies playing different roles. The caste system may vary depending on the different roles of the termites. The first two types of castes are those of worker castes, that is true workers and pseudergates (Khan and Ahamed, 2018). The third caste is those of alates or imagoes, which develop normally as do the other hemimetabolous insects (Figure 1b). The fourth caste is those of soldiers, which are formed from a pre-soldier or white soldier stage after the post-embryonic developmental pathway. Young workers execute domestic jobs like feeding, grooming and caring for the young ones, while the older workers are recruited on the hazardous jobs of foraging and nest building. Accordingly, Korb and Hartefelder (2008) reported that pseudergates that do the job of workers like food collection, construction or brood care have also the capacity to become reproducers. The primary function of the soldiers is to defend the colony, usually against ants, which are their main enemies (Kumari*et al.,* 2013).

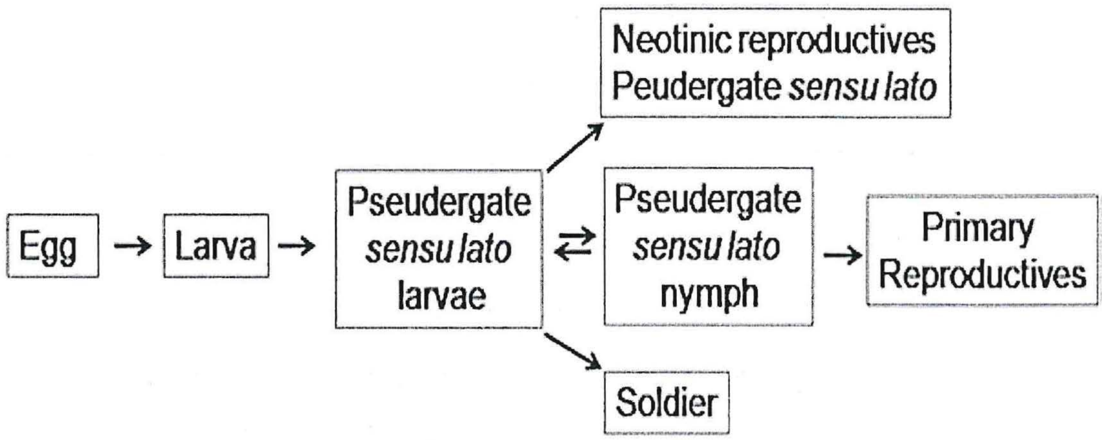


Figure 1b: Foraging termite development

Source: Ahmad and Wasim (2018)

2.2 Effects of termites on crop production

In the arid and semi-arid tropics, termites pose a great threat to crop production(Ahmad et al., 2016; 2021). The polyphagous and devastating nature of termites (Govorushko, 2019; Apori *et al.,* 2020). Attacking crops at any developmental stage makes this pest a concern to farmers. Termites attack different types of plants such as soil crops, cereals, legumes, fruit plants, root crops, and others (Qasim*et al*., 2015).The level of damage by termites is dependents on socio-institutional and biophysical factors (Legesse*et al*., 2013;Apori *et al.,* 2020). The losses caused by the termites vary depending on the country and intervention measures. For example, in Ethiopia, Mulatu and Getu (2015) reported up to 50% loss of cereal crops because termite damage experienced by farmers.

In Uganda, termites destroy over 60% of the vegetation exposing arable land to elevated levels of erosion which reduces soil fertility and consequently crop production (Mugerwa *et al*., 2014). For example, crop losses 50 to 100% as described to termite attack in Uganda (Sekamatte et al., 2001). Another report in Tororo district located in the eastern region of Uganda indicated 23 main crops seriously ravaged by termites. The report also found that, all termite species reported to damage to trees also damaged most of the crops. The challenge of termites causing devastating losses to maize and other crops has been reported in various parts of the country including Pallisa, Tororo, Jinja, Mayuge, and Lira among others. The level of damage becomes more severe during drought period (Nyeko and Olubayo, 2003).

In Zimbabwe, termites (mainly Macrotermitinae subfamily) caused crop losses by destroying the plant root and system interfering with translocation of water and nutrients and causing lodging (Govorushko, 2019) with the yield losses effect exacerbated by delayed in harvesting of the lodged plants Mutsamba *et al.*, 2016).Overall, termite damage in crop cultivation systems in African systems is over 60% (Maniania*et al.* 2001), with varying yield losses (Nyagumbo*et al.*, 2015).Generally, in Africa, more than 50% termite maize damage in croplands is in Nigeria, Ethiopia and Uganda (Orikiriza *et al.*, 2012). In Uganda, losses of crops and tree stands ranges from 50 to 100% by termite attack (Sekamatte et al., 2001;Demissie *et al.* 2019). Accordingly, the latest comprehensive report in Eastern Uganda showed that yield loss by termites in Bugiri district was 44.7%, Bukedea (41.6%) and Tororo (36.6%) (Girma*et al.*, 2020). Overall, termite infestation and yield loss data is still scanty in Uganda.

2.3 Management strategies to termites

2.3.1 Chemical methods of termite control

Extremely chemical with high effectiveness avert subterranean termite outbreaks and to reduce their infestation levels and damageare available (Verma *et al.*, 2009; Yadav *et al.*, 2015; Ahmad *et al.*, 2016). However, termiticides use for controlling termites has created several environmental and biological dangers in air, soil, water, and food. Besides, these problems, termiticides are expensive and necessitate special equipment for their application (Ahmad et al., 2016). Kamarudin et al. (2022) reports that among other challenges could be development of resistance to chemical pesticides. Besides, soil penetration ability and level of persistence influences effectiveness of chemical control (Verma*et al.*, 2009; Paul *et al.*, 2018).

However, the efficacy of the termiticides is dependent termiticide concentrations and distance of application. For example, Chemical control of termites reduces subject to horizontal or vertical as well as termiticide's inoculation point distance (Riekert and Van den Berg, 2003).Chemicals are normally used in fields with high severity of termite attack. But factors like limited knowledge and cost, besides, the associated human health and environmental concerns may hinder their use (Iqbal and Saeed, 2013; Tasisa*et al.,* 2013). The use of highly persistent organo chlorine insecticides developed in the 1940's largely prevented termite damage to maize (Logan*et al.*, 1990). Research to develop alternative chemical control methods has centered on newer, less persistent insecticides (Ahmad et al., 2016) such as imidacloprid. Imidacloprid is reported to disrupt social behavior and to kill *Reticulitermesflavipes*, a wood feeding termite species (Ramakrishnan*et al.*, 2000).

Damage of maize by termitesbegins at seedling stage and intensifies at the start of senescence, (about 10 weeks after germination) (Riekert and Van den Berg, 2003). Thus, chemical pesticides are to be correctively applied rather at late stages of plant growth and/or as preventive actions ensuring economic maize production in termite susceptible areas. Report by Iqbal and Saeed (2013) revealed that spinosade and chlorfenapyre were more efficacious in controlling termites compared to other chemicals like, fipronil and indoxacarb, fipronil, Smilalrly, Ahmed *et al.* (2015) revealed that insecticides chlorpyrifos, hiamethoxam and acetamiprid were more effective in controlling *Psammotermes hypostoma.* Bhagawati *et al.* (2014) revealed no significant difference between sole use of clothianidin combination of clothianidian with a mixture of acephate + imidacloprid to in field conditions. However, a laboratory study by Manzoor *et al.* (2014) imidacloprid being a non-repellent insecticide caused 90% mortality.

2.3.2 Baiting as a termite control strategy

Baiting is among the new technologies to control termites in an integrated termite manner (Wang et al., 2012). This method requires extra regular field visits to monitor and report the field pest dynamics (Thorne and Forschler 2000). An effective termites bait is considered successful if termite damage on a crop is decreased at tested points/fields (Thorne and Forschler 2000). In Uganda, farmers use sugarcane husks and meat from dead animals to poison termite mounds (Sekamatte *et al.*, 2001) just like in Mozambique where leftovers beef or pork are used (Sileshi *et al.*, 2008). In South Africa, fish meal was experimentally proved to be effective for controlling termites (Rickert and van den Berg, 2003) because of improved activity of ants in treated fields (Sekamatte *et al.*, 2001). Similarly, Logan *et al.* (1990), argued that baits made from protein increased ant nesting around maize plants consequently reducing decreasing in termite damage. However, the challenge with baiting is that particular termite species may avoid bait points since they are sensitive to disturbance. Therefore, sealing baits in soil (for few months or years) can greatly advance the efficacy of the bait though physical monitoring is difficult making it unfeasible on large farms. Generally, the efficacy of baits can be improved by using them in combination with bacteria (Natsir and Dali, 2014) or mixing with chemical pesticides.

2.3.3 Planting time as a termite control strategy

Management of planting time is among the key valuable strategies to minimise the effects of crop pests (Krell et al., 2005). The effectiveness of planting time varies depending on the pest type and other agronomic factors (Halerimana *et al.,* 2022). Early planted maize is less vulnerable to pests such as stem borer and earworm though some insect pest community studies show antagonist effects of sowing date. For example, early planting of oilseed rape tends increases damage cabbage root fly though it lowers effect of by Psylliodes *chrysocephala* (Rusch *et al.,* 2010). Early planting allows crop flowering stages to escape harsh conditions like elevated temperatures (Kamara *et al.,* 2020) ensuring proper establishment and resistance to pests. Damage by bean leaf beetles was reported high in late planting as reflected by high abundance in all agro-ecological zones in Uganda (Halerimana *et al.,* 2022). Conversely Muhammad *et al.* (2022) reported a higher infestation of *Helicoperva armigera* both in early and late planting equated to mid-planting. According to Krell et al. (2005), late planting of soybean reduced early colonization and subsequent pod injury by *C. trifurcate.* Delayed sowing of bean in northern Uganda is used by farmers to circumvent bean leaf beetles in the long rainy season (Halerimana *et al.,* 2022). In Nigeria, varied the planting dates of cowpea decreased *Maruca vitrata* infestation (Muhammad *et al.,* 2022). Kamara *et al.* (2020) reports that season progress in late-planting promotes pest's build-up and consequently damage. Overall, the effect of sowing dates on top-down control of pests is not fully evaluated (Rusch *et al.,* 2010).

2.3.4 Role of other cultural practices in termite control

Cultural management practices that may help reduce termite effect on maize include but not limited to weeding, mulching, timely harvesting, crop rotation and intercropping. One of the general aspects with these practices is that they improve general plant growth vigour and soil fertility. Specifically, mulching with dead plant material or green plant biomass in the field is a good approach to keep crops less exposed termites since they are attracted to and feed on an alternate food source (Ahmad et al., 2015; Nyagumbo *et al.*, 2015) though there is a likelihood of an increase in termite population because of excess availability of food (Ahmad et al., 2015). On the other hand, crop rotation and intercropping tactics increase termite natural enemies and breakdown termites life cycle by growing non-preferred crops (Ahmad et al., 2015). According to Ahmad et al. (2015) intercropping maize with legumes especially groundnut or soybean decrease the population of termite by increasing the population of predatory ants. An integrated study by Girma *et al.* (2009) showed that apart from reducing termite infestation, mulching, intercropping and joint application of mulching and intercropping improved maize crop yield. But the same report emphasized that intercropping and crop rotation are ineffective in small-scale areas despite being good practices. Other cultural practice used in Zambia and Nigeria is application of wood ash (Sileshi *et al.*, 2008) though the protection mechanism of wood ash against termites is uncertain (Nkunika, 1998). Relatedly, several species of plants like *Euphorbia tirucalli, Tephrosia vogelli* have been planted as termite repellants or extracts from its roots or leaves sprayed on seedlings to control termites in Zambia, Tanzania, and Malawi (Logan *et al.*, 1990; Sileshi *et al.*, 2008). Although this is environmentally friendly, their effect is short lived since the products breakdown rapidly in the soil besides, robust safety, toxicological, and environmental assessments are also required for their wider application. Overall, in this section, most of the cultural practices have been studied and showed a positive effect in control of pests including termites. However, the use of timely planting had no relevant literature available to be included in this section.

2.3.5 Biological control

Biological control involves keeping termites' population below threshold that can cause economic damage using parasites, predators and pathogens. Studies have evaluated the efficacy of entomopathogenic fungi, bacteria , and nematodes against termites. According to Kalha*et al.* (2014), certain species of bacterial like *Bacillus* spp. Produced considerable effect against termites .A laboratory study by Singha *et al.*(2010) showed that *Bacillus thuringiensis*produced 80% termite's mortality suggesting that it is effective. On the other hand, some species of entomopathogenic nematode such as *Heterorhabditis bacteriophora* andSteinernema *feltiae*infect and suppress subterranean termites (Ahmad *et al.*, 2019). A study by Javed*et al.* (2021) shows that entomopathogenic nematodes *S. bifurcatumN*-KA.93 and pakistanenseN-KA.04 caused up to 100% mortality of termites. Besides, Omoya and Kelly (2014) alsoreported effectiveness of *Bacillus subtilis*is against certain termite species.

2.4 Farmers' perception of termite and their control

Farmers from different communities perceive termites and their control differently. Numerous studies have documented farmers' knowledge of termites in different locations. Local communities are able to recognize termite species using modest community morphological techniques (Nkunika, 1998; Sileshi*et al.*, 2009; Sekamatte and Okwakol, 2007). For example, 14 termite species were identified by respondents in Tororo district using with distinctive local dialect names Nyeko and Olubayo (2003). Features respondents used to characterise termites were mound related (size and shape) and termite traits (color size, and shape). Besides, some respondents had considerable knowledge of the distribution and abundance of termites. In Uganda, respondents reported Macrotermes *subhyallinus* and *Macrotermes bellicosus* as the most common termite species affecting crops with *Pseudacanthotermes spiniger* puported to be a minor pest not meriting control (Nyeko and Olubayo, 2003).

Relating farmer's knowledge of termites to control, its reported that termites that form mounds disrupt farming because they reduce available land for farming. For that reason, therefore, Siame (2005) found that farmers especially in low input agriculture use soil from termite mounds as fertilizer because the psychochemical properties of termite mound soil improve maize yield by over 33%. However, critical examination of the results shows uncertainty in the long term use of those mounds soil as termite control strategy. In Ghana, strategies like use of wood ash, combination of Shea butter residue and salt among other are used. However, some respondents reported using termites as food, providers of ecosystem services vs it being a pest remains a major dilemma.

CHAPTER THREE: SURVEY OF TERMITE PREVALENCE IN EASTERN UGANDA

3.1 Introduction

Maize (*Zea mays* L.) is an essential food security crop for more over 70 million people in Sub Saharan Africa (Melinda *et al.*, 2013). Accordingly, Uganda is the eighth leading producers of maize in Africa with total production of 3.4 million metric tons; although with a low yield levels of 2.2 - 2.5t/ha equated to actual potential yield of 5t/ha in 2015 (UBOS, 2015, 2020). However, termites pose a great threat to maize production. Termites attack maize and cause significant damage. Reports indicate the severity of termite's problem vary depending on so many factors (Jiregna and Tena*et al.,* 2013). Ofgaa (2004) reported that termite diversity and geographical location of an area determines the level of damage other factors constant. Therefore, understanding field termite diversity determines influences the nature of action/control to take. Currently, there is no up-to-date data on the prevalence and diversity of termites in Eastern Uganda yet the considerable amount of maize is produced in there. It is against this background that this study was undertaken.

3.2 Methodology

The study was conducted in the month of May to August 2016 in the lowland districts of Bugiri, Butaleja, Pallisa, Luuka, Manafwa, Sironko and Mayuge, and the highland districts of Bukwo and Kapchorwa during the maize growing season. A total of 272 farmers/households were interviewed, considering both small and large-scale maize farmers (Table 1). The nine districts where the survey was conducted are among the leading producers of maize in eastern

Uganda. Only households involved in maize cultivation at the time of the survey and the previous year were selected.

Table 1: Number of respondents selected per district

District	*Frequency*
Bugiri	30
Bukwo	30
Butaleja	28
Kapchorwa	32
Luuka	30
Manafwa	30
Mayuge	30
Pallisa	30
Sironko	32
Total	*272*

A descriptive cross-sectional survey design was used following a three-stage cluster sampling technique to select the households, based on existing reports on the presence of termites in these districts. A questionnaire (Appendix 1) was used to collect information from farmers and agricultural extension officers. The tools were pretested to determine their reliability and validity. This was followed by physical visit to the field to assess the prevalence and collect termite samples. The collected termites were put in bottles containing alcohol and taken to the laboratory for taxonomic identification by morphological means. Quantitative data was coded and analysed using SPSS (Version 20). Descriptive statistics like frequencies were used to summarise termite infestation and cropping systems, symptoms of termite damage, and control methods. Accordingly, chi-squared tests were used to test the relationship between practices like planting and termite's infestation level. Qualitative data was presented using a thematic approach i.e. themes, patterns and statement that were related were put into categories

3.3 Results

3.3.1 Demographic characteristics

Table 2 shows that most households were headed by females (60.3%). Bugiri District had the highest number (80%) of female headed households while Pallisa District had the highest number (60%) of male headed households.

Table 2: Household heads segregated by gender

DISTRICT	MALE		FEMALE		TOTAL COUNT (N)
	Count	Percentage (%)	Count	Percentage (%)	
Bugiri	6	20.0	24	80.0	30
Butaleja	12	42.9	16	57.1	28
Pallisa	18	60.0	12	40.0	30
Luuka	8	26.7	22	73.3	30
Kapchorwa	14	43.8	18	56.2	32
Manafwa	16	53.3	14	46.7	30
Sironko	18	56.2	14	43.8	32
Mayuge	4	13.3	26	86.7	30
BUKWO	**12**	**40.0**	**18**	**60.0**	**30**

3.3.2 Termite infestation and cropping system

The second most prominent pest reported (39%) was the fall armyworm (FAW) (Table 3). The highland areas of Kapchorwa and Bukwo districts reported higher termite incidences compared to the lowland areas (Figure 2). The most dominant termites' species observed in the field was *Macrotermesbellcosus* (Table 4). Though farmers in eastern Uganda practice both mixed and mono-cropping, mixed responses were given on the level of termite's infestation by cropping system but with slightly more districts reporting more termites under monocropping than under mixed cropping (Table 5).

Table 3: Farmers' response on insect pest incidence per district

	Termites		Fall army worms		
	Count	Percentage %	Count	Percentage %	Total (n)
Bugiri	12	4.4	18	6.6	30
Butaleja	20	7.4	8	2.9	28
Pallisa	12	4.4	18	6.6	30
Luuka	14	5.1	16	5.9	30
Kapchorwa	26	9.6	6	2.2	32
Manafwa	16	5.9	14	5.1	30
Sironko	20	7.4	12	4.4	32
Mayuge	22	8.1	8	2.9	30
Bukwo	24	8.8	6	2.2	30
Total	166	61.0	106	39.0	272

Table 4: Dominate specie of termite in the surveyed area

Termite species	**Frequency (%)**
Macrotermesbellcosus	65.7
Macrotermessubhyalinus	15.2
***Odontotermes*spps**	19.1

Figure 2: Termite incidence in selected districts in Eastern Uganda

Table 5: Farmers' response on level of termite infestation by farming system

DISTRICT	**CROPPING SYSTEM (%)**	
	Mono Cropping	Mixed Cropping
Bugiri	53.3	46.7
Butaleja	42.9	57.1
Pallisa	60.0	40.0
Luuka	46.7	53.3
Kapchorwa	50.0	50.0
Manafwa	13.3	86.7
Sironko	31.2	68.8
Mayuge	60.0	40.0
Bukwo	53.3	46.7

3.3.3 Relating termite infestation to planting dates

Planting date had a significant effect (χ^2 = 23.246, V = 0.219, df=8, P=0.026) on percentage lodging due to termite attack. Generally, respondents reported lodging to be low in early planting as opposed to late planting. For example lodging of 0-25% was slightly higher between 11[th] – 30 March planting time and low in between 20[th] February to 10[th] March. Similarly, the lodging rate of 76 – 100% was low in early planting (20[th] February to 10[th] March) but became slightly higher in late planting (20[th]to30March)(Figure3).

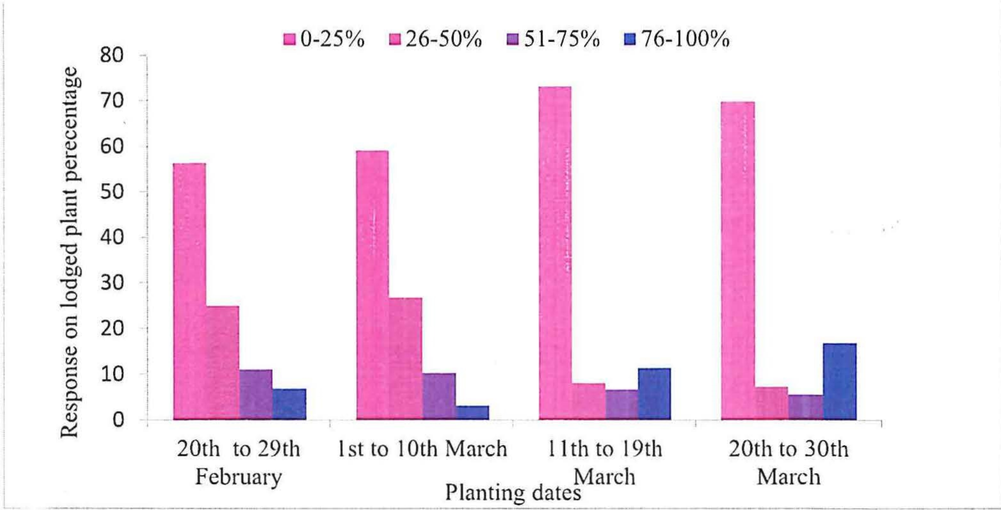


Figure 3: Farmers' response on planting date and percentage lodging due to termite attack

3.3.4 Termite infestation signs and control

From Table 6a, the most observable sign of termites that majority (21.3%) of the farmers noted was lodging of the plant, while some farmers (14%) also observed termites moving in their field. Most farmers (33%) reported using chemicals as the most effective method of controlling termites compared to cultural (3.7%) and mechanical methods (1.5%).

Table 6 a : Termite infestation signs and control

	FREQUENCY	PERCENT
Signs and symptoms observed		
wilting and drying of the maize plant	30	11.0
Trails of soils on the maize plant	36	13.2
Lodging due to termite attack	58	21.3
Termites are seen moving	38	14.0
Others	110	40.4
Mitigation Method		
Spraying with chemicals	90	33.1
None	50	18.4
Cultural methods	10	3.7
Manual or mechanical methods	4	1.5
OTHERS	**118**	**43.4**

Majority (25.7%) of the farmers that use chemicals to control termites relied on rocket insecticide to spray their crops while Super-cyper insecticide was the least (0.7%) used by farmers. Most of the farmers (14%) that used chemicals sprayed their crops only twice during the season. Additionally, majority of the respondents were not sure of which chemical and its rate was effective for control of termites though a small proportion (13.2%) reported Ambush to be effective chemical (Table 6b).

Table 6b : The use of Chemical method in termite control

	FREQUENCY	PERCENT
Chemical used		
Rocket	70	25.7
Ambush	18	6.6
Super-cyper	2	0.7
No chemical used	182	66.9
Number of times sprayed		
Once	30	11.0
Twice	38	14.0
Thrice	22	8.1
None	182	66.9
Effectiveness rating		
Excellently	4	1.5
Good	30	11.0
Fair	38	14.0
It did not work at all	18	6.6
Not sure	182	66.9
Effective chemical		
Rocket	14	5.1
Ambush	36	13.2
Super cyper	24	8.8
Other	2	0.7
Not sure	196	72.1
Total	**272**	**100**

3.3.5 Information on termites

Overall, in terms of access to termite control information, majority (45.6%) of the farmers had no prior information on termites, their effects, and mitigation measures. Other than the neighbours and friends who contribute 11% as major sources of information, most information on termite management as reported by 45.6% of respondents is obtained from quite scattered sources categorised as 'others' herein , such as agro-input dealers, maize middlemen, farmer's own knowledge and occasionally agriculture extension officers (Table 6c).

Table 6c : Information on termites

	FREQUENCY	PERCENT (%)
Ever received information on termite management		
No	124	45.6
Yes	30	11.0
Undecided	118	43.3
Source of information		
Media	6	2.2
Neighbours and friends	32	11.8
Others	124	45.6
Not sure	110	40.4
Total	272	100.0

3.4 Discussion

Results from this survey show that there is high prevalence of termites and *Macrotermes subhyalinuswas* dominant specie eastern Uganda. The dominance of *Macrotermes subhyalinus* in farmers' fields was probably because of the nature of vegetation and soil that allowed them to make mounds easily. This compares with Apori *et al.* (2020) who reported that Uganda, *Macrotermes subhyalinusand Macrotermes bellicosus* were among the dominant specie of termites inhabiting arable land in Uganda. Overall, uncertainty of farmers in the methods of controlling termites and mono-cropping were perceived as the major cause of overall prevalence of all the three termite species. Besides, even the chemicals used to control these termites seemed not very effective. However, from a general perspective, respondents have limited knowledge on management of termites as most of them acknowledged doing nothing to repel the termites. Yet, earlier, the significance of the knowledge of farmers was emphasized in aiding the development and implementation of suitable termite control remedies (Morse and Buhler, 1997). Accordingly, Obi *et al.* (2008) in Nigeria also found that maize was the most affected crop by termites and the effect increased in the order maize>millet>guinea corn>cassava. This could be due to the palatability and nature of maize compared to all the other crops.

In this study, highest termite attack happened at 7 to 8 weeks after planting while the least (1.5%) happened beyond 11 weeks after planting. The increasing infestation during this time of the season (7-8 WAP) could be attributed to the high temperatures as termite damage has been reported to be higher during times of high temperature (Sekamatte and Okwakol, 2007). Results from this survey agree with those of Riekert and Van den Berg (2003) who observed that termite damage to plants sharply increased between 6 to 10 weeks after planting. In Western Ethiopia, Bulto and Hirpa (2016) registered the first termite damage on maize twenty days after planting and after ten days of germination emergency. Therefore, knowing the timing of termite infestation is critical in designing termite control measures and scheduling of times of application of the selected control measures.

Generally, the uncertainty in utilization of chemicals amounted to high termite prevalence in the eastern districts. It became clear that there was an information gap on termites amongst farmers with many of them acquiring information from neighbors, friends and middlemen that tend to be unreliable. Currently, control of termite in East Africa depends primarily on the use of chemicals (Logan *et al.*, 1990). Sekamatte and Okwakol (2007) reported that effectiveness of termite chemical control methods depends on the knowledge of farmers in applying them say dosage, application regime and timing. However, the chemicals used have significant effects on the ecosystem functioning. It is essential to appreciate that termites are both beneficial and destructive ecosystems. Hence, satisfying termite provisioning and functionality ecosystem services can be attained by managing termites using sustainable integrated means(Sileshi*et al.,* 2009; Mugerwa*et al.*, 2014). It is therefore, imperative to understand the explicit structure of termite assemblages in the maize growing areas in order to develop control measures that are sustainable.

CHAPTER FOUR: EFFECT OF PLANTING TIME AND TREATED SAWDUST IN CONTROLLING TERMITES IN MAIZE

4.1 Introduction

Termites are among the most devastating pests of maize globally with an associated yield loss of upto 100% (Sekamate et al., 2001). Termites destructive effects are prominent during drought seasons. This implies that with the increased drought seasons associated with effects of climate change, farmers are bound to continue experiencing yield losses due to termites (Sekamate*et al.*, 2003) and consequently become food insecure. A recent survey by Girma *et al.* (2020) showed that about 95% of the respondents in Eastern Uganda reported termites to cause poverty and food insecurity. This implies that there is need to find appropriate management options. However, termite control measures appropriate for each region are affected the knowledge of farmers, ecology, climatic conditions, among others. Though chemicals have proved effective, they are quite expensive to use, especially if the farmer is relying on them alone. Therefore, integration of different control measures may prove to be the way forward. According to Sekamate and Okwakol (2007),additionof physical barriers and organic material to the soil improves effectiveness for control of termites. If plant materials are treated with recommended insecticides, the efficiency improves. Currently, little is known about the effect of combining sawdust treated with chemicals used in combination with planting time in controlling termites in Uganda, the reason this study was undertaken.

4.2 Materials and methods

4.2.1 Study site

The experiment was conducted at Buginyanya ZARDI, Ikulwe Satellite Station, Mayuge District in 2017B, 2018A and 2018B seasons. Ikulwe is located 15 km Southeast of Musita trading centre at coordinates 0.4399 N, 334781 E. It is situated 2 km South of Mayuge town and 42km from Jinjacity. The minimum and maximum temperatures are 16°C and 30°C, respectively. Rainfall ranges between 1200mm to 1500mm per annum respectively.

4.2.2 Experimental design and treatment structure

The experiments were laid out in a Randomized Complete Block Design (RCBD) arranged as a split with three replications. In total, three experiments were conducted in 2017 and 2018 growing seasons. Whole plot factor was the planting time whereas the subplot factor was the treated sawdust. Planting time was at two levels, specifically at the onset of rains and two weeks into the rainfall season, as described by Rima and Shukila (2013). The treated treatment was at four levels (sawdust only, sawdust + imidacloprid, imidacloprid only and a control characterized by no sawdust and no chemical). Each experimental unit was 5 x 6 m separated by a distance of 1m. The Net plot size was 506m^2.

4.2.3 Land preparation and administration of treatments

Prior to planting, primary and secondary cultivation was conducted two times at an interval of three weeks using a tractor in order to achieve a fine seed bed. In season 2017B, early planting was conducted on 11/09/2017 just at the beginning of the rainy season and lateplanting was done on 25/09/2017. In season 2018A, early planting was conducted on 20th/03/2018 just at the beginning of the rainy season and late planting was done on 03rd /04/2018.

Similarly, in season 2018B early planting was conducted on 3^{th} /09/2018 just at the beginning of the rainy season and late planting was done on 18^{th}/09/2018. Maize variety Longe 10H was used throughout the experiments, planted at of spacing of 75cm × 25cm, at a seed rate of two seeds per hill, which was later thinned to one. Diammonium phosphate (DAP) and urea fertilizers were applied at planting and at four weeks after planting, respectively, at a rate of 125kg/ha. Eastern Uganda, particularly Mayuge District is a termite hotspot (Kagoda (Program Leader – Crops and Natural Resources Program NARO – Buginyanya ZARDI) personal communication) therefore the study relied upon natural infestation. To further ensure natural infestation, the termite mounds around the experimental sites were not destroyed during the entire period of the study.

As soon as 10% termite infestation was observed in the field, the treatments were applied. Treated sawdust and untreated sawdust was applied around the plants (Ring application) at a rate of 138kg ha^{-1} (2.5kgs per plot). Sawdust treatment by was done by mixing sawdust with a solution of water and Imidacloprid(40mls/20 liters of water) in a bucket. Positive control (Imidacloprid only) was applied using a knapsack sprayer following the recommended rate of 500mlsha^{-1} (40ml/20litres of water)(Riekert and Van den Berg 2003) and negative control consisted of maize grown without sawdust and imidacloprid.

4.2.4 Data collection

The Quadrat method was used to determine the infestation level of termites following the procedures as described by Ana *et al.* (2017). A wooden quadrat used was 1m×1m in dimension. Three samplings were done per plot accordingly, at an interval of one week. The termites got in the quadrat at every inspection point were manually collected with entomological forceps and counted.

Data collection on termite infestation and its effect commenced at five weeks after planting and continued at interval of one week for twelve weeks. Data was collected on number of lodged plants due to termites' attack, and number of plants with termite cob damage following procedure described by Riekert and Van den Berg (2003).

4.2.5 Data Analysis

Termite number and lodged plants data were tested for assumptions of ANOVA (normality and homogeneity of variance). Since, these assumptions were not violated, data was analyzed using Analysis of Variance (ANOVA) of Genstat software for windows (15^{th} edition). Combined analysis was done to test the season effect. Significant differences between the means were separated using lowest significant difference (LSD) test at 5% probability level.

4.3 Results

4.3.1 Number of termites

Results were obtained for analysis of variance for the number of termites as affected by planting time and treated sawdust in 2017B, 2018A and 2018B seasons. Treated sawdust and planting time significantly affected the number of termites. Similarly, a significant difference in the number of termites was observed as a result of different planting seasons (Table 7). However, it's important to note that this thesis concentrates reporting on week 8 to 12week that had peak infestation by termites. The interaction between Season planting time, Season treatment, planting time treatment and Season.plantingtime.treatment were not significant except in the early weeks of plant growth (Table 7).

Table 7 : Summary of ANOVA mean squares for number of termites across three seasons (2017B, 2018A and 2018B) under different termite bait treatment regimes.

Source of variation	d.f.	5 WAP	6 WAP	7 WAP	8 WAP	9 WAP	10 WAP	11 WAP	12 WAP
Season	2	69.0	390**	232	321.1*	592*	1124**	370.3*	278.8
Planting time	1	107.5	754.0**	868.1**	567**	1431**	2926**	2037.3**	2037**
Treatment	3	299***	663***	2038**	4066**	7085**	12706**	13975.4**	22311**
Season. Planting time	2	86.43	134.85	215.6	196.35	218.3	909.0**	410.1*	257.2
Season. Treatment	6	17.88	26.03	38.1	35.07	15.8	92.82	78.9	43.8
Planting time. Treatment.	3	41.6	36.27	343	100.6	160.3	396*	261.9	397.8
Season. Planting time. Treatment	6	21.19	46.05	296.7	155	65.3	140.04	60.2	150.6

WAP = Weeks after planting, = Significant at 0.01, * = Significant at 0.05

Generally, the number of termites was significantly higher (P < 0.05) in 2018B season than in 2018A season. The detail, of the termite population from 5 – 7WAP is presented in Appendix 2a and b. At 8 WAP, the 2017B early planted trial registered significantly less (P < 0.05) termites under treated sawdust (8.3 termites per plot) and imidacloprid only (5.3 termites per plot) compared to sawdust only (28.3 termites/plot) and the control (44.7 termites/plot). Similarly, under late planting, both the sawdust only and the control had significantly higher ($P < 0.05$) number of termites (59 and 47.3 termites/plot, respectively) compared to treated sawdust (15.7 termites/plot) and imidacloprid only (11.3 termites/plot). Notably, number of termites recovered was generally much higher under late planting than under early planting.

In 2018A season, a significantly lower ($P < 0.05$) number of termites (1.7 and 0.3 termites/plot) were observed in treated sawdust and Imidacloprid only, respectively under early planting, compared to sawdust only (38.3 termites/plot) and the control (26 termites/per plot). Under late planting, a total of 4.3 and 1.3 termites per plot were registered in treated sawdust and imidacloprid only, respectively compared to 38.3 and 30.3 termites in sawdust and control respectively. Similarly, in 2018B season, lower number of termites was recorded in treated sawdust as compared to the control and sawdust only (Figure 4a).

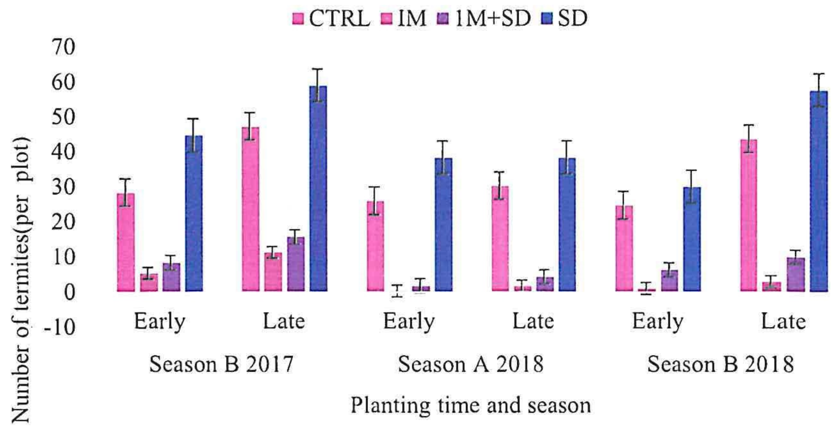


Figure 4 a : Termite populations per plot across seasons and treatments at 8 WAP

CTRL – Control, IM – Imidacloprid, IM+SD - sawdust treated with imidacloprid

SD - sawdust only

At 9 WAP, the number of termites was significantly higher ($P < 0.05$) in 2018B season than in 2018A season (Figure 4b).. However, the 2017B early planted trial registered significantly more ($P < 0.05$) termites under treated sawdust (10.0 termites per plot), saw dust only (52.7 termites/plot) and the control (25.7 termites/plot) compared to imidacloprid only (6.7 termites per plot). Under late planting, both the sawdust only and the control had significantly higher ($P < 0.05$) number of termites (81.7 and 25.7 termites/plot, respectively) compared to treated sawdust (21.0 termites/plot) and imidacloprid only (45.0 termites/plot).

In 2018A season, a significantly lower ($P < 0.05$) number of termites (1 and 0 termites/plot) were observed in treated sawdust and Imidacloprid respectively under early planting, compared to sawdust only (52.3 termites/plot) and the control (37.3 termites/per plot). Under late planting, a total of 1.7 and 7.3 termites per plot were registered in treated sawdust and imidacloprid respectively compared to 52.3 and 45.0 termites in sawdust and control respectively. In 2018B season, lower number of termites was recorded in treated sawdust as compared to the control and sawdust only (Figure 4b).

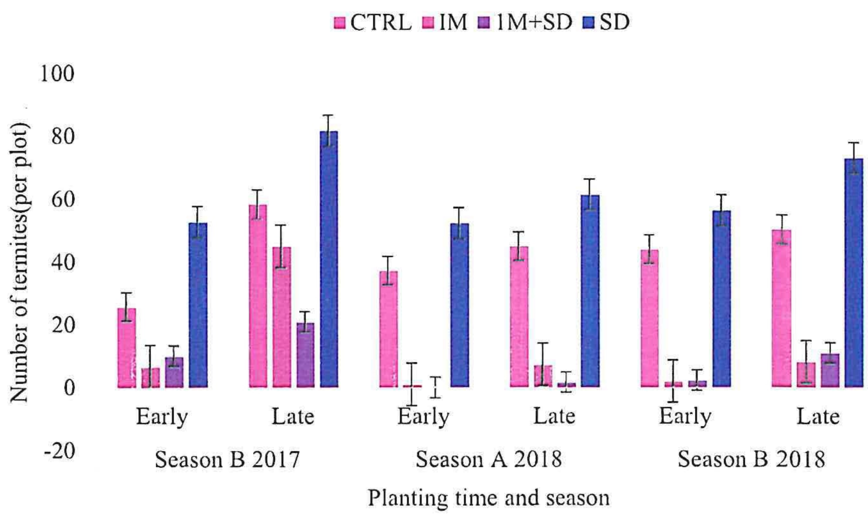


Figure 4 b : Termite populations per plot across seasons and treatments at 9 WAP

Meanwhile at 10 WAP, the number of termites was significantly higher ($P < 0.05$) in 2018B season than in 2018A season (Figure 4c). The 2017B early planted trial registered significantly more ($P < 0.05$) termites under saw dust only (67.7 termites/plot) and the control (28 termites/plot) compared to imidacloprid only (7.7 termites per plot) and treated sawdust (11.7 termites per plot). Under late planting, both the sawdust only and the control had significantly higher ($P < 0.05$) number of termites (103 and 61 termites/plot, respectively) compared to treated sawdust (12.7 termites/plot) and imidacloprid only (7 termites/plot).

In 2018A season, a significantly lower ($P < 0.05$) number of termites (2.3 and 1.3 termites/plot) were observed in treated sawdust and Imidacloprid respectively under early planting, compared to sawdust only (76.7 termites/plot) and the control (36 termites/per plot). Under late planting, a total of 6.3 and 2.0 termites per plot were registered in treated sawdust and imidacloprid respectively compared to 77.7 and 36 termites in sawdust and control respectively. In 2018B season, lower number of termites was recorded in treated sawdust as compared to the control and sawdust only (Figure 4c). In 11 and 12 WAP, the number of termites followed the similar trend as in 10WAP though with increased population (Figure 4 d and e).The overall trend of termite number in all treatments are summarized in figure 5.

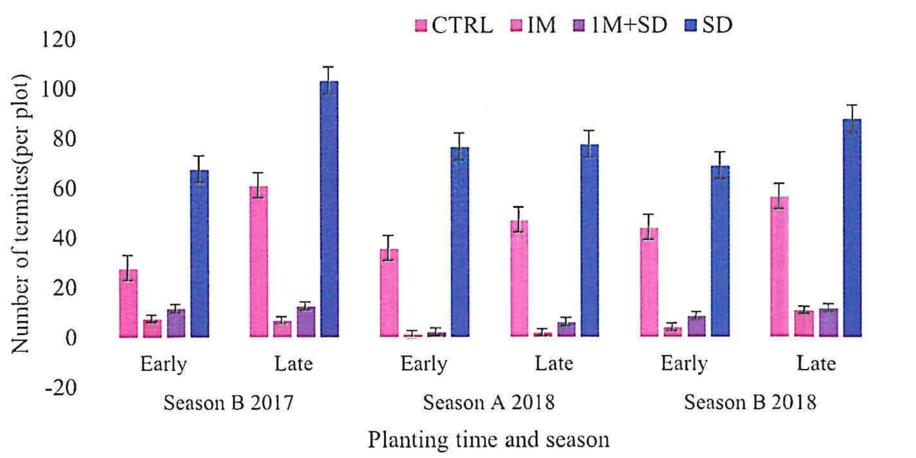


Figure 4 c : Termite populations per plot across seasons and treatments at 10 WAP

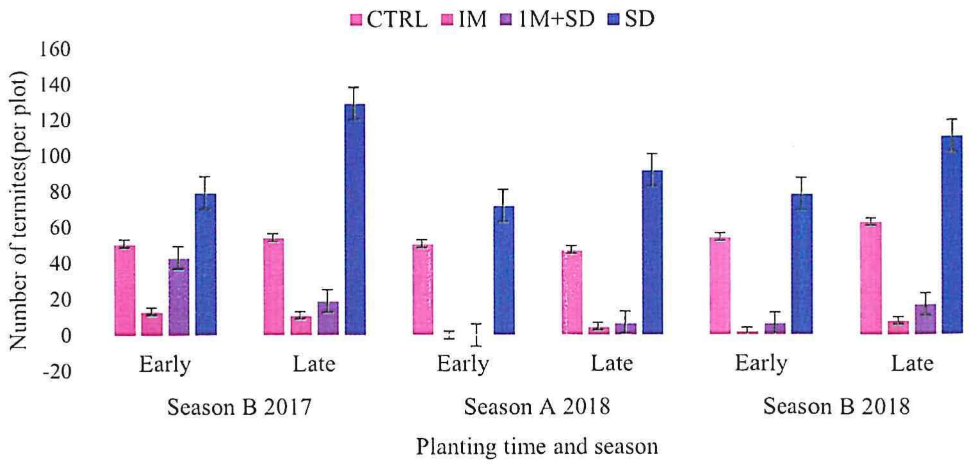


Figure 4 d : Termite populations per plot across seasons and treatments at 11 WAP

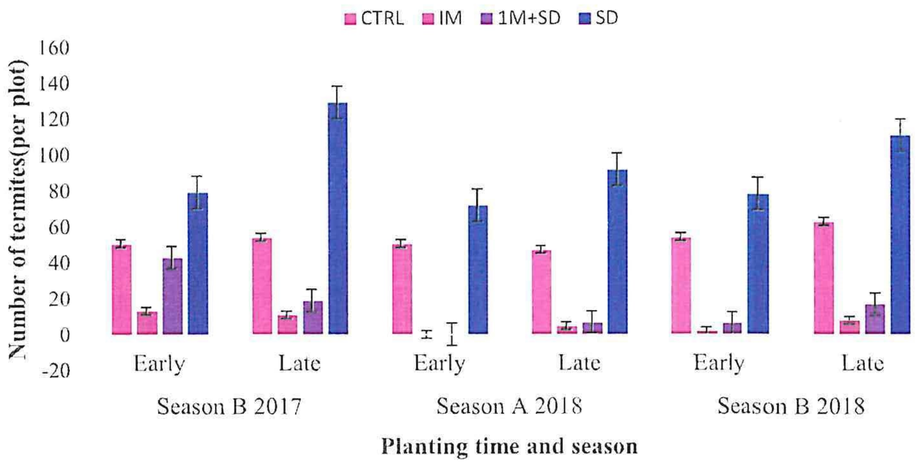


Figure 4c : Termite populations per plot across seasons and treatments at 12 WAP

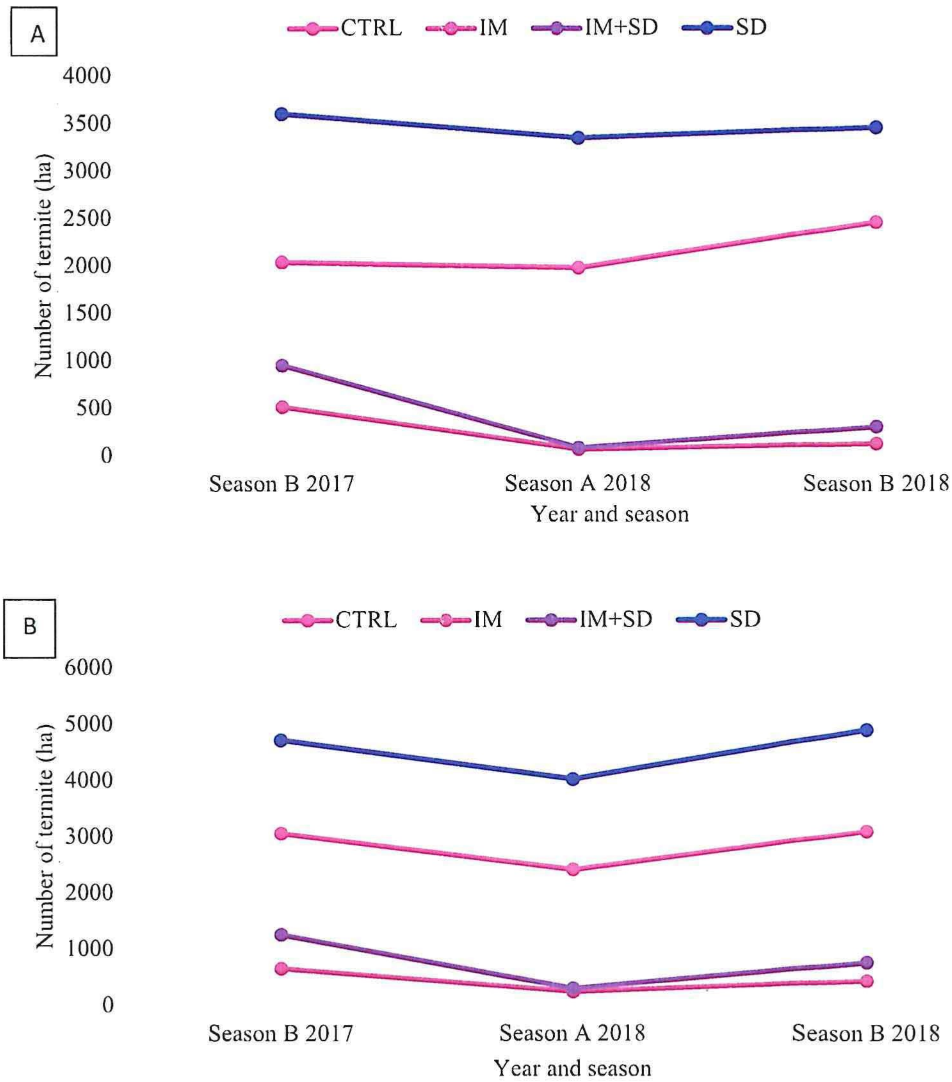


Figure 5 : Overall number of termites per hectare for all treatments A) Early planting, B) Late planting

4.3.2 Number of lodged plant

Season had no significant (P>0.05) effect on the number of lodged plants. Treated sawdust significantly (P<0.05) influenced the number of lodged plants. Planting time didn't significantly (P>0.05) influence number of lodged plants. The interactions of Planting time x Treatment, Season x Treatment, Season x planting time, Season x planting time x sawdust had no significant (P>0.05) effect on the number of lodged plants except Season x planting time from 11 to 12 WAP (Table 8). Generally, the treatment effect on the number of lodged plants was very high (P < 0.001) from 8 WAP to harvest time.

Table 8 : Summary of ANOVA mean squares for number of lodged plants across three seasons (2017B, 2018A and 2018B) under different termite bait treatment regimes

Source of variation	d.f.	5 WAP	6 WAP	7 WAP	8 WAP	9 WAP	10 WAP	11 WAP	12 WAP
Season	2	3.38	23.38	34.76	56.29	52.18	76.26	81.01	44.26
Planting time	1	19.014	4.5	4.2	4.01	21.12	42.01	51.68	37.56
Treatment	3	25.34**	66.1**	122.9**	237.5***	317.16***	503.5***	655***	845***
Season. Planting time	2	26	24	34.85	12.93	30.04	64.6	123**	98.4*
Season. Treatment	6	5.05	7.75	6.89	13.75	17.77	42.36	43.94	32.02
Planting time. Treatment.	3	2.64	8.35	9.27	19.46	32.83	57.46	44.79	58.33
Season. Planting time. Treatment	6	7.79	11.59	12.61	8.88	7.08	10.1	6.07	11.37

WAP Weeks after planting*** Significant at 0.001** Significant at 0.01* Significant at 0.05

Even though the number of lodged plants increased gradually, the overall treatment effect on the number of lodged plants was very high from 8 to 12

WAP. Number of lodged plants at 5-7 is presented in Appendix 3a and b. At 8 WAP, the early planting treatment option in 2017B recorded 5.24 lodged plants/plot in treated sawdust compared to 3.34 in Imidacloprid and 10.67 in the control respectively. Conversely, under late planting, only the control had significantly higher ($P < 0.05$) number of lodged plants (18 lodged plants/plot) compared to treated sawdust (7 lodged plants/plot) and imidacloprid only (7.3 lodged plants/plot). Similarly, in 2018A and 2018B, treated sawdust significantly reduced the number of lodged plants as compared to the control (Figure 6a).

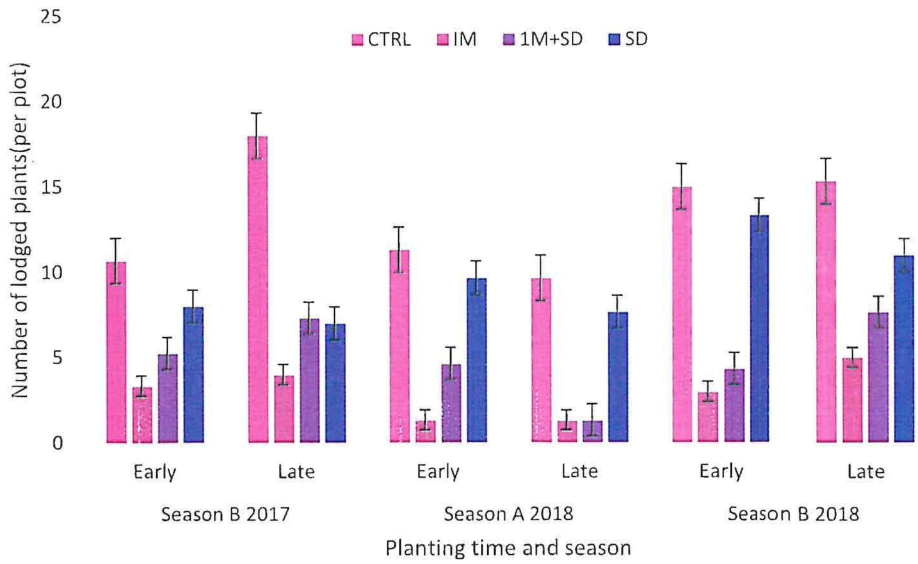


Figure 6a : Number of lodged plant per plot across seasons and treatments at 8 WAP

At 9 WAP, early planting in 2017B recorded 5.33 lodged plants/plot in treated sawdust and only 3.44 in Imidacloprid compared to 12.67 in the control respectively. On the other hand, under late planting, both the sawdust only and the control had significantly higher ($P < 0.05$) number of lodged plants (10 and 22.3 lodged plants/plot, respectively) compared to treated sawdust (9.33 lodged plants/plot) and imidacloprid only (2.47 lodged plants/plot) (Figure 6b).

In season 2018A, 4.32 lodged plants/plot were recorded in treated sawdust and only 2.7 in imidacloprid compared to 13.33 in the control, respectively. On the other hand, under late planting, both the sawdust only and the control had significantly higher ($P < 0.05$) number of lodged plants (10 and 12.0 termites/plot, respectively) compared to treated sawdust (1.33 lodged plants/plot) and imidacloprid only (1.33 lodged plants/plot). Accordingly, in season 2018B, treated sawdust and imidacloprid only had low lodged plant number as compared to control and sawdust alone (Figure 6b).

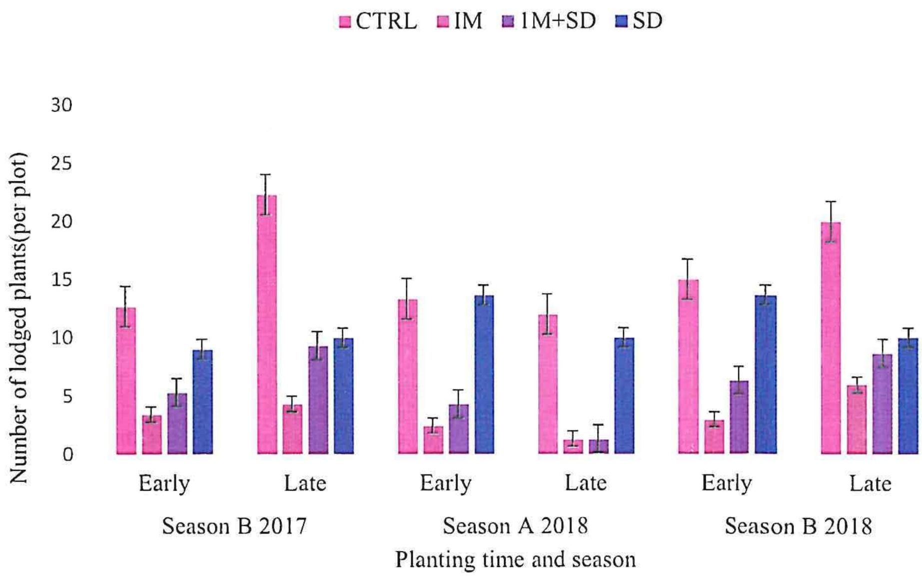


Figure 6b : Number of lodged plants per plot across seasons and treatments at 9 WAP

The peak infestation by termites was in the 10 to 12 WAP. However, treated sawdust and imidacropid only, especially where planting was conducted early, still maintained significantly lower ($P < 0.05$) number of lodged plants as compared to control and sawdust alone (Figure 6 c,d and e). The overall trend of number of lodged plants in all treatments is summarized in figure 7.

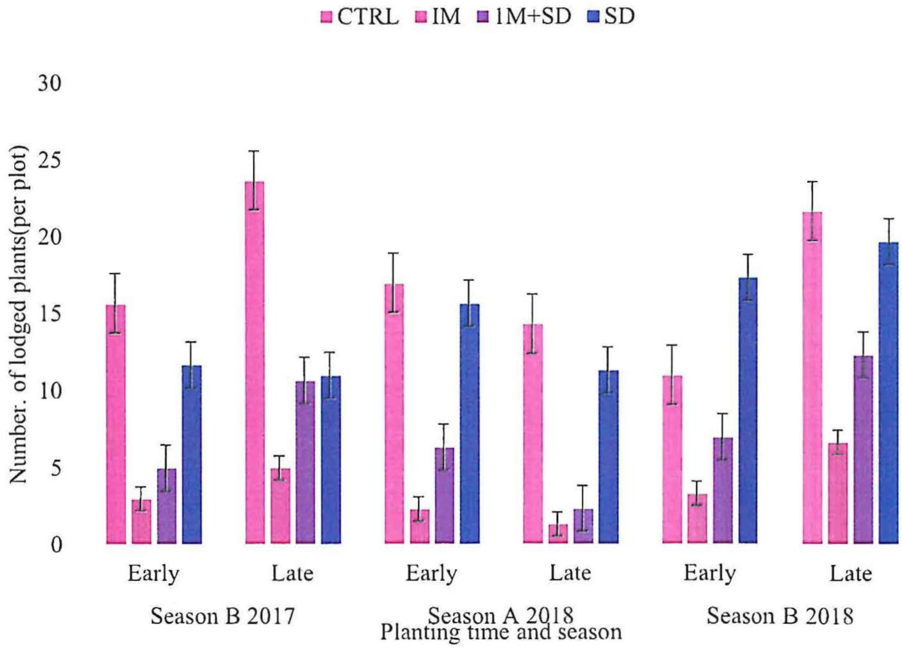


Figure 6c : Number of lodged plants per plot across seasons and treatments at 10 WAP

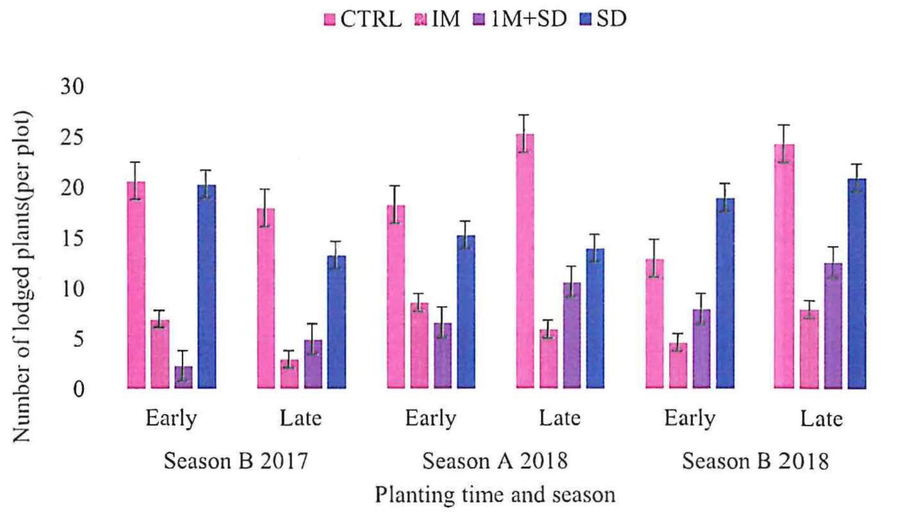


Figure 6d : Number of lodged plants per plot across seasons and treatments at 11 WAP

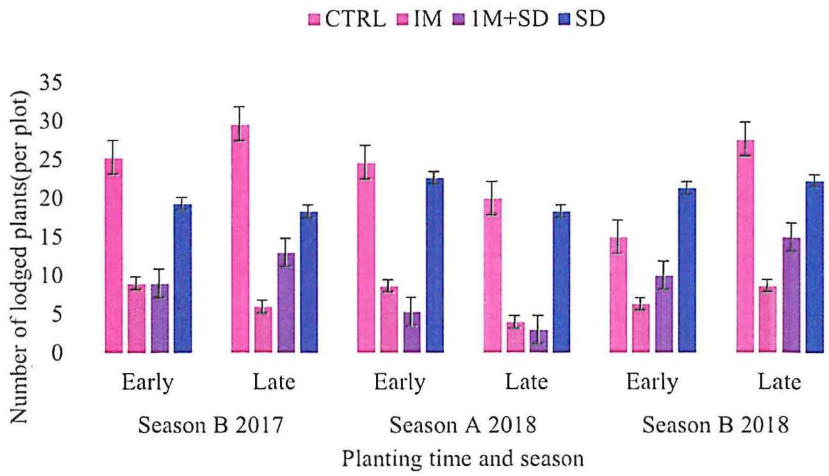
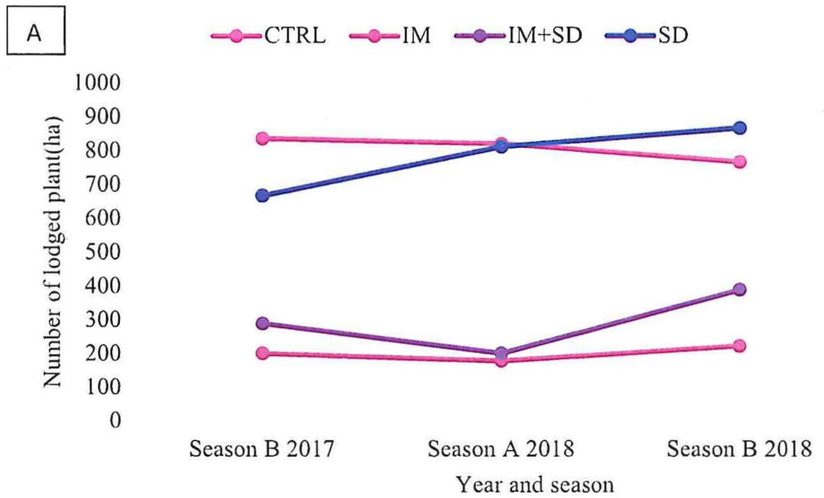


Figure 6 e : Number of lodged plants per plot across seasons and treatments at 12 WAP



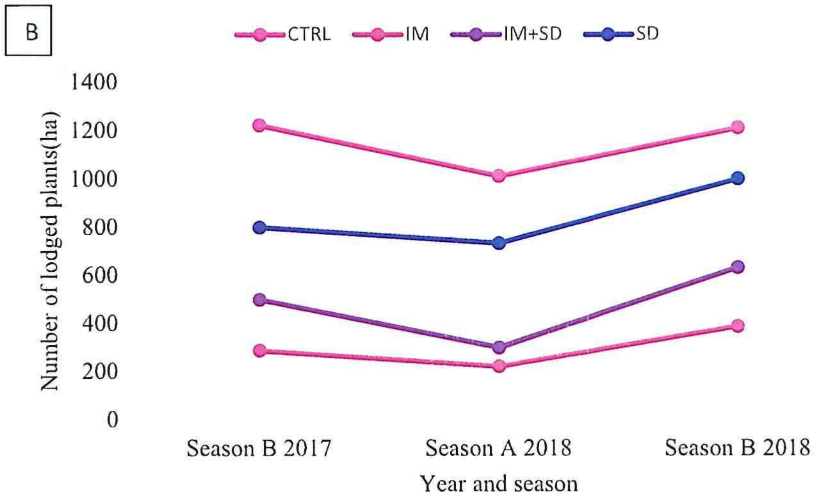


Figure 7 : Overall number of lodged plants per hectare for all treatments A) Early planting, B) Late planting

4.3.3 Damaged cobs and yield of maize

Treated sawdust had significant ($P<0.01$) effects on the number of damaged cobs. Similarly, planting time and planting time .treatments also had significant ($P<0.05$) effects on the number of damaged cobs. The interaction between Season.treatment similarly had significant effects on the number of damaged cobs, but this was not the case for Season.planting time, and Season. Planting time.treatments (Table 9). A significantly lower ($P < 0.05$) number of damaged cobs were recorded in early planting as compared to late planting. Similarly, treated sawdust had a significantly lower number of damaged cobs as compared to the control. In terms of season, low number of damaged cobs was reported in 2018A as compared to 2017B (Figure 8).

In terms of yield, treated sawdust recorded the highest yield compared to untreated sawdust. Similarly, early planting had the highest yield across all season as compared to late planting. Overall, season 2018A had higher yield compared to other seasons (Figure 9).

Table 9 : Summary of ANOVA mean squares for number of maize damaged cobs across three seasons (2017B, 2018A and 2018B) under different termite bait treatment regimes

Source of variation	df	Number of damaged cobs	Yield (Kg/ha)
Season	2	520.32*	1890.32**
Planting time	1	499.81***	1640.24**
Treatment	3	193.2***	703.4NS
Season. Planting time	2	46.81NS	608.45NS
Season. Treatment	6	22.56NS	503.90NS
Planting time. Treatment.	3	60.11*	489.45NS
Season. Planting time. Treatment	6	9.77NS	401.6NS

*** Significant at 0.001** Significant at 0.01* Significant at 0.05

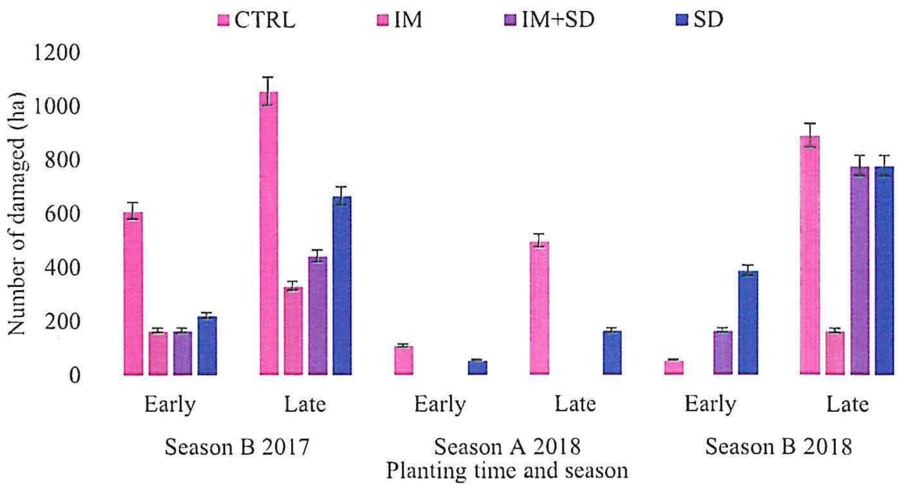


Figure 8 : Number of maize damaged cobs across seasons and treatments at 12 WAP

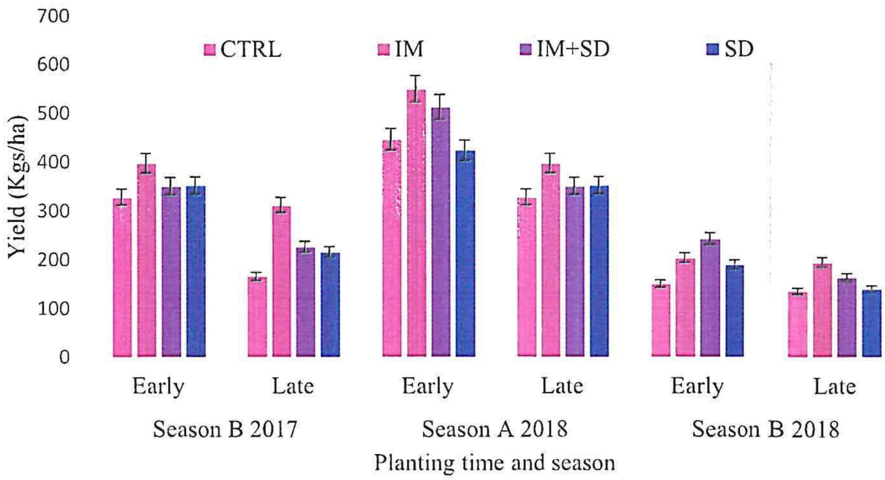


Figure 9 : Maize yield across seasons and treatments at 12 WAP

4.4 Discussion

The study was aimed at understanding the effects of treated sawdust and planting time on termite populations in maize. The treated sawdust reduced termite number and subsequently the number of lodged plants and damaged cobs as evidenced by the significant differences in these variables in all the seasons. The high termite population in the control plots (untreated sawdust) was due to the fact that termites are cellulose digesting organisms therefore attracted to sawdust and eventually the maize plants. Mali *et al.* (2019) reported that termite organic matter preference is illustrated by their occurrence within biomass litter. Therefore, the addition of chemicals enables the sawdust to control termites as a bait. These results agree with Alisop *eta l.* (2017) who reported that bait efficacy can be improved by combining with other methods like chemicals. Moreover, baiting also enhances efficacy of chemicals in controlling termites (Thorne and Forschler, 2000). The wide spread low termite population in the treated sawdust also resulted from the bait spread by the foraging worker termites to other members of the colony within the units where no treated sawdust was applied. Bishwajeet et al. (2018) also emphasized that chemical control of termites decreases depending on vertical and horizontal distance from the bait point; which this study has bridged. In a nutshell, the significant reduction of termites' population and lodged plants under treated sawdust confirms that treated sawdust is a successful bait for elimination of termites from maize.

Seasonal differences in the number of termites, lodged plants and damaged cobs could be attributed to differences in the climatic conditions experienced. Generally, seasons 2017B and 2018B had higher termite infestation as compared to season 2018A. The reason for this could have been because seasons 2017B and 2018B were both characterized by early onset of drought (see rainfall and temperature data, appendix 4) which encourages attack by termites (Mugerwa, 2014). The increase in the proportion of dead vegetation due to drought, means increase in cellulose a recognized desirable food for termites (Veneraldo et al., 2016). Yêyinou Lokoet al. (2017) also reported that variation in the attack and population of termites depends on factors like climate, soil conditions, vegetation cover and management approaches. Globally, recognized invasive termite specie number has increased due to variation in geographic conditions like temperatures, drought patterns, vegetation type and cropping patterns. Overall, increased persistence and spread of invasive termite specie is favored by environmental degradation and climate change (Buczkowski and Bertelsmeier, 2016).

The non-significant interaction effects between planting time and sawdust treatment is a clear indicator that use of treated sawdust is effective on termites regardless of the time of planting. However, it is worth noting that the late planted maize trials had significantly higher termite populations than the early planted trials. It is therefore important to combine good agronomic practices, other IPM strategies with the treated wood sawdust in the control of termites in maize as alluded to by several authors such as Legesse*et al.* (2013).

In terms of damage progress with time, the population of termites and lodging of maize plants increased with time especially from 9-12 WAP. This was because maize plants were maturing hence increase in dry matter for termite consumption and as well maize plants were becoming weak since the prop roots were being consumed by the termites. This concurs with the earlier report by Wood *et al.* (1980) that little damage occurs from termites before nine weeks after emergence but increases from 10 weeks onwards, therefore, delayed harvesting increases lodging of plants. Ahmad *et al.* (2019) indicated that survival ability of termites is higher in places where there is free wooden material. Therefore, reduction of damage at this stage would require mechanisms that are incorporated with the crop/ecosystem which this study tried to achieve by use of treated sawdust.

Generally, treated sawdust had significantly lower termite populations and lodged plants especially in comparison to sawdust only and control (no treatment). Even where treated sawdust had almost similar termite populations just like the imidacloprid only treated plots, treated sawdust was only applied once in the season therefore more cost-effective and environmentally friendlier. This implies that the use of treated sawdust could present a better option because it presents an opportunity of reducing frequency of chemical applications eliminating the several concerns against overuse of chemicals. This corroborates with Paul *et al.* (2018) that sustainable termite control using chemicals requires reduction of concentration, reduction of application intervals or incorporation with other methods including baiting. Apart from reducing the termite effect on maize, the use of treated sawdust could also improve soil fertility in the long run depending on the amount used. Sawdust being an organic material, if appropriate quantity is used improves soil fertility.Legesse*et al.* (2013) also emphasized the use of termite control methods that have more environmental and economic benefits including reinforcing soil fertility and affordability to farmers. In fact, the results from this study show that using treated sawdust would reduce application time to just one application as compared to the use of imidacloprid alone which requires a minimum of three applications. This would ensure reduced application of chemical in the soil since the residual effect would be prolonged by the treated sawdust. Earlier, it was reported that effective combination of conventional practices with latest strategies is the best option for termite management (Otieno 2018; Ahmad *et al.,* 2019). Overall, this aligns well with the concept of integrated termite management (ITM) which balances economic and environmental issues.

CHAPTER FIVE: CONCLUSIONS AND RECOMMENDATION

5.1 Conclusions

From objective one, the study showed a perceived high prevalence of termites on maize in eastern Uganda, with districts of Bugiri, Butaleja, Manafwa, Sironko and Mayuge registering 100% incidence.The dominant termite species was *Macrotermes bellcosus.* Some farming practices like late planting and mono-cropping significantly increased the infestation of termites in the field, and limited knowledge by farmers caused high incidences of termites.

For objective two, the controlled experiments showed that treated sawdust and early planting reduce the incidence of termites and the number of damaged cobs. However, the interactions between treated wood sawdust and planting time were not significant implying that use of treated sawdust is effective on termites regardless of the time of planting. Whereas imidacropid only also reduced the termite populations and lodging incidences, it required a minimum of three applications making it expensive to use, environmentally unfriendly and more dangerous to human health. Additionally, regardless of treatment effect, termite infestation was at its peak from 9 to 12 weeks after planting.

As much as treated sawdust reduced termite infestation and plant lodging, it did affect the total yield of maize harvested. However, planting time and season significantly affected the total yield of maize with early planting and 2018A season registering the highest yield respectively.

5.2 Recommendations

The recommendations below are suggested arising from the results of this study:

i. More sensitization is required to increase farmer's awareness on factors that increase termite prevalence and the associated management methods.

ii. Farmers need to plant maize early in the season to avoid high termite infestations and damage.

iii. Imidacloprid treated wood sawdust may be used to control termites irrespective of planting time because less applications are needed compared to the use of imidacloprid alone.

iv. A comprehensive study on cost -benefit analysis is needed to prove the cost-effectiveness of Imidacloprid treated wood sawdust compared to sole chemical use.

v. On field trials from different agro-ecological zones, there is need to validate the use of treated wood sawdust for termite control

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APPENDICES

Appendix 1: Questionnaire for Farmers

TOPIC: SURVEY OF INCIDENCE AND CONTROL OF TERMITES IN EASTERN UGANDA

Dear Respondent,

I am Najjoma Denis Msc student from Kyambogo University. As part of the requirements for the course, am conducting research on the above topic. You have been voluntary selected to participate in this study. The information you provide will be kept with utmost confidentiality and will not be used to your disadvantage. Thanks in advance.

Interviewer: ____________________ Date: ______________________

A. GENERAL INFORMATION

District: ______________________ Sub county: ....

Parish: ____________________ Village: ....

Name of Farmer/respondent: ___________________ Tel. _________________

Sex: □Male □Female

B. CROP PRODUCTION PROFILE

1. Which farming practice do you mainly use for maize?

□Mono cropping □Mixed cropping

2. Rank in order of importance of crops grown and attacked by termites this season

Crop	Seed source (see options)	Variety planted	Stage of termite attack	Acreage planted
1)				
2)				
3)				
4)				
5)				

Options for seed sources: 1. Home saved seed 2. Agro-input shop 3. Neighbor/friends

4. Extension agents or NGOs operating in Uganda 5. Extension agent from Kenya or other neighboring country 6. Middlemen/Business men 7. Other (specify)

3). What are the major maize production constraints you observed this season?

□ Insect pests □ Diseases □Low soil fertility □Drought □Floods □Other (specify)

4a). Fill in the Table below in regard to termites attack for this season:

Maize variety	Source of seed (check options 1-7)	Planting date	Symptoms observed due to termites	Maize growth stage when termites attacked

Options for seed sources: 1. Home saved seed 2. Agro-input shop 3. Neighbor/friends 4. Extension agents or NGOs operating in Uganda 5. Extension agent from Kenya or other neighboring country 6. Middlemen/Business men 7. Other (specify)

6a). Information on yield loss due to termites

Area of maize portion selected	Total no. of plants planted	Total number of plants lodged due to termites	Percentage lodging

b) What mitigation measure did you use to try and counteract the effect of termites:

Spraying with chemicals (specify)

None

Cultural methods (specify)

Manual/mechanical methods (specify)

c) If you used chemicals to spray against termites, what was the application rate of the chemical?

d) How many times did you spray with that particular chemical

i) Once ii) Twice iii) thrice iv) Four times v) five times vi) More than five times

e) Did the chemical work i) Excellently ii) Good iii) Fair iv) It did not work at all.

f) Are there chemicals you have ever used against the termites but they did not control the pest as anticipated? Name them:

1. 2. 3.

g). How much maize yield per acre (e.g number of bags of dry threshed maize) do you get when you apply a mitigation measure (as mentioned above) against termites?

i). Have you got any information on termites, their effects and mitigation measures?

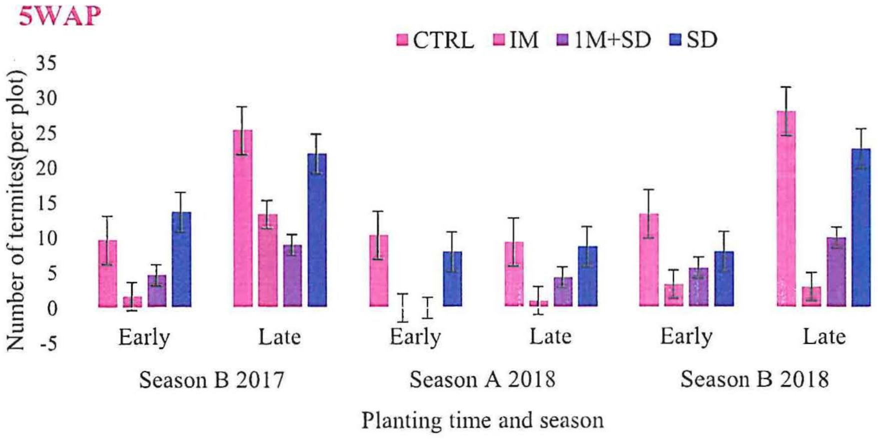
□ Yes □ No

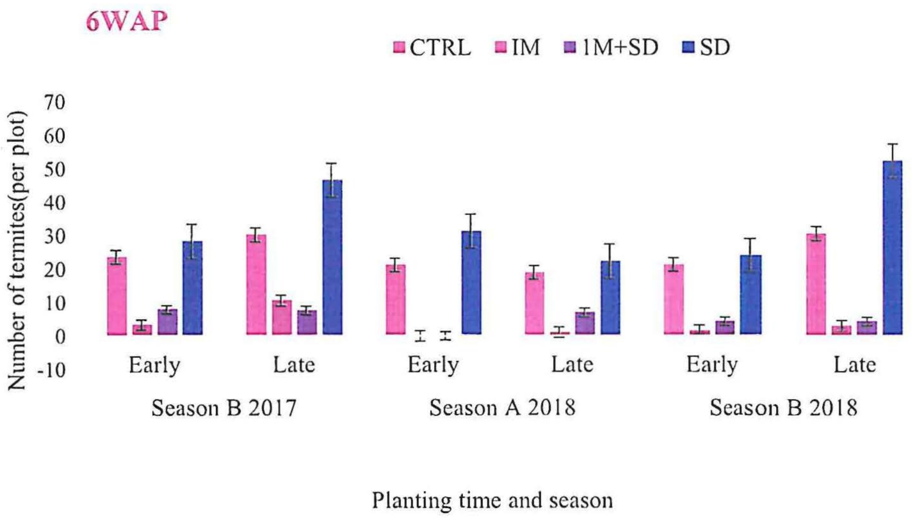
j) If yes, what was the source of the information?

1. Media (Radio, TV or Newspapers)

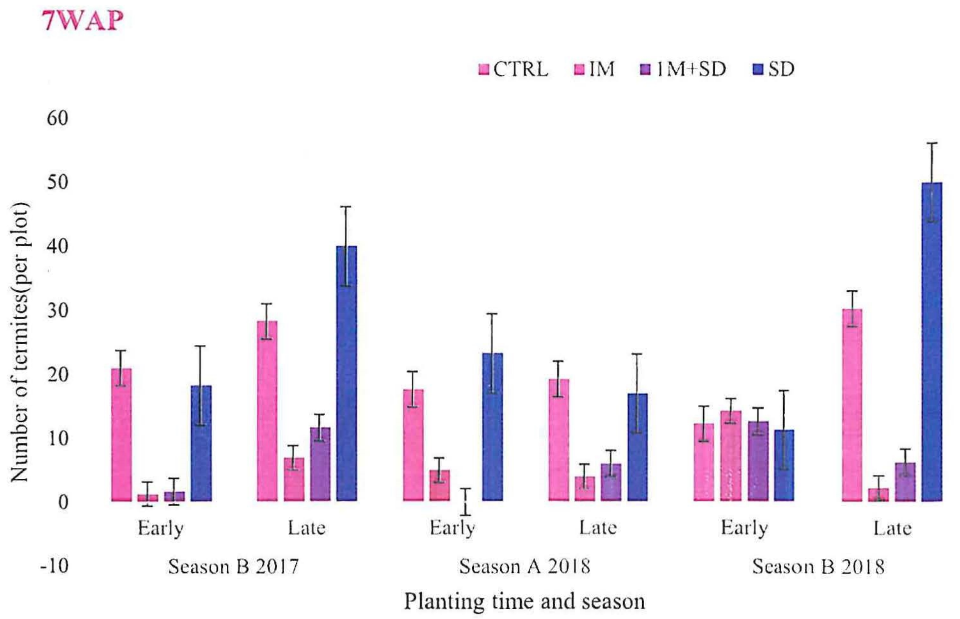
2. Neighbour/friends 3. Extension agent (e.g NAADs, OWC or NGO) 4. Other (specify)

Appendix 2a: Number of termites across per plot treatments and seasons at 5 and 6WAP

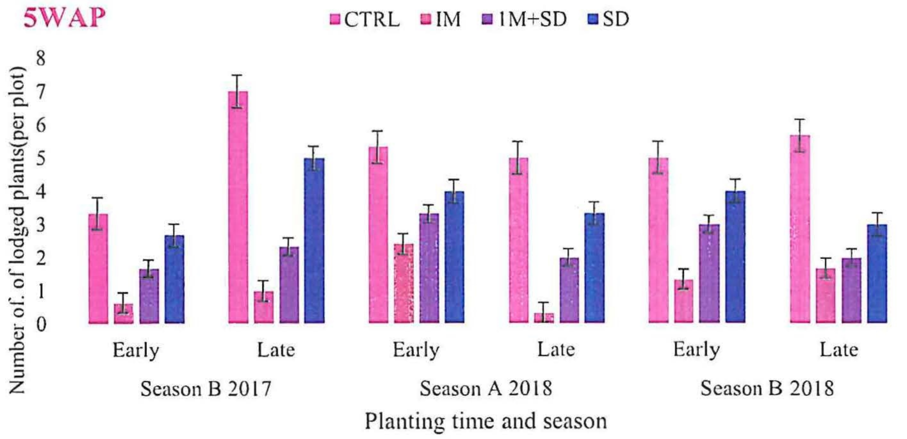


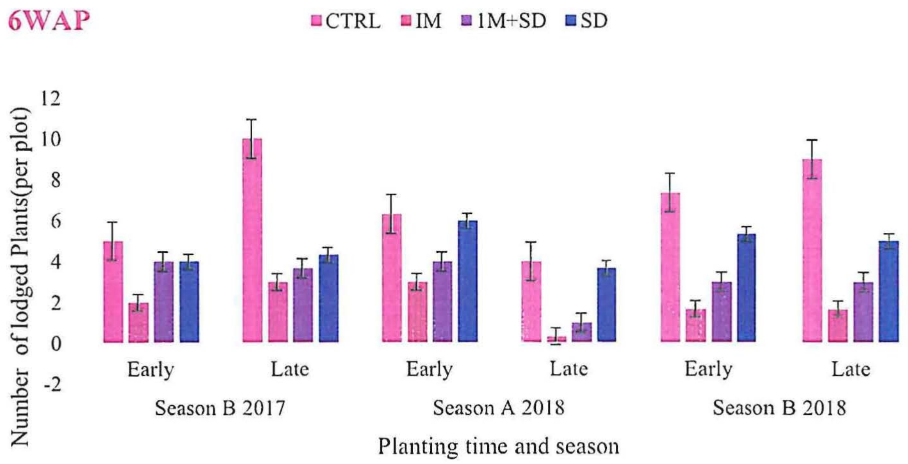


Appendix 2b Number of termites across per plot treatments and seasons at 5 and 6WAP

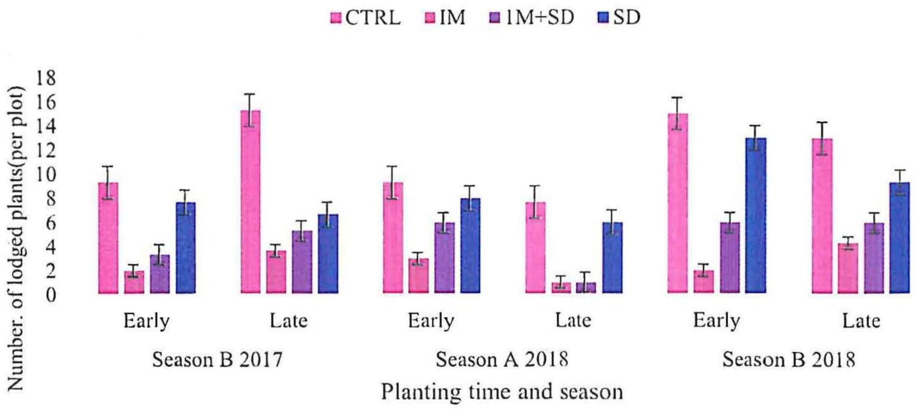


Appendix 3a: Lodged plants across per plot treatments and seasons at 5 and 6 WAP





Appendix 3b: Lodged plants across treatments and seasons at 7WAP



Appendix 4: Climate data at Ikulwe Research institute from 2017 to 2018