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Research Article

Pesticide Treated Sawdust and Early Planting Salvage Maize Yield Through Reduction of Termite Infestation and Damage

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Termites (Isoptera: Termitidae) infestation is a key constraint to maize production in Uganda. This study was conducted to determine the effect of integrating planting time and imidacloprid-treated wood sawdust in the control of termites. Three experiments were established at Ikulwe Satellite Station in Mayuge in 2017B, 2018A, and 2018B in a randomized complete block design (RCBD) with three replications. Planting time was at the onset of rains and 2 weeks later. The treatment regime comprised (i) sawdust treated with imidacloprid (IM + SD), (ii) sawdust only (SD), (iii) imidacloprid only (IM), and (iv) the control (no treatment). Data were collected on the number of lodged plants, termite numbers, and grain yield, among other parameters and subsequently analyzed. The results revealed that the use of imidacloprid-treated wood sawdust and early planting significantly reduces termite infestation. This was justified by the significantly lower ($p < 0.05$) average population of termites (442 termites ha^{-1}), the negligible number of lodged plants (293 plants ha^{-1}), and just a handful of damaged cobs (167 cobs ha^{-1}) compared to 3455 termites ha^{-1}, 760 lodged plants ha^{-1}, and 782 damaged cobs ha^{-1}, respectively, in the untreated sawdust control. Grain yield of 5.0 t ha^{-1} was realized under imidacloprid-treated sawdust in early planting, compared to only 3.5 t ha^{-1} under imidacloprid treated sawdust but in late planting. Therefore, the use of imidacloprid-treated sawdust as a bait to control termites damage and early planting of maize proved effective in reducing termite prevalence, infestation, and consequently optimized maize yield.

Keywords: bait; imidacloprid; maize; planting time; sawdust; termites

1. Introduction

Maize (*Zea mays* L.) is a key food security crop and one of the most widely cultivated crops in Uganda and Africa at large [1]. It is estimated that about 92% of Ugandan households consume maize as their major food, with a per capita consumption of about 22 kg per year [2]. However, termites are very much devastating to the maize crop [3, 4] to the extent of causing a yield loss of up to 100% [5]. The damage is particularly noticeable during dry seasons or in areas with erratic rainfall [6]. This implies that with increased drought, farmers are bound to continue experiencing yield losses due to termites damaging their crops [7–9]. Though chemicals have proved effective in the control of termites, they are quite expensive to use, especially if the farmer is relying solely on them [10, 11]. Chemicals, if not carefully used, will kill the termites and a lot of other soil fauna, yet these provide useful ecosystem services [12].

Therefore, integration of different control measures may prove to be the way forward. For example, according to Okwakol and Sekamate [13], adding organic material to the soil and mounting physical barriers can improve effectiveness for the control of termites. If the plant materials are treated with recommended chemical insecticides, the efficiency improves. Wood sawdust is quite a common material in carpenters' workshops. This material is much liked by termites; therefore, it should be effective in acting as a bait in the control of termites. Habibpour et al. [14] used wood sawdust bait to increase the efficacy of entomopathogenic fungi (*Metarhizium anisopliae*) against the termite species *Microcerotermes diversus* in Iran. According to Bernklau et al. [15], termites enjoy foraging in chambers containing carbon dioxide (CO_2) generating formulations than those without CO_2. Therefore, carbon-containing materials, if used as a baiting system, could be effective in allowing earlier exposure of termites to an insecticide. The aim of this study was, therefore, to determine the effectiveness of imidacloprid-treated sawdust in controlling termites in maize across different planting times.

2. Materials and Methods

2.1. Study Site. The study was conducted in Uganda at Ikulwe Satellite Station, Mayuge District, in the years 2017 and 2018. In total, three experiments were conducted, designated as 2017B, 2018A, and 2018B. Ikulwe is situated 2 km south of Mayuge town and 42 km from Jinja town at coordinates 0.4399°N, 334781°E. The rainfall was on average 273, 521, and 317 mm in 2017B, 2018A, and 2018B, respectively, during the study period. On the other hand, temperatures were 27.7, 23.8 and 28.7°C in 2017B, 2018A and 2018B, respectively. The average temperature at the station is 23.1°C and the annual precipitation is about 237 mm with 292.1 rainy days [16].

2.2. Experimental Design and Treatment Structure. The experiments were laid out in a randomized complete block design (RCBD) with three replications. Planting time was at two levels, that is, at the onset of rains and 2 weeks into the rainfall season, as described by Rima and Shukila [6]. The treatment regime was at four levels (sawdust only, sawdust + imidacloprid, imidacloprid only, and a control characterized by no sawdust and no chemical).

Prior to planting, primary and secondary tillage were conducted at an interval of 3 weeks using a tractor. In season 2017B, the first planting was conducted on September 11, 2017, just at the beginning of the rainy season, and the second planting on September 25, 2017. Accordingly, in season 2018A and 2018B, the first planting was conducted on March 20, 2018, and September 3, 2018, just at the beginning of the rainy season, and the second planting on April 4, 2018, and September 18, 2018, respectively. Maize variety Longe 10H was used throughout the experiments, planted at an interrow spacing of 75 cm and an interplant spacing of 25 cm, at a seed rate of two seeds per hill, which were later thinned to one. This translates to a population of 53,333 plants ha^{-1}. Each experimental unit (net plot comprising a single treatment) was 5 m × 6 m, hence, the total treatment area of 360 m^2. However, the experimental units were separated by a distance of 1 m within a replicate and 2 m between replicates. Thus, the experiments were conducted in an area of 506 m^2. The diammonium phosphate (DAP) and urea fertilizers were applied at planting and at 4 weeks after planting (WAP), respectively, at a rate of 125 kg ha^{-1}. Eastern Uganda, particularly Mayuge District, is a termite hotspot [17], 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 termites were evident in the field (as observed from damaged or lodged maize plants, sight of live termites on soil surface (0–20 cm) or presence of mud tubes), the treatments were applied. Remarkably, the infestations were observed just before flower initiation (booting stage) in all the experiments, similar to observations by Riekert and Van den Berg [18].

Imidacloprid-treated sawdust and untreated sawdust were applied around the plants (ring application) at a rate of 138 kg ha^{-1} (2.5 kg per plot, and considering only the six plots, which required sawdust in the entire experiment). Sawdust treatment was done by mixing sawdust with a solution of water and imidacloprid in a bucket. This implies that one hectare of maize field required 138 kg of sawdust soaked in 500 mL of imidacloprid and 250 L of water. Positive control (Imidacloprid only) was applied using a knapsack sprayer following the recommended rate of 500 mL ha^{-1} (2 mL/L of water) [18], and negative control consisted of maize grown without sawdust and imidacloprid. It is worth noting that the amount of chemical applied per ha and the dilution factor are subject to change in case a farmer uses a different ant-killer with a different chemical concentration, but the amount of sawdust (138 kg ha^{-1}) may remain constant.

2.3. Data Collection and Analysis. The quadrat method was used to determine the infestation level of termites following the procedures as described by Ana et al. [19]. The quadrat used was made from ordinary wood and had dimensions of 1 m × 1 m. Data collection on termites infestation and their effects commenced at 5 WAP and continued at intervals of 1 week for 12 weeks. Samplings for termites were conducted three times per plot, at an interval of 1 week. The soldier termites and workers found in each inspection point inside the quadrats, and within 0–20 cm below the ground, were manually collected with entomological forceps. The soldier termites were hand-sorted according to different castes and kept in glass vials containing 70% alcohol, then taken to the laboratory for identification. The collected termites were examined using a real-time imaging dissecting microscope at the Faculty of Agriculture Laboratory, Kyambogo University in Uganda. Identification of termites was based on key body features as described by Ackerman et al. [20], Anantharaju et al. [21], and Caleb et al. [22].

Data were also collected on the numbers of lodged plants due to termites attack, and the number of plants with termite cob damage following the procedure described by Riekert and Van den Berg [18]. The cob damage count was conducted on all cobs, whether fallen or not, provided the cob or grains had evidence of termite damage, which is majorly "eaten and soiled cob or grains with live termite activity most of the time, if no control effort undertaken." Grain yield of each plot was recorded at harvest and then adjusted to 12.5% moisture content following CIMMYT [23] as follows:

TABLE 1: 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.	8 WAP	9 WAP	10 WAP	11 WAP	12 WAP
Season	2	321.1*	592*	1124**	370.3*	278.8
Planting time	1	567**	1431**	2926**	2037.3**	2037**
TreatReg	3	4066**	7085**	12706**	13975.4**	22311**
Season × Planting time	2	196.35	218.3	909.0**	410.1*	257.2
Season × TreatReg	6	35.07	15.8	92.82	78.9	43.8
Planting time × TreatReg	3	100.6	160.3	396*	261.9	397.8
Season × Planting time × TreatReg	6	155	65.3	140.04	60.2	150.6

Abbreviations: TreatReg, treatment regime; WAP, weeks after planting.
*Significant at 0.05.
**Significant at 0.01.
***Significant at 0.001.

$$\mathrm{GY}(\mathrm{t\,ha^{-1}}) = \frac{\mathrm{FW\_P} \times 0.8 \times (100 - \mathrm{MC}) \times 10,000}{(100 - 12.5) \times \text{plot area} \times 1000},$$

where FW_Pis the field weight (kg) of maize per plot; MC is the moisture content of grain for each plot; 0.8 is the shelling coefficient.

All the data collected were tested for normality using *Q–Q* plots in Genstat statistical software (15$^{\text{th}}$ edition) and were found to be near normal distribution for windows. Therefore, no transformation was conducted. The data were then subjected to analysis of variance (ANOVA) as RCBD. Significant differences between the means were separated using least significant difference (LSD) test at 5% probability level.

3. Results

3.1. Termites Species and Number. Key termite species observed in the experimental area and in order of abundance were *Macrotermes bellicosus*, *Macrotermes subhyalinus*, and *Odontotermes* spp. However, other than the termites species identification, counting was conducted without species disaggregation, thus, only aggregated termite count data is available. Results from the ANOVA for the number of termites as affected by planting time and treatment regime in 2017B, 2018A, and 2018B seasons are presented in Table 1. A significant difference ($p < 0.05$) in the number of termites was observed as a result of the different planting seasons. Similarly, treatment regime and planting time significantly affected ($p < 0.01$) the number of termites. The interaction between season × planting time, season × treatment regime, planting time × treatment regime, and season × planting time × treatment regime was not significant except at 10 and 11 WAP for season × planting time, and at 10 WAP for planting time × treatment regime.

Generally, the number of termites was significantly higher ($p < 0.05$) in 2018B and 2017B seasons than in 2018A season (Figure 1a). However, at 8 WAP, the 2017B early planted trial registered a significantly lower ($p < 0.05$) number of termites under imidacloprid-treated sawdust (222 termites ha^{-1}) and imidacloprid only (56 termites ha^{-1}) compared to sawdust only (1667 termites ha^{-1}) and the control (1389 termites ha^{-1}). Similarly, under late planting in 2017 B, both the sawdust only and the control had significantly higher ($p < 0.05$) number of termites (3167 and 2444 termites ha^{-1}, respectively), compared to imidacloprid-treated sawdust (556 termites ha^{-1}) and imidacloprid only (167 termites ha^{-1}). Notably, the number of termites observed was generally much higher under late planting than under early planting, regardless of the season. In the 2018A season, a significantly lower ($p < 0.05$) number of termites (111 and 10 termites ha^{-1}) were observed in imidacloprid-treated sawdust and imidacloprid only, planting, compared to sawdust only the control (144 termites ha^{-1}). Under late planting, a total of 222 and 111 termites ha^{-1} were registered in imidacloprid-treated sawdust and imidacloprid only, respectively, compared to 2111 and 1667 termites in sawdust and control, respectively. Similarly, in the 2018B season, a significantly lower ($p < 0.05$) number of termites were recorded in imidacloprid-treated sawdust compared to the control and sawdust only.

At 9 WAP, the number of termites was significantly higher ($p < 0.05$) in 2017B season than in 2018A season (Figure 1b). However, the 2017B early planted trial registered significantly more ($p < 0.05$) termites under sawdust only (2944 termites ha^{-1}) and the control (1389 termites ha^{-1}) compared to imidacloprid only (389 termites ha^{-1}) and imidacloprid-treated sawdust (556 termites ha^{-1}). Under late planting, both the sawdust only and the control had significantly higher ($p < 0.05$) number of termites (4556 and 3222 termites ha^{-1}, respectively), compared to imidacloprid-treated sawdust (1167 termites ha^{-1}) and imidacloprid only (1001 termites ha^{-1}). In the 2018A season, a significantly lower ($p < 0.05$) number of termites (49 and 56 termites ha^{-1}) were observed in imidacloprid-treated sawdust and imidacloprid only, respectively, under early planting, compared to sawdust only (2333 termites ha^{-1}) and the control (2056 termites ha^{-1}). Under late planting, a total of 111 and 389 termites ha^{-1} were registered in imidacloprid-treated sawdust and imidacloprid only, respectively, compared to 3389 and 2500 termites ha^{-1} in sawdust and control, respectively. In the 2018B season, a lower number of termites was recorded in imidacloprid-treated sawdust as compared to the control and sawdust only.

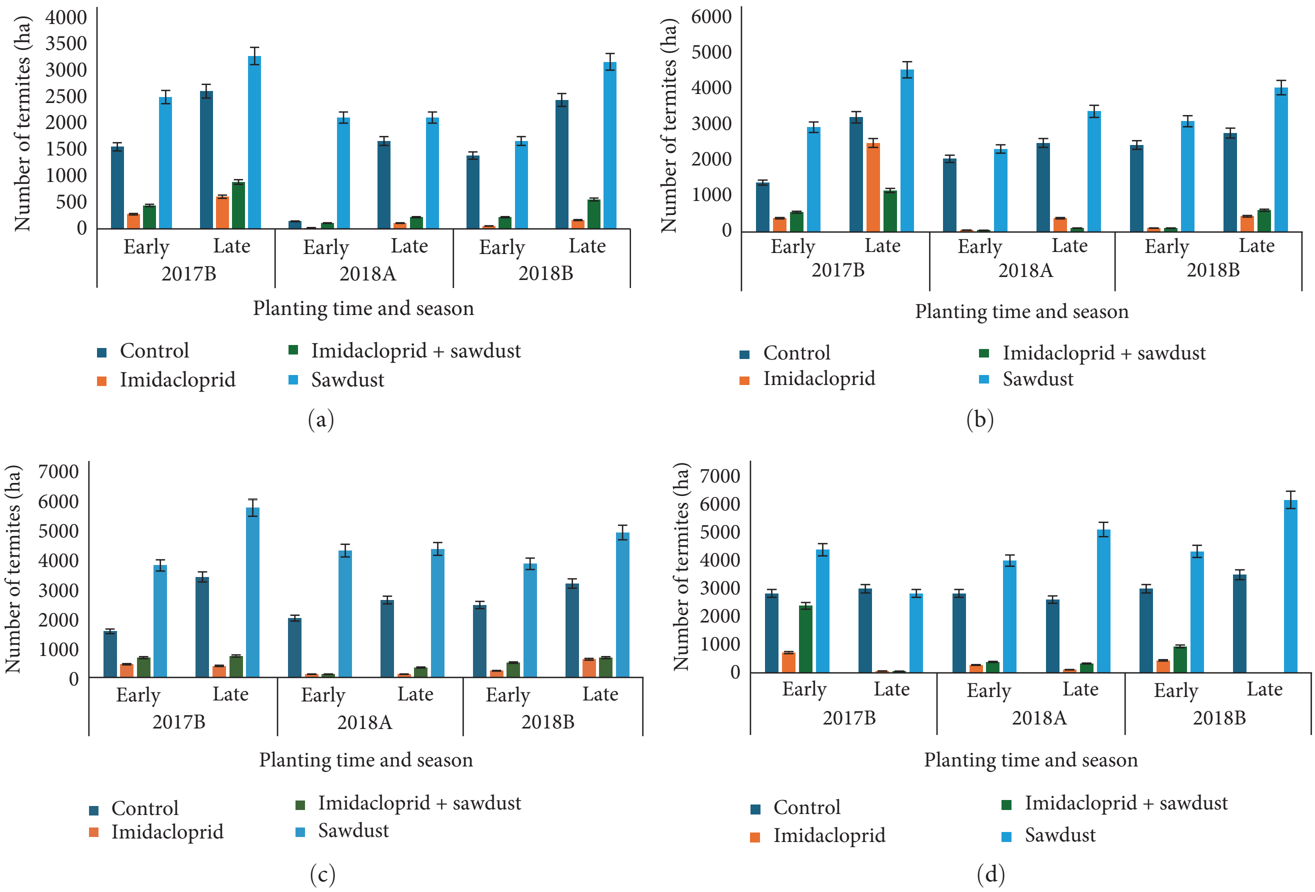

Figure 1: Termite population across seasons and treatments at (a) 8 WAP, (b) 9 WAP, (c) 10 WAP, and (d) 12 WAP. WAP, weeks after planting. Bars represent the confidence interval at 5% probability level.

Meanwhile, at 10 WAP, the number of termites was significantly higher ($p < 0.05$) in the 2017B season than in the 2018A season (Figure 1c). The 2017B early planted trial registered significantly more ($p < 0.05$) termites under sawdust only (3778 termites ha^{-1}) and the control (1556 termites ha^{-1}) compared to imidacloprid only (444 termites ha^{-1}) and imidacloprid-treated sawdust (667 termites ha^{-1}). Under late planting, both the sawdust only and the control had significantly higher ($p < 0.05$) number of termites (5722 and 3389 termites ha^{-1}, respectively), compared to imidacloprid-treated sawdust (722 termites ha^{-1}) and imidacloprid only (389 termites ha^{-1}). In 2018A season, a significantly lower ($p < 0.05$) number of termites (111 termites ha^{-1}) was observed in imidacloprid-treated sawdust and imidacloprid only, respectively, under early planting, compared to sawdust only (4278 termites ha^{-1}) and the control (2000 termites ha^{-1}). Under late planting, a total of 333 and 111 termites ha^{-1} were registered in imidacloprid-treated sawdust and imidacloprid only, respectively, compared to 4333 and 2611 termites ha^{-1} in sawdust and control, respectively. In the 2018B season, a significantly lower ($p < 0.05$) number of termites were recorded in imidacloprid-treated sawdust as compared to the control and sawdust only.

At 11 WAP, the number of termites followed a similar trend as at 10 WAP, though with increased population (data not shown). Likewise, at 12 WAP, though the signs of physiological maturity were now evident (Figure 1d).

3.2. Number of Lodged Plants. Seasonal variations had no significant effect on the number of lodged plants. The treatment regime significantly influenced ($p < 0.05$) the number of lodged plants from 8 to 12 WAP. Planting time did not significantly influence the number of lodged plants. All interactions had no significant effect on the number of lodged plants except season × planting time from 11 to 12 WAP (Table 2).

At 8 WAP, the early planting treatment option in 2017B recorded 277 lodged plants ha^{-1} in imidacloprid-treated sawdust compared to 167 in imidacloprid only and 611 in the control, respectively (Figure 2a). Conversely, under late planting, only the control had significantly higher ($p < 0.05$) number of lodged plants (1000 lodged plants ha^{-1}) compared to imidacloprid-treated sawdust (389 lodged plants ha^{-1}) and imidacloprid only (222 lodged plants ha^{-1}). Similarly, in 2018A and 2018B, treated sawdust significantly reduced ($p < 0.05$) the number of lodged plants as compared to the control.

At 9 WAP, early planting in 2017B recorded 278 lodged sawdust and a meager 167 in imidacloprid only compared to 722 lodged plants ha^{-1} in the control (Figure 2b). On the

Table 2: 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.	8 WAP	9 WAP	10 WAP	11 WAP	12 WAP
Season	2	56.29	52.18	76.26	81.01	44.26
Planting time	1	4.01	21.12	42.01	51.68	37.56
TreatReg	3	237.5^{***}	317.16^{***}	503.5^{***}	655^{***}	845^{***}
Season × Planting time	2	12.93	30.04	64.6	123^{**}	98.4^{*}
Season × TreatReg	6	13.75	17.77	42.36	43.94	32.02
Planting time × TreatReg	3	19.46	32.83	57.46	44.79	58.33
Season × Planting time × TreatReg	6	8.88	7.08	10.1	6.07	11.37

Abbreviations: TreatReg, treatment regime; WAP, weeks after planting.
*Significant at 0.05.
**Significant at 0.01.
***Significant at 0.001.

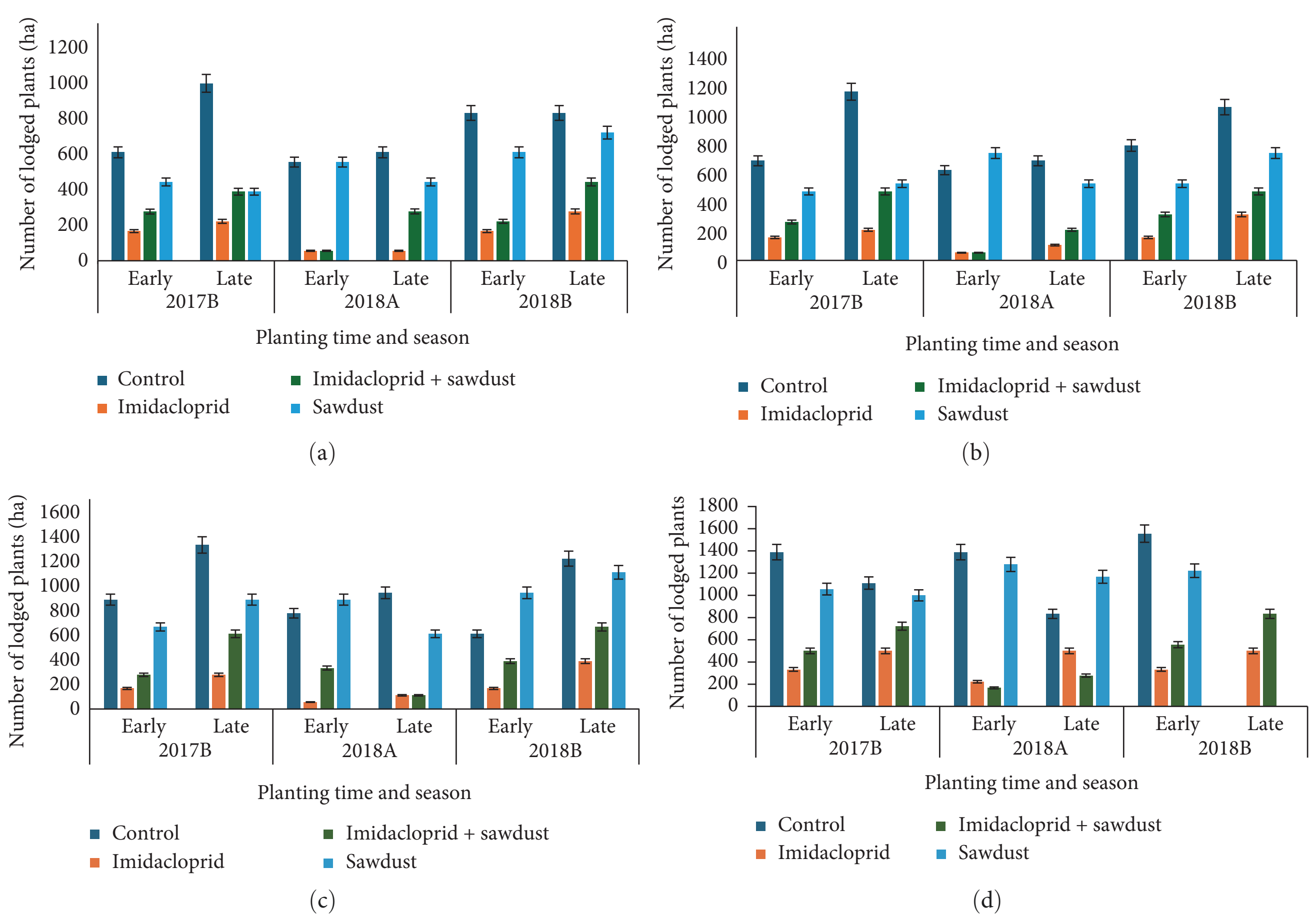

Figure 2: Number of lodged plants across seasons and treatments at (a) 8 WAP, (b) 9 WAP, (c) 10 WAP, and (d) 12 WAP. WAP, weeks after planting. Bars represent the confidence interval at 5% probability level.

other hand, under late planting, both the sawdust only and the control had significantly higher ($p < 0.05$) number of lodged plants (556 and 1222 lodged plants ha^{-1}, respectively), compared to imidacloprid treated sawdust (500 lodged plants ha^{-1}) and imidacloprid only (222 lodged plants ha^{-1}). In season 2018A, 56 lodged plants per hectare were recorded in imidacloprid-treated sawdust and imidacloprid only compared to 654 and 778 in the control and sawdust only, respectively, in early planting. On the other hand, under late planting, the sawdust only had significantly higher ($p < 0.05$) number of lodged plants (556 termites ha^{-1}) compared to imidacloprid-treated sawdust (222 lodged plants ha^{-1}) and imidacloprid only (111 lodged plants ha^{-1}). Accordingly, in season 2018B, imidacloprid-treated sawdust and imidacloprid only had a few lodged plants as compared to the control and sawdust alone. From 10 to 12 WAP (Figures 2c,d), the

Table 3: Summary of ANOVA mean squares for number of maize damaged cobs and grain yield across three seasons (2017B, 2018A, and 2018B) under different termite bait treatment regimes.

Source of variation	d.f.	Number of damaged cobs	Yield (kg ha^{-1})
Season	2	520.32*	1890.32**
Planting time	1	499.81***	1640.24**
TreatReg	3	193.2***	703.4
Season × planting time	2	46.81	608.45
Season × TreatReg	6	22.56	503.90
Planting time × TreatReg	3	60.11*	489.45
Season × planting time × TreatReg	6	9.77	401.6

Abbreviations: TreatReg, treatment regime; WAP, weeks after planting.
*Significant at 0.05.
***Significant at 0.01.
***Significant at 0.001.

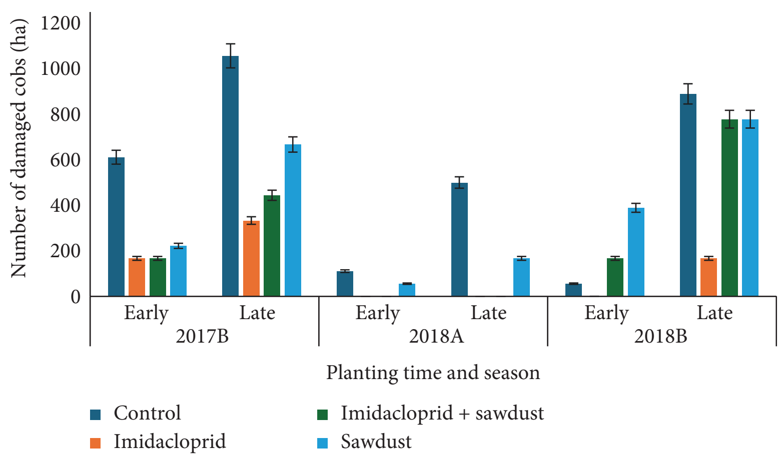

Figure 3: Number of maize damaged cobs across seasons and treatments at 12 WAP.

number of lodged plants followed a similar trend as observed at 8–9 WAP.

3.3. Damaged Cobs and Yield of Maize. The treatment regime had significant effects ($p < 0.01$) on the number of damaged cobs. Similarly, planting time and planting time × treatment regime also had significant effects ($p < 0.05$) on the number of damaged cobs. The interaction between season × treatment regime similarly had significant effects ($p < 0.05$) on the number of damaged cobs, but this was not the case for season × planting time, and season × planting time × treatment regime (Table 3). A significantly lower ($p < 0.05$) number of damaged cobs was recorded in early planting as compared to late planting. Similarly, imidacloprid-treated sawdust had a significantly lower ($p < 0.05$) number of damaged cobs as compared to the control. In terms of season, low number of damaged cobs were reported in 2018A as compared to 2017B (Figure 3). In terms of yield, imidacloprid-treated sawdust recorded the highest grain yield compared to untreated sawdust. Similarly, early planting resulted in the highest grain yield across all seasons as compared to late planting. Overall, under imidacloprid-treated sawdust, season 2018A had the highest grain yield (3.5 and 5.0 t ha^{-1} under late and early planting, respectively), whereas season 2018B had the lowest grain yield (1.6 and 2.4 t ha^{-1} under late and early planting, respectively), at 12 WAP (Figure 4).

4. Discussion

All the termite species (*M. bellicosus*, *M. subhyalinus*, and *Odontotermes* spp) recorded in the study plots are known crop pests in the subfamily Macrotermitinae [14]. This is also indicated in the preprint previously published by Kagoda et al. [24]. The imidacloprid-treated sawdust reduced termite numbers 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. [25] reported that termites' preference for organic matter is depicted by their presence within biomass litter. Therefore, the addition of chemicals enables the sawdust to control termites as a bait. These results agree with Su [26], who reported that bait efficacy can be improved by combining with other methods like chemicals. Moreover, baiting also enhances the efficacy of chemicals in controlling termites [27]. The widespread low termites population in the imidacloprid-treated

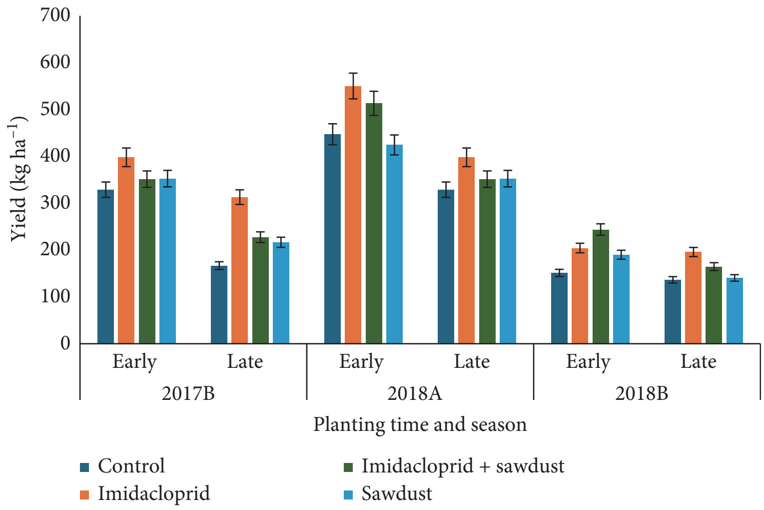

Figure 4: Maize yield across seasons and treatments at 12 WAP.

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. Beal and Carter [28] also emphasized that chemical control of termites decreases depending on horizontal and vertical distance from the bait point, which this study has bridged. In a nutshell, the significant reduction of termites' population and lodged plants under imidacloprid-treated sawdust confirms that the treated sawdust is a successful bait for the elimination of termites from maize. Similar findings were made by Su and Scheffrahn [29].

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 termites 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, which encourages attack on maize plants by termites [30]. The increase in the proportion of dead vegetation due to drought means an increase in cellulose, which is a known preferred food for termites [2, 31]. Nyeko and Olubayo [7] and Ana et al. [19] also reported that variation in the attack and population of termites depends on factors such as climate, soil conditions, vegetation cover, and management approaches. Worldwide, the number of recognized invasive termite species has increased due to variation in geographic conditions such as temperatures, drought patterns, vegetation type, and cropping patterns. In fact, overall, climate change and environmental degradation have increased the opportunities for the spread and persistence of invasive termite species [32].

The nonsignificant interaction effects between planting time and treatment regime are a clear indicator that the use of imidacloprid-treated sawdust is effective in controlling termites regardless of the time of planting. However, it is worth noting that the late-planted maize trials had significantly higher termites population than the early planted trials. It is, therefore, important to combine good agronomic practices and other integrated pest management (IPM) strategies with the wood sawdust bait in the control of termites in maize, as alluded to by several authors such as Legesse et al [33] and Mulatu and Getu [34].

In terms of damage progression, the population of termites and lodging of maize plants increased with time, especially from 9 to 12 WAP. This was because maize plants were maturing, hence, an increase in dry matter for termites consumption, and also 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. [35] that little damage occurs from termites before 9 weeks after emergence but increases from 10 weeks onward. Therefore, delays in harvesting can result in a substantial increase in lodged plants. Ahmad et al. [36] indicated that the 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 the use of imidacloprid-treated sawdust.

Generally, imidacloprid-treated sawdust had significantly lower termites population and lodged plants in comparison to sawdust only and the control (no treatment). Even where treated sawdust had almost similar termites population just like the imidacloprid only treated plots, imidacloprid-treated sawdust was only applied once in the season, therefore, more cost-effective and environmentally friendlier. This implies that the use of imidacloprid-treated sawdust is a far better option because it presents an opportunity of reducing frequency of chemical applications, eliminating the several concerns against over use of chemicals. Similarly, Paul et al. [11] reported that sustainable termites control using chemicals requires reduction of concentration, reduction of application intervals, or incorporation with other methods including baiting. Apart from reducing the termites' effect on maize, sawdust being an organic material, if appropriate quantity is used, can improve the fertility of the soil. Legesse et al. [33] 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 imidacloprid-treated sawdust would reduce application time to just one application as compared to the use of imidacloprid alone, which requires a minimum of six applications, thus, from 6 to 12 WAP [18]. This would ensure reduced application of chemicals in the soil since the residual effect would be prolonged by the imidacloprid-treated sawdust. Earlier, a report showed that the application of an effective combination of traditional practices with recently developed approaches like chemicals is the best option for termite management [36], especially where there is higher diversity of termites [37, 38] since higher diversity causes high crop damage. Overall, this aligns well with the concept of integrated termite management (ITM), which is a sustainable program aiming not to get rid of the termite population but to keep it away or to reduce its economic damage to crops, since termites have been reported to feed less from treated baits [23]. From the study, the interactions between imidacloprid-treated wood sawdust and planting time were not significant implying that the use of imidacloprid-treated sawdust is effective on termites regardless of the time of planting. Whereas "imidacloprid 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. In addition, regardless of treatment effect, termites infestation was at its peak from 9 to 12 WAP. The study further reveals that imidacloprid-treated wood sawdust was able to control termites irrespective of planting time. However, integration with early planting of maize increases grain yield, making their combined application promising. However, the fact that only one chemical was tested with sawdust bait, additional studies with several pesticides are necessary to prevent the development of insecticide resistance. This will make practical pesticide rotation with sawdust bait integrated with other strategies effective long-term termite management.

5. Conclusion

This study was conducted to determine the effect of integrating planting time and imidacloprid-treated wood sawdust in the control of termites. The use of imidacloprid-treated wood sawdust and early planting significantly reduced termites infestation, justified by the significantly lower population of termites, low number of lodged plants, and damaged cobs. A grain yield difference of 2.5 t ha^{-1} was observed under imidacloprid-treated sawdust and early planting, compared to imidacloprid-treated sawdust under late planting. Therefore, use of imidacloprid-treated sawdust as bait to control termites damage and early planting of maize proved effective in reducing termites prevalence, infestation, and consequently optimized maize yield. However, the fact that only one chemical was tested with sawdust bait, additional studies with several pesticides are necessary to prevent development of insecticide resistance. This will make practical pesticide rotation with sawdust bait integrated with other strategies effective long-term termite management strategies.

Data Availability Statement

The data are available upon request from the authors.

Disclosure

The funder did not influence the establishment of experiments, analysis of results, and the publication process of the article.

Conflicts of Interest

The authors declare no conflicts of interest.

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