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Variations in Stem Borer Infestation and Damage in Three Maize (*Zea mays* L.) Types in Southern Guinea Savanna and Rainforest Zones of Nigeria

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Abstract: The effects of location, maize types and borer control with carbofuran (Furadan 3G®) on the severity of maize stem borer infestation and damage was investigated in the late maize planting season of 2011. Treatments were laid out in randomized complete block design using a split-slip-plot factorial arrangement. Whole plot factor consisted of two locations (Southern Guinea Savanna and Rainforest agro-ecological zones of Nigeria), subplot factor consisted of 1.5 kg a.i.ha^{-1} and 0.0 kg a.i.ha^{-1} of carbofuran, while the sub-sub-plot factor comprised of three endosperm types of maize (flint, pop and sweet corn). Stem borer infestation (quantified by dead heart count and larval population per plant) and damage (quantified by %lodged stem, %bored internodes, %bored ears, number of exit holes, number of stem borer cavities and number of damaged seeds per plant) as well as yield were compared. Results revealed that borer infestation and damage were significantly higher ($P < 0.05$) in the Rainforest compared with the Savanna. Single dose application of carbofuran (1.5 kg a.i. ha^{-1}) also significantly ($P < 0.05$) increased grain yield in all the maize types at both locations. For all parameters, no significant ($P > 0.05$) location × carbofuran × maize type and location × maize type effect was detected. However, significant ($P < 0.05$) location × carbofuran and carbofuran × maize type interaction effects were observed. We conclude that in both agro ecologies, flint corn was more tolerant of borer attack while sweet corn was more susceptible compared to either flint or popcorn. In addition, carbofuran at 1.5 kg a.i.ha^{-1} can significantly reduce stem borer population in the three maize types.

Keywords: Borer, Flint, Pop, Sweet, Corn, Control

1. Introduction

Expansion in the cultivation of flint, pop and sweet endosperm types of maize in Nigeria is increasingly becoming inevitable given government's ban on continued importation of food grains. The demand for maize in Nigeria is high and it comprises high demand for it as food for the teeming human population, as feed for livestock, and as raw material for the production of some food and non-food products in agro-allied industries [14, 15]. About 42% of the 785 million tons of maize produced worldwide annually are from the United States of America, while Africa accounts for only for 6.5% [16]. The 2011 estimated figure for maize yield in Nigeria shows a 17.5% increase in yield between 2000 and 2011 [7], yet indications are that production of maize inadequately meets demand quantitatively and qualitatively.

Insect pests are the most limiting factor to the production of maize and research efforts have shown that maize stem borers are the major insect pest of maize [5, 18, 15, 17]. [19] listed 21 species considered being of economic importance; however, [18] reported that only a subset is damaging within any region/crop combination. The common species infesting maize in Nigeria include: *Busseola fusca* Fuller (Noctuidae), *Eldana saccharina* Walker (Pyralidae), *Sesamia calam*istis Hampson (Noctuidae), *Chilo partellus* Swinehoe (Cambridae) and *Acigona ignefusalis* Hampson (Pyralidae) [11, 22]. Depending on the species, the larval stage may last 25-58 days and may have 6-8 instars [20]. Pupal stage normally takes 5-14 days after which adult moths emerge [12, 13, and 19]. Maize stem borers usually pupate close to the tunnel exit or even partly outside the stem [28]. The larvae occupy and feed on different parts of maize whorl, leaves, stalk, tassel and ears. At the early stages of plant growth, damage to the growing point causes 'dead heart'. Borer damage also causes early leaf senescence, reduced translocation, lodging, direct damage to ears and increment in the incidence off stalk rot and ear rot diseases, sometimes resulting to significant yield losses [25, 4]. The severity and nature of stem borer damage depend upon the borer species, the plant growth stage, the number of larvae feeding on the plant, and the plant's reaction to borer feeding [4, 17]. Yield losses caused by maize borers in Africa have been estimated to range from 10 - 100 % [4].

Manipulating time of sowing to avoid severe borer infestation, removal of damaged cobs and stems from the field, selection of resistant varieties, biological controls with naturally occurring biotic agents are relied upon for stem borer control. However, where control failure exists or where they are pest outbreak, control with synthetic insecticides has been recommended. Carbofuran (Furadan 3G) applied at the rate of 1.5 kg a.i.ha^{-1} as well as Carbaryl (Vetox 85) applied at the rate of 0.75 kg a.i.ha^{-1} has been recommended [6, 23]. Most of these recommendations for maize stem borer control emanated for researches with flint corn.

As regular pests of maize, the knowledge of yield–loss relationships between maize types grown in any locality and the stem borers is important in planning effective management strategies for the pest [10]. We therefore set up this experiment to assess the impact of maize types (flint, pop and sweet corn) and borer control with carbofuran on the severity of maize stem borer infestation and damage in two agro ecological zones of Nigeria.

2. Materials and Method

2.1. Description of the Planting Materials and Study Areas

Three maize types [flint (SUWAN-1-SR(DMR)), pop (Kaduna pop corn) and sweet corn (Oba Super 2] obtained from the Department of Crop Production, University of Agriculture, Makurdi were used for field experiment carried out between the month of August and November, 2011 at the Teaching and Research Farm of the University (coordinates: 07°41'N 05°40'E) and Federal University of Agriculture, Abeokuta (coordinates: 07°15'N, 03°25'E). The maize type varieties used are open pollinated and medium maturing. The flint corn was also resistant to Downy mildew disease of corn.

2.2. Research Design

The plots were laid out in randomized complete block design made up of six plots replicated four times giving a total of 24 plots in each location. The experiment was set up in split-slip-plot factorial arrangement with the whole plot factor consisting of two locations (Southern Guinea Savanna and Rainforest agro ecological zone of Nigeria), while the subplot factor consisted of 1.5 kg a.i.ha^{-1} and 0.0 kg a.i.ha^{-1} rates of carbofuran (Furadan 3G®). The sub-sub-plot factor was the three endosperm types of maize (flint, pop and sweet corn). Each plot was 5 m long and six rows wide. An inter row spacing of 0.75 m was maintained within plots while a 1 m alley way existed both within and between blocks. The total area of the field in each location was 736 m^2. Paraquat at 3.0 kg a.i.ha^{-1} and pendimethaline at 2.5 kg a.i.ha^{-1} were applied immediately after sowing for weed control. This was supplemented with manual hoe weeding 7 weeks after planting (WAP). Four seeds per hole were sown on ridges and seedlings were thinned down to 2 plants per stand at 2 WAP to give a population density of approximately 53,333 plants ha^{-1}. Four weeks after planting, NPK (20:10:10) fertilizer was applied.

2.3. Data Collection

Sampling for stem borer damage assessment was carried out at harvest (12 WAP). Data on dead heart count, % lodged stem, % bored stem, % bored internodes, % bore ears, mean number of exit holes per plant, mean number of damaged seeds per plant and mean number of filled cobs per plant were collected from 10 plants selected at random from plants in the four middle rows of each plots. At 4 WAP, plants showing "dead heart" symptoms (destruction of the growing point in the whorl as a result of the stem borer's feeding activities on young maize plants) were counted per plot. Furthermore, the stem of each sample was split and the number of larvae recovered was recorded. The length of borer tunnel on one half of the stem was measured and cumulated. The number of borer cavities was derived as a quotient of total tunnel length and mean length (32 mm) of mature larvae of *B. fusca*, the predominant borer species recovered in both locations. Ears from the sample of 10 plants were picked, dehusked and sorted into grain-filled and unfilled categories, thereafter; the ears were dried. Grain weight was recorded after threshing.

2.4. Statistical Analysis

All data in percentage were transformed to arcsine before the analysis of variance. Mean larval population per plant was analyzed as $\sqrt{x + 0.5}$ before the preliminary F-test which was carried out for each parameter using GENSTAT Discovery Edition 4, [8]. Significantly different mean values were separated using least significant difference (LSD) at 5% level of probability.

3. Results

Busseola fusca was consistently the most abundant borer species in the three types of maize in both locations (51.7% of total collection in flint corn, 58.3% in popcorn and 56.7% in sweet corn at Makurdi, Southern Guinea Savanna agro ecological zone and 48.3%, 54.2% and 50.0% of total collection in flint, pop and sweet corn respectively in the Rainforest agro ecological zone) (Figures 1 and 2). Higher populations of *B. fusca* were recovered from popcorn in both locations compared to the other maize types. *S. calamistis* was next in abundance with a higher population of the borer was recovered in the Rainforest zone compared to the Southern Guinea Savanna zone. Next in relative abundance was *E. saccharina* followed by *A. ignefusalis* and *C. partellus*. The later was not found in the Rainforest zone. In addition, *A. ignefusalis* was not encountered in flint corn in the Southern Guinea Savanna zone and in all the maize types evaluated in the Rainforest zone.

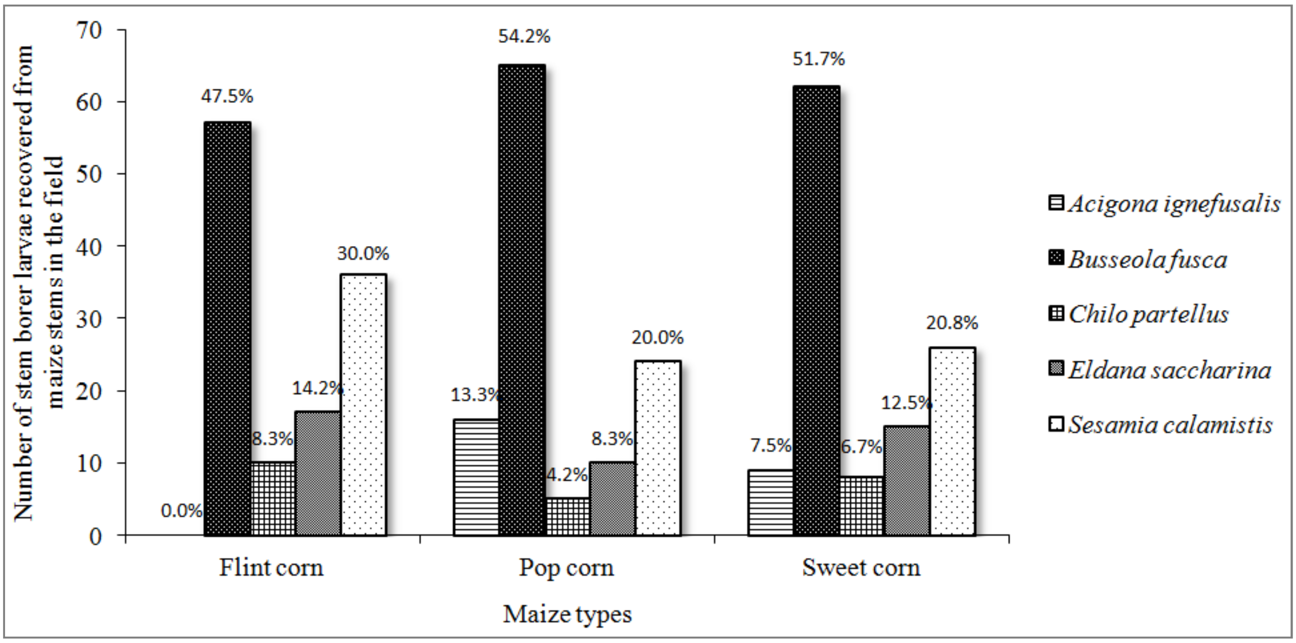

Figure 1. *Species composition and relative abundance (%) of borer recovered from the stems of maize at harvest in Makurdi, Southern Guinea Savanna agro-ecological zone of Nigeria. (n = 120).*

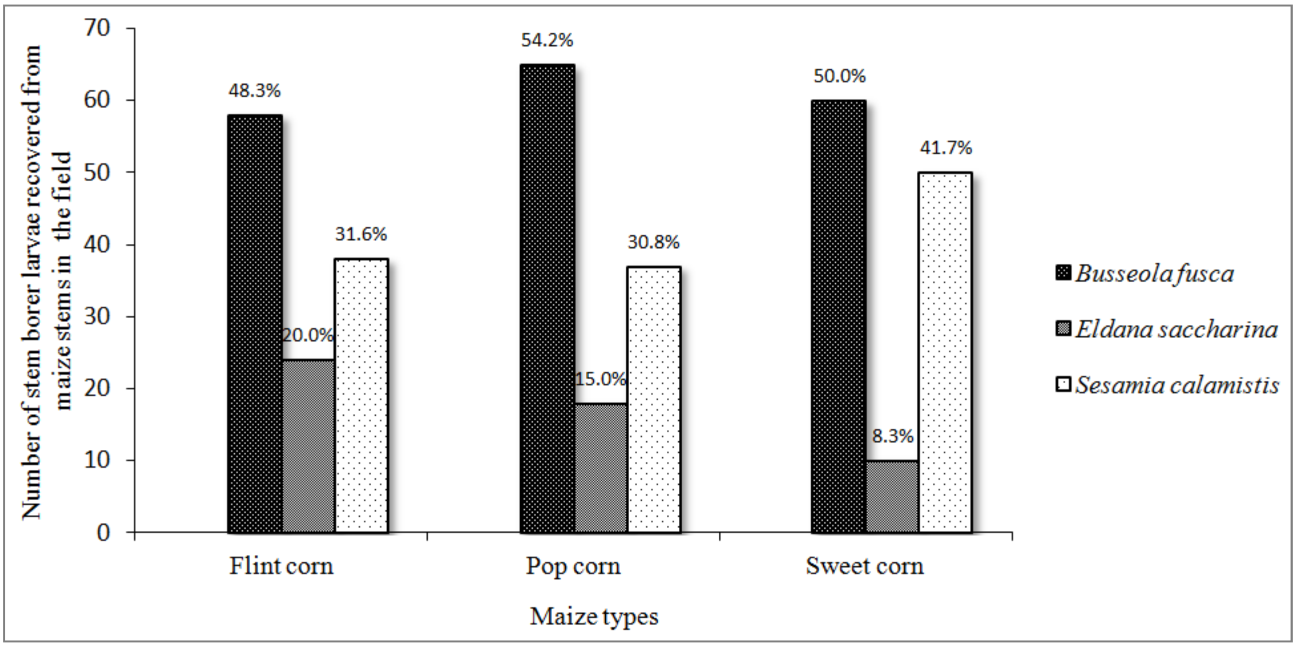

Figure 2. *Species composition and relative abundance (%) of borer recovered from the stems of maize at harvest in Abeokuta, Rainforest agro-ecological zone of Nigeria. (n = 120).*

For all parameters, stem borer infestation and damage were significantly higher ($P < 0.05$) in the Rainforest zone compared to the Southern Guinea Savanna zone and this resulted in a significantly lower ($P < 0.05$) number of filled cobs and total grain yield of the crops grown in that environment (Table 1). Maize grain yield was about 22.8% lower in the Rainforest compared with the Savanna zone. However, the mean number of exit holes per plant and mean number of stem borer cavities per plant in both locations were not significantly different ($P > 0.05$) from each other.

Single dose soil application of carbofuran at the rate 1.5 kg a.i.ha^{-1} significantly suppressed ($P < 0.05$) borer infestation and damage in the three maize types in both locations (Table 1). This increased the number of filled cobs per plant and grain yield from 0.91 to 1.48 and 1.36 to 1.96 tha^{-1} respectively. About 44.9% increase in grain yield was recorded from the pesticide application in all the maize types at both locations

The three maize types were susceptible to borer attacks, given the relatively high borer activities observed in them in both locations (Table 1). Apparently, sweet corn was more susceptible to the attacks given the significant ($P < 0.05$) loss of seedlings due to dead heart and other damages caused by the borer which resulted in low yield values from sweet corn plots. Marginal increase in mean larval population per plant, number of exit holes per plant and number of stem borer cavities per plant observed in sweet corn plots over pop and flint corn plots, but the differences were not significant ($P > 0.05$). Flint corn was more tolerant of the borer attack, in spite of the relatively high borer activity observed in the maize type; a significantly higher yield value of 2.26 tha^{-1} was obtained.

Table 1. *Main effects of location and stem borer control with carbofuran on infestation, damage and yield in three endosperm types of maize (Zea mays L.).*

Treatments	Dead heart count (3WAP)	% lodged stem	% bored stem	% bored internodes	% bored ears	Larval population per plant	Number of exit holes per plant	Number of stem borer cavities per plant	Number of damaged seeds per plant (n= 100)	Number of filled cobs per plant	Grain yield (tha^{-1})
Location											
Guinea Savanna	1.38	20.65	54.40	23.90	49.20	1.70	1.00	1.96	36.71	1.35	1.83
Rain forest	2.50	31.44	59.40	26.99	53.46	1.98	1.01	2.47	40.46	1.05	1.49
$LSD_{0.05}$	0.45	5.12	2.29	1.66	2.74	0.08	Ns	Ns	1.94	0.17	0.11
F-value	62.49	45.01	45.27	34.98	24.09	116.92	0.15	4.89	37.73	32.04	30.99
P-value	0.004	0.007	0.007	0.010	0.016	0.002	0.723	0.114	0.009	0.011	0.002
Df = 1, 3											
Carbofuran											
0.0 kg a.i.ha^{-1}	2.54	15.09	75.09	32.68	66.50	2.56	1.32	3.08	62.17	0.91	1.36
1.5 kg a.i.ha^{-1}	1.33	37.01	38.89	18.21	36.20	1.12	0.67	1.36	15.00	1.48	1.97
$LSD_{0.05}$	0.67	1.69	8.35	2.31	8.27	0.11	0.32	0.39	2.10	0.13	0.21
F-value	19.26	1011.59	112.70	67.52	80.16	1096.67	24.05	115.10	1479.70	116.16	51.79
P-value	0.005	<0.001	<0.001	<0.001	<0.001	<0.001	0.003	<0.001	<0.001	<0.001	<0.001
Df = 1, 6											
Maize types											
Flint corn	1.63	21.19	49.93	23.52	42.82	1.75	0.79	1.91	29.69	1.44	2.26
Popcorn	1.75	24.14	57.23	25.18	51.02	1.90	1.08	2.34	40.06	1.24	1.70
Sweet corn	2.44	32.82	63.81	27.64	60.19	1.90	1.14	2.41	46.00	0.91	1.03
$LSD_{0.05}$	0.47	3.35	4.65	1.79	4.78	Ns	Ns	Ns	2.82	0.15	0.16
F-value	7.47	27.76	19.03	16.10	28.11	1.82	10.71	2.59	97.31	28.00	121.99
P-value	0.003	<0.001	<0.001	0.001	<0.001	0.122	0.184	0.096	<0.001	<0.001	<0.001
Df = 2, 24											

Means are values of four replicates

$LSD_{0.05}$ = Fisher's Least Significant Difference at 5% level of probability

Data in percentage were transformed to arcsine values and insect count was analysed as $\sqrt{x + 0.5}$ before the F-test

There was no significant ($P > 0.05$) location × carbofuran × maize type and location × maize type interaction effect was detected for all parameters (Table 2). But significant ($P < 0.05$) location × carbofuran and carbofuran × maize type interaction effect in some parameters were observed. Percentage bored stem, mean larval population per plant and number of exit holes in carbofuran-untreated plots in the rainforest zone were significantly higher ($P < 0.05$) compared with the treated plots and treated and untreated plots in the southern Guinea Savanna zone. The untreated plots of sweet corn had significantly higher ($P < 0.05$) %bored stem, %bored ear, mean number of exit holes per plant, mean number of stem borer cavities per plant, number of damaged seeds per plant and a significantly lower ($P < 0.05$) number of filled cobs per plant compared with the treated and untreated plots of the other maize types.

Table 2. *Interactions effects of location stem borer control with carbofuran and maize types on infestation, damage and yield parameters.*

Treatments	Dead heart count (3WAP)	% lodged stem	% bored stem	% bored internodes	% bored ears	Larval population per plant	Number of exit holes per plant	Number of stem borer cavities per plant	Number of damaged seeds per plant (n=100)	Number of filled cobs per plant	Grain yield (tha^{-1})
Location × Carbofuran											
Guinea Savanna × 1.5 kg a.i.ha^{-1}	0.66	8.26	37.16	17.64	35.41	1.04	0.66	1.09	13.50	1.70	2.39
Guinea Savanna × 0.0 kg a.i.ha^{-1}	2.08	32.95	71.98	30.17	63.05	2.36	1.33	2.85	59.92	1.00	1.36
Rain forest × 1.5 kg a.i.ha^{-1}	2.00	21.82	40.61	18.78	37.00	1.21	0.69	1.63	16.50	1.28	1.85
Rain forest × 0.0 kg a.i.ha^{-1}	3.00	41.06	78.20	35.19	69.91	2.76	1.33	3.31	64.42	0.82	1.78
$LSD_{0.05}$	Ns	4.80	Ns	Ns	Ns	0.12	0.32	Ns	Ns	Ns	Ns
F-value	0.57	15.10	0.16	1.22	0.61	7.02	0.01	0.07	0.37	5.06	2.31
P-value	0.478	0.008	0.699	0.312	0.465	0.038	0.909	0.801	0.563	0.066	0.180
Df = 1, 6											
Carbofuran × Maize types											
1.5 kg a.i.ha^{-1} × Flint	1.00	10.23	36.88	16.70	33.45	1.01	0.58	1.43	12.13	1.850	2.73
1.5 kg a.i.ha^{-1} × Pop	1.25	11.52	39.86	17.88	36.94	1.18	0.66	1.34	16.00	1.54	2.13
1.5 kg a.i.ha^{-1} × Sweet	1.75	23.52	39.92	20.06	38.24	1.18	0.77	1.32	16.88	1.08	1.51
0.0 kg a.i.ha^{-1} × Flint	2.25	32.15	62.98	30.34	52.19	2.48	0.99	2.39	47.25	1.03	1.90
0.0 kg a.i.ha × Pop	2.25	36.75	74.60	32.47	65.10	2.61	1.51	3.35	64.12	0.95	1.13
0.0 kg a.i.ha × Sweet	3.13	42.12	87.70	35.23	82.14	2.57	1.49	3.50	75.13	0.75	0.77
$LSD_{0.05}$	Ns	Ns	9.21	Ns	9.22	Ns	0.35	0.66	3.81	0.20	Ns
F-value	0.36	2.09	11.75	0.56	15.05	0.09	3.80	3.74	47.96	6.21	1.49
P-value	0.704	0.145	<0.001	0.578	<0.001	0.911	0.037	0.038	<0.001	0.007	0.246
Df = 2. 24											
Location × Maize type											
$LSD_{0.05}$	Ns	Ns	Ns	Ns	Ns	Ns	Ns	Ns	Ns	Ns	Ns
F-value	0.46	3.32	0.20	0.84	0.64	0.01	0.38	0.16	0.45	2.58	0.72
P-value	0.638	0.056	0.816	0.446	0.534	0.994	0.964	0.849	0.642	0.097	0.495
Df = 2, 24											
Location × Carbofuran × Maize type											
$LSD_{0.05}$	Ns	Ns	Ns	Ns	Ns	Ns	Ns	Ns	Ns	Ns	Ns
F-value	0.05	1.98	0.12	2.88	0.19	0.05	0.03	0.55	0.17	1.77	0.61
P-value	0.951	0.161	0.886	0.075	0.826	0.951	0.974	0.547	0.842	0.191	0.550
Df = 2, 24											

Means are values of four replicates

$LSD_{0.05}$ = Fisher's Least Significant Difference at 5% level of probability

Data in percentage were transformed to arcsine values and insect count was analysed as $\sqrt{x + 0.5}$ before the F-test.

4. Discussion

Population density and damage activities of stem borers observed in the study confirm previous reports which implicated the insect as a major pest of maize. The higher density of *B. fusca* in the maize types observed in both locations is similar to the findings of Nigeria by [2] in southwestern part of Nigeria, but contrary to the findings of [3] and [26] who reported that *E. saccharina* and *S. calamistis* as the most important stemborers on maize in the forest zone of eastern Nigeria, the forest/savanna transition zone of south western Nigeria. Though not investigated, the nature of the vascular tissues of popcorn may have contributed to the relatively higher preference of *B. fusca* for it. The absence of *A. ignefusalis* in flint corn in the Guinea Savanna zone is yet to be determined whether or not it is a case of escape of infestation. But its absence in the Rainforest zone maybe due to location effects and absence of millet in neighboring plots. *A. ignefusalis* is a millet stem borer, but could infest other cereals [29]. In addition, *C. partellus* was absent in larval population recovered from both location. But [27] reported that factors such as temperature, rainfall and humidity influences the distributions of *B. fusca* and *C. partellus*, with temperature being the most important. He indicated that *C. partellus* was found in warmer regions and *B. fusca* in cooler areas. This generalization may be the possible reason for the absence of *C. partellus* in cooler environment of the Rainforest zone of Nigeria.

The significant reduction in borer population by single dose application of carbofuran at the rate of 1.5 kg a.i.ha^{-1} further confirms the effectiveness of the chemical in the control of stem borers. Similar results have been reported by [6, 4]. In spite of health and environmental risks associated with the use of chemicals for pest control, they continues to play the important role of minimizing crop loss associated with increase in insect pest population in farmer's field. It is important to note that carbofuran is a systemic insecticide which is effective even after the larvae penetrate into the stem [4]. Their use in late season maize could leave residues in the grains; hence, non-systemic alternative is suggested.

The three maize types used in the experiment were susceptible to stem borer infestation and damage. The high population of larvae observed in their stems may be the reason for high level of borer damage observed in the study. This agrees an earlier observation by [9] who found significant increase in infestation and damage as well as yield reduction with increase larval population.

The higher grain yield observed in flint corn compared with either pop or sweet corn may be due to the lower damage observed in the maize type in both locations as well as differences in grain morphometrics and weight. Noteworthy, infested plants also yielded cobs filled with grains in spite of borer tunneling activities which resulted in stem lodging and cavities in the stems of the three maize types. This result was not unexpected because maize has scattered vascular bundle typical of a monocotyledonous plant, which enables the plant to translocate nutrients and water through undamaged tissues to the yield bearing sink(s) without significant reduction in yield. In addition, adequate rainfall as well as the use of fertilizers has been reported to exert significant influence on maize yield and stem borer damage [24, 21].

The no significant location × carbofuran × maize type and location × maize type interaction effect detected for all parameters show that infestation, damage and yield were not significantly affected by the combinations of these factors. However, the significantly higher damage values observed in carbofuran-untreated plots in the Rainforest zone compared with the treated plots and treated and untreated plots in the Southern Guinea Savanna zone reveals the impact of location and borer control with carbofuran on bored stem, larval population per plant and number of exit holes in the maize types. Generally, herbivore activities can vary with habitat type depending on the prevailing conditions in a given ecosystem [1, 20]. Furthermore, the combination of borer control with carbofuran and maize types had significant effect on bored stem, bored ear, number of exit holes per plant, number of stem borer cavities per plant, number of damaged seeds per plant and number of filled cobs per plant. This may also have resulted from differences in maize type's ability to absorb carbofuran from the soil.

5. Conclusion

The study was carried out to assess the effect of three maize types (flint, pop and sweet corn) and borer control with carbofuran on the severity of maize stem borer infestation and damage in Southern Guinea Savanna and Rainforest agro-ecological zones of Nigeria. The results revealed that yield loss due to stem borer infestation and damage could be severe if the pest is not managed during the late maize cropping season (August to November) in both locations. Furthermore, the lower infestation and damage levels in flint corn compared with pop and sweet corn in carbofuran-treated and untreated plot in the Southern Guinea Savanna and Rainforest zone of Nigeria, suggests that flint corn may be more productive when grown by resource–poor farmers in both locations. However, infestation and damage by stem borer can be suppressed with single dose soil application of carbofuran at the rate of 1.5 kg a.i.ha^{-1}. Further studies still should be conducted to assess the extent of damage caused by individual borer species and their implications on the yield of each maize type in controlled environment. This will provide additional empirical evidence of the economic status of the pest.

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