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Maize borer damage in Nigeria's Guinea Savanna: Timing of planting overrides effects of insecticides treatments

Daño del perforador del maíz en Sabana de Guinea nigeriana: el tiempo de siembra anula los tratamientos insecticidas

SIMON I. OKWECHE[1], EPHRAIM E. OSAI[2] and SYLVIA BASSEY A. UMOETOK[3]

Abstract: Stem borers are major insect pests of maize worldwide. In Nigeria, maize yields are threatened by stem borers such as *Busseola fusca, Sesamia calamistis, Eldana saccharina, Coniesta ignefusalis, and Chilo partellus*. Field experiments were conducted in the early and late seasons of 2009 and 2010 in the Guinea Agro-ecological zone of Cross River State, Nigeria, to assess the effects of borer damage and population dynamics. Treatments consisted of seasonal differences (early and late) and synthetic (carbofuran 1.0 at 1.5 kg a.i/ha) and botanical (*Azadirachta indica* and *Gmelina arborea* seed powders at 20 and 30 kg/ha) insecticides. The treatments were laid out in a randomized complete block design (RCBD) with three replications. Data collected included percentages of dead heart, lodged stem, bored stem, tunnel length, larval population, and grain yield. Results showed that damage variables and population dynamics were significantly ($P < 0.05$) lower in early-planted maize as compared to late-planted maize. The lowest incidence of dead heart between the botanicals in the late season was recorded in *A. indica* (30 kg/ha) treated plots (4.81% and 5.13% in 2009 and 2010, respectively). The same was observed for tunnel length (6.27 cm and 9.00 cm) and lodged stem (4.40% and 8.89%) in 2009 and 2010, respectively. Yield was higher in early season maize than in late season maize. The highest yield (2.23 and 2.95 ton/ha) was obtained from carbofuran (1.5 kg a.i/ha), followed by *A. indica* (30 kg/ha) (2.20 and 2.90 ton/ha) treated plots in early plantings of 2009 and 2010, respectively. The results indicated that stem borer population and yield varied by season, which was determined by climate.

Key words: Stem borers. Guinea savanna. Early and Late seasons. Zea mays. Carbofuran.

Resumen: Los barrenadores del tallo son las principales plagas económicas del maíz en el mundo. En Nigeria, los rendimientos de maíz son afectados por los barrenadores *Busseola fusca*, *Sesamia calamistis*, *Eldana saccharina*, *Coniesta ignefusalis* y *Chilo partellus*. Experimentos de campo se llevaron a cabo en las temporadas de siembra tempranas y tardías de 2009 y 2010 en la zona Agro-ecológica Guinea de estado de Cross River, Nigeria para evaluar los efectos del daño del barrenador del tallo y su dinámica poblacional en las temporadas temprana y tardía de siembra. Los tratamientos, en diseño de bloques completos al azar (DBCA) con tres repeticiones, consistieron en estaciones (temprana y tardía), dos niveles de insecticidas (sintético: carbofurano 1,0 y 1,5 kg de ia/ha) y botánicos (*Azadirachta indica* y *Gmelina arborea* polvos de semillas 20 y 30 kg/ha). Los resultados mostraron que las variables daño del barrenador y dinámica de la población fueron significativamente ($P < 0,05$) menores en la siembra temprana que en la tardía. Menores porcentajes de incidencia de corazón muerto (4,81% y 5,13%) se registraron en las cosechas tardías con el insecticida botánico *A. indica* (30 kg/ha) en 2009 y 2010, respectivamente. Lo mismo se observó para largo del túnel de 6,27 cm (4,40%) y 9,00 cm (8,89%), en 2009 y 2010, respectivamente. Rendimientos fueron mayores en siembra temprana que en tardía y en parcelas con carbofurano (1,5 kg ia/ha), seguidos de *A. indica* (30 kg/ha) (2,20 y 2,90 toneladas/ha) de temporadas de siembra temprana tanto en 2009 como 2010, respectivamente. Los resultados sugieren que la población del barrenador del tallo y el rendimiento varían con las estaciones que son determinadas por el clima.

Palabras clave: Barrenadores del tallo. Guinea sabana. Estaciones temprana y tardía. *Zea mays*. Carbofurano.

Introduction

Sweet maize [*Zea mays* L. (Poaceae)] is perhaps one of the most important cereal crops cultivated for food, feed and as industrial raw materials (Benz 1994; Ukeh *et al.* 2010). However, sustainable maize production especially in the developing world is threatened by various stresses including insect pests such as stem borers (Polaszeck 1998; Ukeh *et al*. 2007). The most relevant stem boring species associated with maize production in Nigeria are moths belonging to the families Noctuidae and Pyralidae, namely: the maize stalk borer (*Busseola fusca* Fuller), the pink stem borer (*Sesamia calamistis* Hampson), the millet stem borer (*Acigona ignefusalis* Hampson) and the African sugar cane borer (*Eldana saccharina* Walker); (Polaszek 1998; Balogun and Tanimola 2001). In fact, stem borers have been the most damaging group of insect pests in maize cultivation worldwide (CIMMYT 2000). Nigeria is with nearly 8 million tons Africa's largest producer of maize (IITA 2014) and stem borers cause 10-100% loss in maize grain yield (Sosan and Daramola 2001). However, Kakule *et al*. (1997) reported that within Africa, damage to maize varies with locations/regions, with sub-Saharan Africa recording the highest population of stem borers being directly correlated with damage and grain yield. Crop losses and grain yield reduction may result from the damage caused to growing points leading to loss of stands (dead heart), damage to leaf (window pane) stem tunneling, hole (as portal of entry to secondary rot organisms), stem lodging, stem breakage, tassel and direct damage to ear shank and ear (Sosan and Daramola 2001). However, the consequence on yield is variable and depends upon sowing, borer species composition and abundance as well as insecticide treatment (e.g. Ajala *et al*. 2010; Bosque-Perez 1992; Kakule *et al.* 1997; Okweche *et al*. 2010; Ukeh *et al.* 2007). It has been observed that early-planted maize suffers less from borer attacks than late-planted maize in

[1] Doctor of Philosophy. Department of Forestry and Wildlife Resources Management, University of Calabar, P. M. B. 1115, Calabar, Nigeria. *idokosi@yahoo.com.* Corresponding author. [2] Doctor of Philosophy. Department of Crop Science, University of Calabar, P. M. B. 1115, Calabar, Nigeria. [3] Department of Crop Science, University of Calabar, P. M. B. 1115, Calabar, Nigeria. *sbaumoetok@yaho.com.*

the Middle Belt of Nigeria (Okweche *et al*. 2010; Sosan and Daramola 1999; Ukeh *et al.* 2007). Heavy stem borer infestations have precluded second cropping of maize even in areas with potentials for two rain-fed crops (Ogunwolu 1987). The different recommendations on dates appropriate for sowing exist across all agro-ecological zones where maize is cultivated. Maize cropping is between March/April (early) and August/September (late) in the Southern agro-ecological zone of the country (rainforest) where it is highly produced.

Most insecticidal compounds used today fall within organophosphates and carbamates (Ware 1982; Dorow 1993). There are problems of pesticide resistance and negative effects on non-target organisms including man and the environment (Rembold 1984; Franzen 1993; FAO 1992). These synthetic insecticides are more hazardous to handle, leave toxic residues in food products, not easily biodegradable. Besides, their influence on the environment is deleterious. Unlike synthetic that kill both pests and predators outright the natural insecticides are relatively inactive against the latter. The botanical insecticides are generally pest-specific and are relatively harmless to non-target organisms including man. They are also biodegradable and harmless to the environment (Jacobson 1975; Ukeh *et al*. 2007). Furthermore, unlike conventional insecticides which are based on a single active ingredient, plant derived insecticides comprise an array of chemical compounds which act concertedly on both behavioral and physiological processes. Thus the chances of pests developing resistance to such substances are less likely (Saxena 1987). One plant species may possess substances with a wide range of activities, for example extracts from the the neem tree *Azadirachta indica* Juss are antifeedant, antioviposition, repellent and growth-regulating (Ukeh 2007; Okweche *et al*. 2013) The insecticidal properties of *A. indica* products have been reported by many authors (Schmutterer 1990; Emosairue and Ukeh 1996). Azadirachtin, the most active component of *A. indica* seed oil has been reported to alter insect behavior due to its antifeedant, repellent and phagodeterrent properties (Schmutterer 1990; Emosairue and Ukeh 1996). Oparaeke (2005) reported the effectiveness of *Gmelina* fruit extract on the control of *Clavigralla tomentosicollis* and on *Maruca* pod borer on cowpea. *Gmelina arborea* L. (Vernabaceae) is a tropical, evergreen perennial tree growing over 20 m high. The tree has high alkaloid content particularly in the fruit, stem bark and root and some little amount in the leaves. It is less attacked by insect pests all through the season probably due to its high alkaloid and tannin contents. Liquid from the fruits has been found to be toxic to larvae of moths and butterflies (Oparaeke 2005).

Most farmers in Africa depend on local methods of farming with little or no idea of pesticides usage and time of planting. Pests continue to ravage farms causing low level of productivity. Even in area where pesticides are used, poisonous substances such as organophosphates and organochlorines are used and are very toxic to humans and soil organisms. Therefore, environmentally friendly approach such as time of planting be adopted for better management of maize stem borers and increased productivity. The objectives of the study were to determine yield loss due to stem borers in the guinea agro-ecological zones of Cross River State and to determine the intensity of stem borers attack on early and late planted maize.

Materials and methods

Study species. Stem borers infestation begins with arrival of migrant population moths from wild host as well as maize stems left on the field after the previous season's crop harvesting, or the stems used for fencing in homestead (Polaszek 1998 Sosan and Daramola 1999). *B. fusca* and *S. calamistis* are the earliest arrival, followed later from eight weeks after planting (8 WAP) by *E. saccharina.*

Land preparation and planting. The experiment was conducted at the Teaching and Research Farm of Ujia Secondary Commercial College, Bekwarra, in the Guinea agro-ecological zone of Cross River State, situated in latitude 5º5'E - 8º22'E, Nigeria. The experimental site was cleared, ploughed and harrowed to give a uniform and smooth planting surface. The experiment occupied 0.05 ha demarcated into three blocks containing seven plots. Each plot measured 4 m x 2 m. Adjacent plots were separated by 0.5 m path while 1.0m path was used to separate the blocks. Three seeds were sown manually at a spacing of 75 cm x 25 cm and a planting depth of 3cm.The seedlings were thinned to one plant per stand at two weeks after sowing to maintain a population of about 53,333 plants/ha.

Planting materials. The maize variety (OBA Super 1 OPV-yellow) used for the experiment was obtained from the Cross River Agricultural Development Programme, Ogoja, Cross River State, Nigeria. Matured ripe fruits from *Azadirachta indica* A. (Juss) and *Gmelina arborea* L. (Verbenaceae) seeds

Table 1. Effects of season on some stem borer damage parameters in 2009.

	Dead heart (%)			Tunnel length (cm)			Lodged stem (%)			Bored stem (%)		
Treatments	Early	Late	P	Early	Late	P	Early	Late	P	Early	Late	P
Control	9.36	19.61	0.026	32.23	49.83	0.045	16.28	38.11	0.003	41.33	60.00	0.011
C1.0	2.81	4.44	0.057	3.80	6.40	0.027	4.07	5.05	0.326	11.00	17.00	0.117
C1.5	2.45	4.07	0.018	2.93	5.23	0.052	2.96	3.70	0.323	12.00	14.00	0.339
N20	7.40	8.51	0.171	5.74	8.80	0.143	6.66	6.66	0.499	12.33	19.33	0.140
N30	3.02	5.55	0.062	4.47	6.27	0.133	3.33	4.44	0.312	11.33	17.67	0.029
G20	10.67	10.73	0.255	16.33	19.80	0.190	11.47	14.66	0.152	26.67	32.67	0.093
G30	8.62	8.88	0.383	10.37	13.53	0.022	12.21	11.84	0.468	12.00	24.00	0.018

C1.0 and C1.5 = Carbofuran at 1.0 kg a.i/ha and 1.5 kg a.i/ha respectively; N20 and N30 = *A. indica* at 20 kg/ha and 30 kg/ha respectively; G20 and G30 = *G. arborea* at 20 kg/ha and 30 kg/ha respectively. P = Probability values at 5% level.

Table 2. Effects of season on some stem borer damage parameters in 2010.

	Dead heart (%)			Tunnel length (cm)			Lodged stem (%)			Bored stem (%)		
Treatments	Early	Late	P	Early	Late	P	Early	Late	P	Early	Late	P
Control	12.21	36.65	0.001	15.20	36.40	0.009	22.22	41.85	0.002	29.26	56.40	0.007
C1.0	2.22	13.33	0.001	3.13	12.93	0.009	7.41	12.96	0.043	12.28	24.87	0.002
C1.5	0.74	8.15	0.001	3.13	8.67	0.003	6.67	8.89	0.224	12.68	24.28	0.002
N20	2.22	12.96	0.001	6.07	14.37	0.007	7.04	10.74	0.060	14.74	31.12	0.024
N30	2.59	10.00	0.001	5.47	9.00	0.055	6.30	8.89	0.078	12.44	26.22	0.024
G20	8.52	16.30	0.001	10.07	18.53	0.014	16.67	18.12	0.320	22.09	29.51	0.060
G30	7.78	11.81	0.019	5.27	11.80	0.003	14.45	18.52	0.213	12.24	26.03	0.008

C1.0 and C1.5 = Carbofuran at 1.0 kg a.i/ha and 1.5 kg a.i/ha respectively; N20 and N30 = *A. indica* at 20 kg/ha and 30 kg/ha respectively; G20 and G30 = *G. arborea* at 20 kg/ha and 30 kg/ha respectively. P = Probability values at 5% level.

were collected washed and sun dried for 8 days then ground into powder, using a mechanical grinder. The powder of both products was weighed into 0.19 g and 0.28g usin g Mettler P163 weighing balance.

Treatments. The treatments included: Seasons (early and late), *A. indica s*eed powder (NSP), *G. arborea* seed powder (GSP) at the rates of 20 kg and 30 kg/ha while carbofuran was applied at the rates of 1.0 and 1.5 kg a.i /ha (13.33 kg/ha and 20 kg/ha) and an untreated plot which serves as control. The treatments were laid out in a randomized complete block design (RCBD) with three replicates each. Planting was done on 2nd of April 2009 for early and 12th of September 2009 for late season. In 2010, planting was done on 3rd of April for early and 4th of September for late seasons, respectively.

The plots were kept weed-free during the experiment using manual weeding method. Compound fertilizer N.P.K (20:10:10) was applied at the rate of 90 kg N/ha, 45 kg P_2O_5/ha and 45 kg K_2O/ha.

Data collection and analysis. Dead heart was recorded at six weeks after sowing (WAP) as percentage of total number of plants in the plot. At harvest, lodged stems were counted and expressed as percentage of total number of plants per plot. A random sample of 5 stems from each experimental unit was examined for the number of bored stems, total number of internodes bored. Bored stems were split to record the number of recovered alive stem borer larvae and borer tunnel length. The different borer larvae were recorded after sorting to species level (Polaszek 1998). Grain weight (yield) per plot was measured and computation done to tones per hectare. Data on the effect of season on stem borer abundance and damage variables were subjected to t-test while the effects of the insecticides (synthetic and non-synthetic) on damage and abundance was subjected to analyses of variance (ANOVA) using StatView statistical software for windows. The significance level was set to $P \leq 0.05$.

Results

Data in Tables 1 and 2 show the effect of season on dead heart incidence (%), tunnel length (cm), percentage lodged and bored maize stems for 2009 and 2010 cropping seasons. The untreated plots had significantly higher infestation and damage (dead heart, tunnel length, lodged and bored stems) in late season planting than early. In 2009 cropping season (Table 1), plots treated with carbofuran at 1.5 kg a.i/ha showed significantly higher incidence of dead heart (%) in late season than early season.

Tunnel length in 2009 was significantly longer in late season than early season in the untreated crops and in the G30 treated crops. Percent lodged stem was significantly higher in late season planting in untreated plots during both years than treated plots. Similar results were observed in percent bored stem. Again, in 2010 (Table 2) dead heart incidence and tunnel length were significantly higher in late season than early season planting except that crops treated with *A. indica* at 30 kg/ha showed no significant difference between early and late season in tunnel length. Similar result was observed

Table 3. Effects of season on stem borer population in 2009.

	B. fusca			*S. calamistis*			*E. saccharina*			*C. partellus*			*C. ignefusalis*		
Treat	Early	Late	P	Early	Late	P	Early	Late	P	Early	Late	P	Early	Late	P
Control	27.67	44.67	0.046	9.00	11.00	0.416	4.33	6.33	0.255	8.33	9.33	0.360	2.00	2.00	0.500
C1.0	7.33	6.00	0.400	0.67	3.67	0.027	0.00	0.00	-	1.00	0.00	0.211	1.00	1.33	0.426
C1.5	7.67	13.00	0.036	0.33	0.00	0.211	0.00	0.00	-	0.00	0.00	-	0.00	1.33	0.211
N20	16.33	12.00	0.274	3.67	5.00	0.265	2.00	0.00	0.211	3.00	2.3 3	0.346	-	0.00	0.00
N30	11.00	9.67	0.228	3.00	1.33	0.187	2.33	0.00	0.168	2.00	2.33	0.426	0.00	0.33	0.211
G20	20.67	23.33	0.355	4.67	5.00	0.469	2.67	2.00	0.386	4.00	4.33	0.408	0.00	2.33	0.096
G30	20.00	14.67	0.220	4.00	2.67	0.197	2.67	2.33	0.259	3.33	4.67	0.202	0.00	1.00	0.211

C1.0 and C1.5 = carbofuran at 1.0 kg a.i/ha and 1.5 kg a.i/ha respectively; N20 and N30 = *A. indica* at 20 kg/ha and 30 kg/ha respectively; G20 and G30 = *G. arborea* at 20 kg/ha and 30 kg/ha respectively. P = Probability values at 5% level.

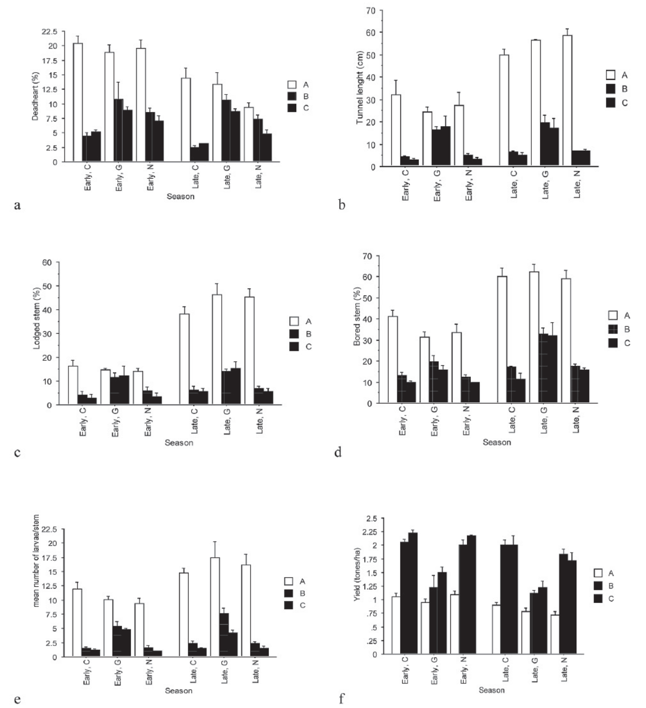

Figure 1. Effects of treatments of carbofuran (C), Gmelina (G) and neem (N) on dead heart (%),tunnel length (cm), logged stem (%) bored stem (%), number of borer /plant and yield in 2009. Columns represent control (A), treatment of 20 kg/ha neem or Gemlina and 1.0 kg/ha carbofuran (B) and treatment of 30 kg/ha neem or Gemlina and 1.5 kg/ha carbofuran (C).

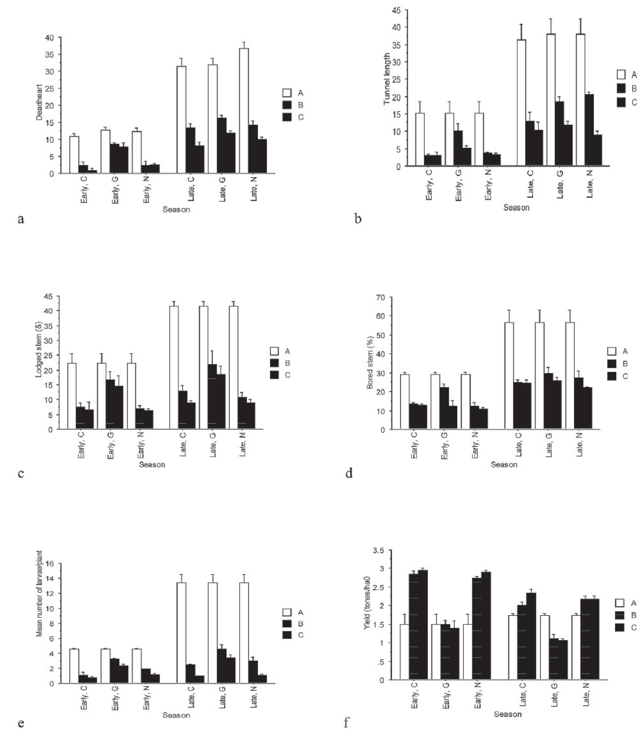

Figure 2. Effects of treatments of carbofuran (C), Gmelina (G) and neem (N) on dead heart (%), logged stem (%) bored stem (%), tunnel length (cm), number of borer /plant and yield in 2010. Columns represent control (A), treatment of 20 kg/ha neem or Gemlina and 1.0 kg/ha carbofuran (B) and treatment of 30 kg/ha neem or Gemlina and 1.5 kg/ha carbofuran (C).

in percent bored stem, except in plots treated with *G. arborea* at 20 kg/ha, which showed no significant difference between early and late planting. Control plot and the crops treated with carbofuran at 1.0 kg a.i/ha had significantly higher percent lodged stems in late season than other treatments. For most treatments (and stem borer species as well) there were no differences between early and late planting (Tables 3 - 4). In 2009, *B. fusca*, mean abundance was significantly higher in late planting than in early planting seasons in the control, compared with other borer species (Table 3). No significant difference was observed in the treated crops in early and late season with the exception of crops treated with carbofuran C1.0, where *B. fusca* and *S. calamistis* were significantly higher in late than early season. In 2010, *B. fusca, S. calamistis* and *C. partellus* were significantly higher for untreated crops in late than early season while there was no significant difference between early and late planting seasons in the treated crops (Table 4).

Figures 1 and 2 show the effect of insecticides (carbofuran, neem and *Gmelina*) on damage parameters for 2009 and 2010 planting seasons. Application of either carbofuran or botanicals (neem seed powder and *Gmelina* seed powder) significantly reduced the incidence of dead hearts, tunnel length, lodged and bored stems, number of larvae per stem in early and late season planting for the two years. Figure 3 shows that Neem at 30 kg/ha was as effective as carbofuran at 1.5 kg a.i/ha in reducing damage in most of the variables for the two seasons and years. In 2009 early and late plantings, significantly higher grain yield was observed in crops treated

Table 4. Effects of season on stem borer population in 2010.

	B. fusca			*S. calamistis*			*E. saccharina*			*C. partellus*			*C. ignefusalis*		
Treat	**Early**	**Late**	**P**	**Early**	**Late**	**P**	**Early**	**Late**	**P**	**Early**	**Late**	**P**	**Early**	**Late**	**P**
Control	14.67	42.67	0.009	4.67	10.33	0.034	3.00	5.33	0.139	4.33	6.67	0.004	0.67	2.00	0.191
C1.0	4.33	6.00	0.237	1.33	4.00	0.069	0.00	0.67	0.211	1.00	1.00	0.500	1.00	1.33	0.399
C1.5	3.67	5.00	0.191	1.00	0.00	0.113	0.00	0.00	-	0.00	0.00	-		0.00	0.00
N20	7.67	8.00	0.421	3.00	5.00	0.154	2.00	1.00	0.343	2.00	2.33	0.404	0.33	1.33	0.136
N30	4.67	5.00	0.326	2.00	1.33	0.333	1.00	0.00	0.113	1.00	1.00	0.500	0.00	0.33	0.211
G20	11.00	10.33	0.349	4.00	4.67	0.326	1.00	2.67	0.169	2.33	3.00	0.196	0.67	02.33	0.156
G30	8.00	9.33	0.246	3.33	2.67	0.323	2.67	1.67	0.051	3.33	2.33	0.136	0.33	1.00	0.296

C1.0 and C1.5 = carbofuran at 1.0 kg a.i/ha and 1.5 kg a.i/ha respectively; N20 and N30 = *A. indica* at 20 kg/ha and 30 kg/ha respectively; G20 and G30 = *G. arborea* at 20 kg/ha and 30 kg/ha respectively. P = T-test values values at 5% level.

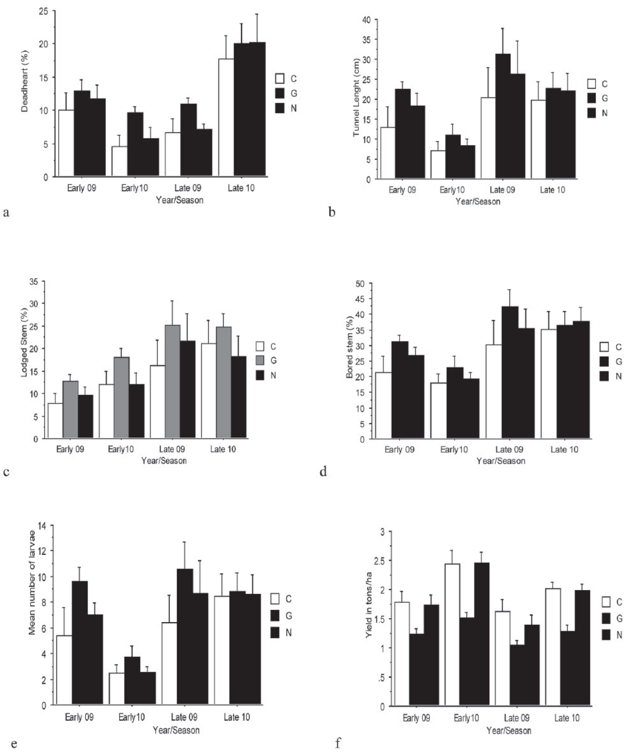

Figure 3. Effects of seasons (early and late) and pesticides (carbofuran (C), Gmelina (G) and neem (N)) on dead heart (%), logged stem (%) bored stem (%), tunnel length (cm), number of borer /plant and yield in 2009/2010. Columns represent carbofuran (C), Gemlina arborea (G) and neem (N).

with carbofuran and *A. indica than on G. arborea* and the control. Similar result was observed in the early planting of 2010. In the late planting of same year (2010) *A. indica* at all levels and carbofuran at 1.5 kg a.i/ha had significantly higher grain yield compared with *G. arborea* and the control. However, maize yield on crops treated with carbofuran at 1.0 kg a.i/ha was not significantly different from *A. indica* in the late planting season of same year.

Discussion

Results showed that stem borer species recorded in 2009 and 2010 planting seasons included *Busseola fusca, Sesamia calamistis, Elana saccharina, Acigona ignefusalis,* and *Chilo partellus*. *Busseola fusca* was the most predominant borer species recorded in the Guinea agro-ecological zone for both seasons and years. This study showed that season, the type of insecticide and rates of application had significant effects on damage and abundance of stem borers. This result is in agreement with similar reports by Ajayi and Labe (1990) and Polaszek (1998) that stem borer infestation and severity of damage vary with season, ecological zones and region depending on weather conditions. The early season planting recorded significantly lower borer population compared to late planting. Bosque-Perez and Dabrowski (1989), Polaszek (1998) and Okweche *et al.* (2010) have also reported that early planting suffers less attack by borers and build up is higher in late season planting (September/October). Stem borer population and damage were significantly reduced by application of both carbofuran and the plant products.

Generally, carbofuran applied to the soil at the rate of 1.5 kg a.i/ha significantly reduced stem borer infestation and damage in agreement with the findings of Bosque-Perez (1992), Seshu and Sum (1992) and Polaszek (1998). Higher yield recorded in the carbofuran and *A. indica* seed powder treated crops could be attributed to the lower larval population recorded in the study. Again, yields obtained from early season plantings were significantly higher than in late season planting, this report agrees with the findings of Okweche *et al.* (2010) that there was a higher yield of maize in early planting than in late planting. The effects of stem borers on grain yield and quality of maize have been assessed by a number of research workers including Usua (1966, 1968) and Schulthess *et al.* (1991). This study revealed a significant difference between yields of treated and untreated crops.

In conclusion, heavy infestation and damage by stem borers in borer endemic zones may be reduced by early planting, since there were no significant differences in many cases in results obtained by applying carbofuran and the two bio-insecticides. *G. arborea* was less efficient than carbofuran and *A. indica* used the later are preferred since they are environmentally more friendly. Besides, they are readily available, cheap and do not require robust processing to obtain the products hence can be recommended for use by the poor resource farmers.

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