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Effect of Neem Seed Kernel Extracts in the Management of Rice Stem Borers in the Field in Nigeria

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Abstract
Stem borers are economic pests of rice and its management through conventional methods has not given the desired results. Hence in this study field experiments were conducted to determine the comparative efficacy of neem seed kernel extracts (*Azadirachta indica;* (Neem) and synthetic insecticide (Carbofuradan) against rice stem borers in Nigeria during 2006/07 farming season. The effect of these sprayings was also recorded on natural enemies and yield attributes. Results showed that the two pesticides significantly ($p < 0.01$) reduced stem borers damage (number of dead hearts, white heads) compared to untreated check, and also significantly ($p < 0.05$) increased number of productive tillers with resultant increase in grain yield than the control plots. Maximum numbers of different natural enemies were found in neem extract treated plots against the carbofuran treated plots. It is suggested that on the basis of infestation of borer, high yield and conservation of natural enemies, neem seed extract can be regarded as suitable alternative to synthetic insecticides for the management of rice stem borers in the field.

Keywords: Botanical/insecticide, stem borer control
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Introduction

Rice (*Oryzae sativa* L.) is one of the world's most important crops providing a staple food for nearly half of the Global population (FAO, 2004), and for 2.7 billion people in developing countries (FAO, 1995). Nigeria is the largest producer of rice in West Africa with average of 3.2 million tons of paddy rice (USDA, 2002, Nwilene *et al.*, 2008). Although rice is grown virtually in all agro ecological zones of Nigeria, rice production is still far below the potentials and domestic needs. One of the major reasons for the low yield of rice in Nigeria is depredation by insect pests (Imolehin and Ukwungwu, 1992). Rice plant is an ideal host for a large number of insect pests in West Africa (Heinrichs and Barrion, 2004). Of all the insect pests of rice, stem borers are the most important insect pests of rice especially to small-scale farmers.

They are about 20 species of stem borers identified damaging rice plant worldwide. However, only four species are of economic importance in Nigeria. These include *Chilo zacconius* Bles, *Diopsis macropathalman* Daman, *Maliarpha separatalla* Rog, and *Sesamia calamistis* (Heinrichs ang Barrion, 2004). The distribution and abundance of these species vary among rice ecosystem within a given location. For example, *Maliarpha separatella and Chilo* spp occurs in all climatic zones in West Africa but they are more abundant in the rain fed lowland and irrigated ecosystems than in the uplands and is the most abundant stem borer species in the mangrove swamps while *Sesamia* spp predominated the uplands (Heinrichs and Barrion 2004).

These borers attack rice plant at different growth stages from vegetables stages to grain development. Feeding during the vegetable growth stage causes death of the central shoot 'dead heart' (DH). Damaged shoot do not produce a panicle and thus produce no grain. Feeding of stem borers during the reproductive stage (panicle initiation to milk grain) causes a severing of the developing panicle at its base. As a result, the panicle is unfilled and whitish in colour; rather than filled with grain and brownish colour 'whitehead' (WH), (Mahmood-ur-Rehman, *et al.* 2007). Rice stem borers have been reported to cause yield losses ranging from 30 to 80 % and 100 % loss has been recorded in worst affected fields in Nigeria (Imolehin and Ukwungwu 1992). In many parts of Africa the borers destroy to 30% -50% of plant tillers during the wet cropping season thereby compromising the whole harvest (Daouo *et al*., 1991).

For farmers and researchers alike reducing the numbers of these pests is therefore a priority. In the past emphasis has been on the use of synthetic insecticides for the control of stem borers; however, insecticides have not been effective in the control of stem borers due to cryptic nature of its attack. In addition, insecticides are known to destabilize the ecosystem for sustainable production of rice and are generally not affordable to African peasant farmers. In order to alleviate growing public concerns regarding the effects of synthetic pesticides on human health and environmental impact much attention has been given to botanicals pesticides in the recent decades. Botanicals are considered environmentally friendly; besides, this method does not only reduce application of synthetic insecticides, but also reduce the cost of pest management, which is an important factor for farmers in developing countries. More so the interest in the use of biopesticides is on the increase in the recent years particularly in cropping system where the use of natural enemies are being emphasized as a major component of integrated pest management (Rausell *et al*., 2000). Use of these natural compounds in place of conventional insecticides can reduce environmental pollution, preserve non-target organisms and avert insecticide induced pest resurgence.

Bioinsecticides are seldom as effective as chemicals in their wild-type form. The efficacies of botanicals are largely demonstrated in insect management and have been advocated for use by resource poor farmers (Huang *et al.* 2000; Dal Bello *et al*. 2001; Taponjou *et al*. 2002). Plants produce a diversity of biologically active substances that affect the growth and development of other organisms and can provide protection against the herbivores. These plant products discourage or prevent an attack from the non-adapted organisms and play an important role in the ecology and physiology of phytophagous insects (Sukumar, 1993). These include neem products, chilies, tobacco products and wood ashes etc (Anon. 2000). However some of these botanicals have not been fully evaluated especially under field conditions in Nigeria. The neem tree *Azadirachta indica* A. Juss (Meliaceae) has been widely studied because it presents a great number of compounds with insecticides properties which can effectively reduce the population of several insect pests (Dhuyo and Soomro 2007, Sagheer *et al*., 2008). It is generally believed that the bioactivity of neem is due to its complex limonoids that suppressed the feeding, growth, and reproduction aspects of the pest insects (Walter 1999) and have, thus, been used in many integrated pest management (IPM) programs (Huang *et al.,* 2004). Chemical preparations from the leaves and seeds of the Indian neem tree, *Azadirachta indica* A. Juss. (Meliaceae), have been shown to have deleterious effects on the insects (Schmutterer, 1990). The use of neem products for the management of insect pest has been demonstrated with variable success (Bhanukiran & Panwar, 2000). The fact that azadirachtin is selective towards phytophagous insects with minimal toxicity to beneficial insects increases its potential value to pest management (Naumann and Isman 1996). Their use on field crops is not yet popular in Nigeria and the spectrum and level of its efficacy are not yet known against the rice stem borers in the field.

Furthermore Pest management programme in rice in recent years rely on the impact of natural enemies in maintaining economic pest population below economic injury levels and a number of natural enemies have been employed in the control of stem borers of rice, selective biopesticides that aid in managing these borers without harming these natural enemies may be needed.

Consequently, this study was conducted to determine the efficacy of neem seed extracts as an alternative to synthetic insecticides in the management of rice stem borers in the field in Nigeria.

Materials and Methods

Study site: The experiments were conducted at Africa Rice Centre (WARDA) Research Farm at Ogidiga in Abakaliki during 2006 and 2007 farming seasons under rain fed low land conditions. Abakaliki falls within the forest savannah transition agro-ecological zone with geographical bearing of latitude 06^o 17′ N, longitude 08^o 04′ E and altitude 104.40m above sea level, with an annual average rainfall of about 1800-2200mm per annum, distributed between May and October. The average daily temperature fluctuates between 20 and 35 ^{o}C with an annual mean of 26.5^{o}C. Mean relative humidity is in the range of 64 – 83. The soil is Utisol and slightly acidic with 4.5 to 4.9 acidity**.**

Experimental design: The experiments were laid out in split-plot in randomized complete block design with three replications. A susceptible and improved rice variety ITA 306 (FARO 37) used for the experiments served as the main plot treatments while the application of crude neem seed kernel extracts (NSK), Carbofuran and untreated control plots constituted the subplots. Earth bunds were used to demarcate both the main-plots and sub-plots respectively to avoid lateral pesticides drift. Twenty–eight day old rice seedlings were transplanted in rows into 20 m^2 plots. Two seedlings were transplanted per hill at 20 x 20 cm plant spacing.

Preparation and application of treatments: The neem seed kernel crude extracts was prepared as follows:

Dried neem seeds were decorticated in a blender and kernels were separated out in an air driven aspirator. NSK were crushed to powder, sieved through 36 + 52 mesh then dispersed in water, stirs for 1 hr and left for 24 hrs before filtering according to (Tanzubil 1991). The extract was concentrated at 50^{o}C in a rotary evaporator and stored in a desicator for subsequent use. Liquid soap at 0.1% of soap was added as emulsifier. The extracts was applied at 5% NSK concentration at 10 days interval starting from 14 days after transplanting, to cover early tillering; maximum tillering; and early booting. It was sprayed to the runoff point at each application.

Carbofuran 3G at 13 kg ha^{-1} was applied at 1, 30 and 60 DAT while the control plots did not receive either of the pesticides. All treated and untreated control plots received basal fertilizer application at the rate of 40 kg urea, 40 kg,P_2O_5 and 40 kg K_2O per ha. Thereafter, nitrogen fertilizer in form of urea was applied in two splits doses; 25 % top dressing four weeks after transplanting and 25 % top dressing at panicle initiation to all the plots. Weeding was done at three weeks interval. The number of plants attacked by stem borers was recorded at 50 and 80 days after transplanting.

Parameters measured: Data were collected on percent dead heart (DH) and whitehead (WH) from 20 hills randomly selected from each plot. The 20 hills were randomly selected at set intervals along parallel transects through the crops, while leaving the border rows. The selected plants were used for closer examination on incidence of stem borers' damage at 50 and 80 DAT. Sampled rice hills were up rooted and dissected ten days before harvest to record different species of stem borers that were prevalent in the experimental plots. The collection and identification of natural enemies of rice stem borers was done fortnightly starting from 30 days after transplanting on all the treatments till 80 DAT. The natural enemies were collected by sweep net and the visual count method. The collected natural enemies were kept separately, and identified in the laboratory.

Grain yield was recorded from each plot. All plants on each plot were harvested, dried and threshed and the grains were weighed at 14% moisture content; the weights were converted in terms of tons per ha before comparisons were made between the treatments.

All the data collected were subjected to analyses of variance by PROC GLM (SAS 1996). Damage percentages were subjected to arsine transformation before analyses of variance were carried out on them. Significant differences between treatments were determined by student-Newman-Keuls (SNK) test at 5% probability level.

Results

The result of the investigation showed that the two pesticides significantly ($p < 0.01$) reduced stem borers damage compared to untreated check (Table 1). The application of pesticides at different plant growth stages reduced DH incidence but the values were not significantly different from that of the untreated control plot. However, application from maximum tillering onward reduced DH significantly compared to that of the untreated control plots. Plots treated with Carbofuran recorded the least percentage DH damage throughout the experimental period and significantly different from the untreated plots, but were not significantly different from plots treated with neem seed extract during 2006 experimental period. However, that was not the case during 2007 farming season that showed significant effect on all the three factors assessed with Carbofuran giving the least percentage DH.

Table 1: Effect of neem seed extracts and Furadan on the incidence of rice dead heart in the field at 50/80 DAT during 2006/07 farming seasons

	Mean percentage of stem borer damage per treatment			
Pesticides	**2006**		**2007**	
	50 DAT	**80 DAT**	**50 DAT**	**80 DAT**
NSk extracts	10.7±1.2a	12.3±1.3a	13.5±1.3b	16.9±1.8b
Furadan	5.3±0.3a	6.7±1.3a	0.0±0.0a	2.9±1.1a
Control	26.1±2.1b	29.9±2.6b	21.4±0.9c	25.2±2.3c

Mean ± SE within a column followed by the same letter are not significantly different at P> 0.05, Student-Newman-Keuls (SNK) test

Likewise, comparable white head percentage was noted among the treatments (plant extracts and chemical pesticide), which was significantly lower than the white dead percentage recorded in un-treated control (Table 2).

Table 2: Effect of neem seed extracts and Furadan on incidence of rice white head in the field during 2006/07 farming seasons

	White head	
Pesticides	**2006**	**2007**
NSk extracts	16.7±1.3a	28.9±2.1b
Furadan	20.6±2.0a	13.9±1.4a
Control	46.1±3.5b	42.9±3.1c

Mean ± SE within a column followed by the same letter are not significantly different at P> 0.05, Student-Newman-Keuls (SNK) test

The results of the investigation showed that the trend of the stem borer incidence (DH and WH) were the same throughout the experimental years. However the incidences were more in 2006 than in 2007 farming season.

The correlation between dead heart at 50 DAT and white heads at 80 DAT were positive ($r = 0.866$, and $r = 0.686$, ($P = 0.001$) for 2006 and 2007 respectively, indicating that as dead heart formation at the vegetative stage increased, the rate of white head formation at the heading stage increased.

Three borer species were recovered after sampling each plot. The species were *Maliarpha separatella, Chilo zacconius and Sesamia sp.* The mean percentage population for the two years of each species recovered to the total population was 70.6, 24.9 and 4.5 respectively (Fig. 1). Although *Maliarpha* was the predominant species, many of its larvae were recovered from tillers that did not show any visible signs of damage. These tillers appear normal unlike the tillers which showed dead heart or white head from which other borers were recovered. Some adults of *Diopsis* sp that were present at the rice field at the early stages of the plant growth might have contributed significantly to the damage at the early vegetative growth. However, during the dissection of the tillers, before harvest, no *Diopsis* larvae or pupae were recovered.

Results on the availability of natural enemies (predators and parasitoids) in different treatments showed that almost same number of these organisms were found in the plots treated with neem seed extracts and un-treated control (*Conocephalus conocephalus* 15 and 16; *Labiduria riparia* 5 and 5; *Oxyopes javanus* 8 and 9; *Goniozus indicus* 4 and 6; *Bracon*

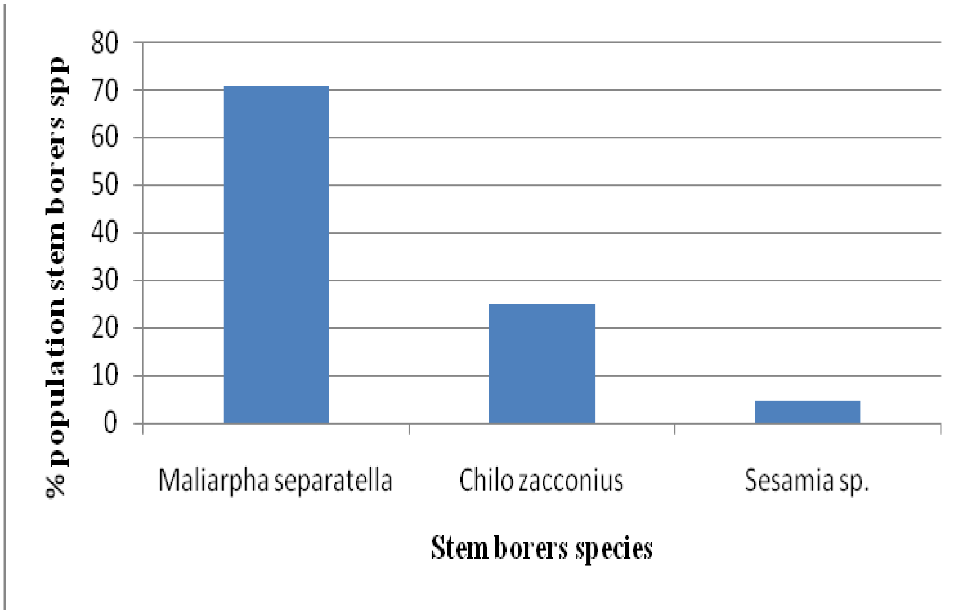

Fig. 1: Percentage population of different stem borers found in the field

testaceorufatus 3 and 3; *Trichogramma japonicum* 5 and 6) for 2006 and 2007 respectively, which was higher than the number of these organisms available in Furadan treated plots. The least number of these organisms were recorded in the plots treated with Carbofuran (Table 3).

Effect of the treatments on rice grain yield: There were significance relationships between the stem borers' incidence and the grain yield of rice throughout the period of the experiments. Plots treated with neem, seed extracts produced significantly (P<0.05) higher grain yield of 4.5 t and 5.0 t ha^{-1} for 2006 and 2007 respectively, than Carbofuran treated plots; 4.1t and 4.5t ha^{-1} and untreated control 2.8 and 3.0 t ha^{-1} for 2006 and 2007 respectively (Table 4). In terms of grain yield the order was neem extracts (ha^{-1}) > Carbofuran (t ha^{-1}) > Control (t ha^{-1}).

Table 3: Population of different natural enemies of stem borers found in the rice field

Treatments	Predators			Parasitoids		
	Conocephalus conocephalus	*Labiduria riparia*	*Oxyopes javanus*	*Goniozus indicus*	*Bracon testaceorufatus*	*Trichogramma japonicum*
NSK	15	5	8	4	3	5
Furadan	1	-	1	-	-	-
Control	16	5	9	6	3	6

Table 4: Effect of treatments on rice grain yield (t ha^{-1}) and percentage yield gain/loss due to treatment application during 2006/2007 farming season

Treatment	Yield (t)		Yield gain/loss			
	2006	2007	2006		2007	
			% yield loss	% yield gain	% yield loss	% yield gain
NSK	4.5	5.0	43	56.7	21	78.6
Furadan	4.1	4.5	38.5	61	19.7	79.7
Control	2.8	3.0				

Yield gain as a result of the treatments showed that plots treated with neem seed extract gave the highest yield return throughout the period of the experiment with 61% and 79.7% yield gain for 2006 and 2007 respectively, while plots treated with Carbofuran gave yield return of 56.7% and 78.6% or 2006 and 2007 respectively. On the other hand, yield loss was highest in untreated control plots than the treated plots (neem seed extract and Carbofuran).

Discussion

Field results indicated that neem seed extract was effective in controlling rice stem borers at concentration as low as 5%. The results of this study reveals that the plots treated with neem extract had the lowest percentage dead hearts and white heads incidence. These results are in line with the findings of Rath (2001); Prasad *et al.*, (2004) and Bora *et al.* (2004) who found Neem products to control yellow rice stem borer. Experimental trials have reported the control of pests of several field crops and stored products using neem derivative (Bhanukiran & Panwar, 2000). Neem oil and neem cake were found to be highly effective in reducing rice tungro virus transmission by the green leafhopper, Nephottettix virescens (Stool 2000). The application of 5% neem seed kernel extract on rice has been reported to give significant control of yellow rice stem borer by reducing damage and increasing the yield (Amaugo and Emosairu, 2005).

The results of this study have important implications for field control of rice stem borers. Application of neem seed extracts in the field could protect growing rice in two ways. Firstly, the crop would be protected via the primary gustatory repellent action of the extracts which they ingest in attempting to feed on foliage, and secondly, larvae picking up residues on sprayed foliage during spray application or through foraging behaviour can suffer feeding inhibition and high mortality, resulting in reduced crop damage. Neem seed kernel extract has been reported as an antifeedant and insect growth regulator against many insect pests (Mordue and Blackwell, 1993). The growth regulatory effect is the most important physiological effect of neem on insects. It is because of this property that neem has emerged as a source of insecticides. Antifeedant activity and inhibition of hormone and enzyme activity have been attributed to the tetranortriterpenoid, azadirachtin, in the extract (Nathen *et al,* 2004; Nathen *et al.,* 2005a, b).

Although ultimate and comprehensive control of stem borers may not be achieved through neem application alone, their use could still guarantee reasonable levels of protection to a growing crop. Application of botanicals could greatly reduces the large-scale use of synthetic insecticides.

The positive correlation recorded on the dead heart at 50 DAT and white head at 80 DAT indicated that re-infestation at the flowering stage was higher in cultivar that attracted more insects at the vegetative stage.

The presence of almost the same number of natural enemies on neem seed extracts treated and untreated plots indicates that this biopesticide is nontoxic to beneficial insects, and might be compatible with biological controls currently invoke in desirable crops such as rice that often cover large hectares. Similar result has been reported by Dhuyo and Soomro (2007) in their study on efficacy of plant extracts against yellow rice stem borer. According to them maximum number of different predators was found in neem extract treated plot.

The presence of Maliarpha sp on tillers that appear to be normal observed in this study has been reported by Akinsola (1990). He reported Maliarpha as the major rice stem borer, making up about 70 percent of the borer population in most parts of Nigeria and because of their peculiar feeding habits, they do not show external signs of infestation.

The comparable but significantly higher grain yield produced by the treatment than un-treated control showed that plant extracts controlled rice stem borers as efficiently as chemical pesticides. Similarly the higher yield return recorded in plots treated with neem extracts indicated that neem did not only serve as biopesticid, rather it increased the fertility of the soil as well. Similar result has been recorded by earlier researchers. Neem biopesticide may therefore be suited for inclusion in rice integrated pest management programmes.

Conclusion

Although in this experiment it was impossible to completely prevent stem borer damage through the pesticides applied, the results obtained amply demonstrate the adverse effect of the pesticides on the incidence of stem borers and yield implications. The results indicated that substantial yield increases when they are effectively protected from stem borers attack.

Therefore, it is concluded that neem extract can be a suitable alternate to synthetic pesticide for controlling rice stem borer without disrupting agro-ecosystem.

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