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ORIGINAL RESEARCH ARTICLE

Population Dynamics and Damage by Pod-Sucking Bugs under Integrated Pest Management Strategies in Cowpea (*Vigna unguiculata* L. Walp.) in the Sudan Savanna of Nigeria

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ABSTRACT

Insect pests remain a major production bottleneck, particularly those that infest the crop during the post-flowering stage. Pod-sucking bug complexes can inflict severe damage on cowpea productivity if unchecked. A field trial consisting of intra-row spacings, sowing dates, and pesticides as a combination of Integrated Pest Management (IPM) was carried out on a complex of pod sucking bugs (CPSBs) population during the rainy seasons of 2015 and 2016, respectively, in Katsina. The experiment was laid out using a split-split plot design, with intra-row spacing allocated to the main plot, sowing dates to the sub-plot, and the sub-sub-plots allocated to pesticides. NKE powder was used at the rate of 5 kg ha^{-1}, mixed with 2 kg ha^{-1} bar soap as an emulsifier. The viral suspension was diluted to a concentration of 7.57×10^{11} and applied at 106 ml in 115 L of water per hectare. The synthetic insecticide containing cypermethrin (30 g L^{-1}) and dimethoate (250 g L^{-1}) was applied at 1.5 L ha^{-1} using a CP-3 knapsack sprayer. The treatments were randomized and replicated three times. Data collected were measured on the CPSB population and final cowpea grain yield, which were subjected to analysis of variance, and means were separated using LSD at 5%. The result showed that varying cowpea sowing from 2nd July (1.29) to 13th Aug. (1.23) significantly ($P \leq .05$) reduced CPSBs, with its peak population occurring on cowpea sown on 23rd July (1.48), respectively, in all the sampling weeks. Use of MaviMNPV (1.30), neem (1.26), and cyper diforce (1.25) significantly reduced CPSBs population compared with the control (1.50). However, synthetic insecticidess recorded lower CPSB but were comparable to other control options. The result of the combined interaction showed that varying sowing to 23rd July and using cyper diforce produced the lowest effect (1.22) CPSB per plot. The result of the use of pesticides showed that, significantly ($\text{P} \leq .05$), the highest grain yield per hectare was recorded in the combine interaction of varying sowing to 13th Aug. + insecticidal spray (631.49 kg ha^{-1}). Therefore, it is concluded that CPSB damage on cowpea is directly proportionate to their numbers. It is recommended that varying cowpea sowing and the use of pesticides will reduce CPSB populations on cowpea and, consequently, reduce cowpea damage in the study area.

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Pod-sucking bugs, population, IPM component, Sadano-Sahelian ecology and Nigeria

INTRODUCTION

Cowpea (*Vigna unguiculata* L. Walp.) is widely cultivated as a grain legume across sub-Saharan Africa, Asia, and parts of Latin America. It is a dicotyledonous plant belonging to the family Fabaceae and represents one of the most important food legumes grown in tropical and subtropical regions (Oyewale & Bamaiyi, 2013). In Africa, cowpea is predominantly produced by smallholder farmers as a subsistence crop and plays a vital role in food security. According to Ajeigbe *et al.* (2012) and the International Institute of Tropical Agriculture (IITA, 2009), cowpea cultivation is concentrated mainly in the savanna zones of Africa, Asia, and South America, where it provides a major source of dietary protein, income generation, and livestock feed (Ajeigbe *et al.*, 2012; Ahmed *et al.*, 2009). The African Agricultural Technology Foundation (AATF, 2011) identified cowpea as the most important grain legume in the dry savannas of tropical Africa, occupying over 12.8 million hectares and providing nearly 200 million Africans with food (AATF, 2014). Despite its socioeconomic importance, cowpea productivity is severely limited by numerous biotic and abiotic constraints.

In West Africa, cowpea significantly contributes to household nutrition and income, especially within the

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savanna agro-ecological zones. However, insect pests remain a major production bottleneck, particularly those that infest the crop during the post-flowering stage. Although cowpea is well adapted to marginal environments, its yield remains far below its genetic potential, largely due to insect pest pressure (Jackai & Daoust, 1986). Post-flowering pests attack flowers, pods, and developing seeds, resulting in considerable yield reduction and deterioration of grain quality (Karungi *et al.*, 2000). Under severe infestation and without control measures, yield losses can exceed 70–80% (Sharma, 1998), and in extreme cases, losses of up to 90% have been reported (Lambot, 2002; IITA, 2009).

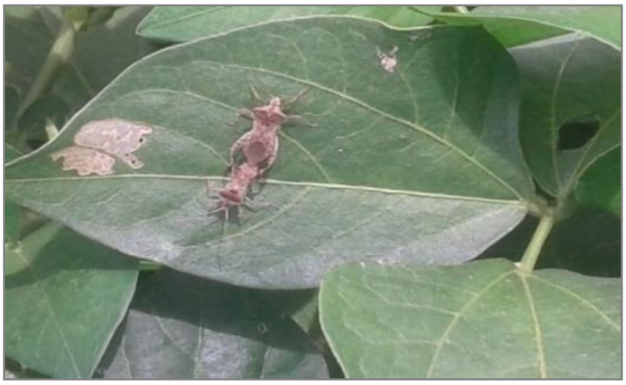

Plate I: Spiny brown bug, *Clavigralla tomentosicollis* Stal. [Hemiptera: Coroeidae]

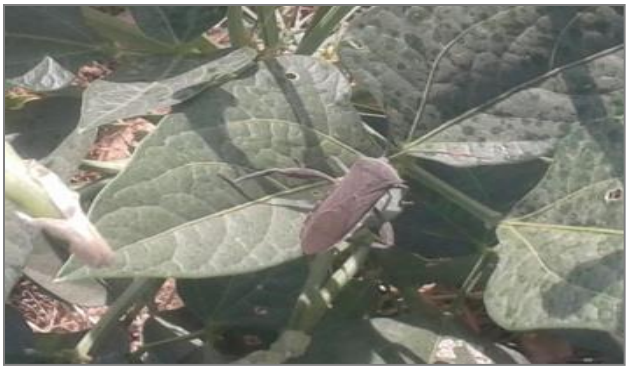

Plate II: Giant coreid bug, *Anoplocnemis curvipes* L. [Hemiptera: Coroeidae]

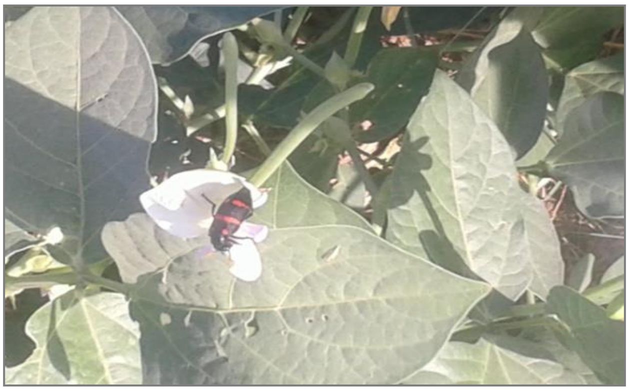

Plate III: Flower/Pollen beetle, *Mylabris* sp L. (Coleoptera: Curculionidae)

The most destructive post-flowering pests of cowpea include: pod-sucking bug complexes such as the spiny brown bug, *Clavigralla tomentosicollis* Stål [Hemiptera: Coroeidae] (Plate I), and the giant coreid bug, *Anoplocnemis curvipes* (F.) [Hemiptera: Coroeidae] (Plate II); flower-feeding blister beetles, *Mylabris* spp. [Coleoptera: Curculionidae) (Plate III); cowpea aphids, *Aphis craccivora* Koch [Hemiptera: Aphididae] (Plate IV); flower bud thrip, *Megalurothrips sjostedti* Trybom [Thysanoptera: Thripidae] (Plate V); the green stink bug, *Nezara viridula* Linnaeus [Hemiptera: Pentatomidae] (Plate VI); the legume pod borer, *Maruca vitrata* (Fab.) (Lepidoptera: Crambidae) (Plate VII) and three-spot shield bug, *Aspagia armigera* L., [Hemiptera: Pentatomidae] (Plate VIII).

Plate IV: *Aphis craccivora* Koch (Hemiptera: Aphidiae)

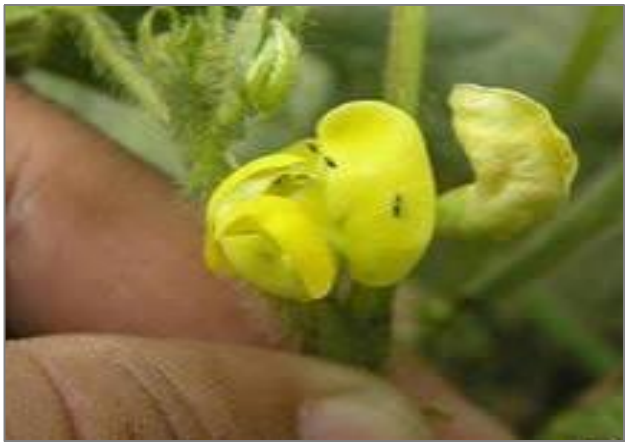

Plate V: Thrips, *Megalurothrips sjostedti* Trybom (Thysanoptera: Thripidiae)

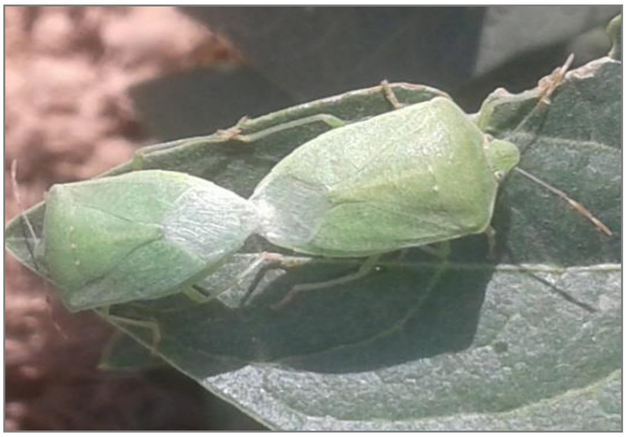

Plate VI: Green stink bug, *Nezara viridula* (Linn.) [Hemiptera: Pentatomidae]

These insects primarily cause damage by extracting sap from developing pods and seeds. Pod-sucking bugs are regarded as the most economically important pod pests of cowpea in Africa. Both nymphs and adults penetrate pod walls to feed on developing seeds, resulting in shrivelled grains, pod discoloration, reduced seed weight, and poor germination (Singh & van Emden, 1979). Additionally, feeding damage facilitates the entry of secondary pathogens, further compromising grain quality (Wudil *et al.*, 2013). Severe infestations significantly lower both marketable yield and seed viability (Karungi *et al.*, 2000).

Plate VII. Cowpea pod-borer, *M. vitrata* (Fab.) (Lepidoptera: Crambidiae)

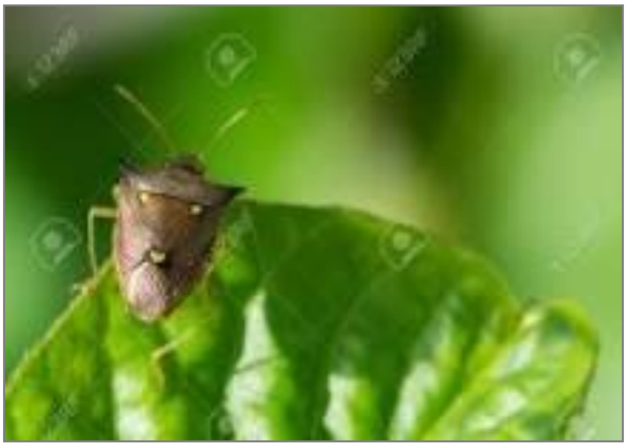

Plate VIII: Three-spot shield bug, *Aspagia armigera* L. [Hemiptera: Pentatomidae]

Post-flowering insect pests are responsible for the greatest proportion of yield losses in cowpea production systems. Evidence shows that combined infestations of *M. vitrata* and pod-sucking bugs can cause yield reductions exceeding 80% when no control measures are applied (Oerke, 2006). Beyond quantitative yield loss, these pests adversely affect seed quality, germination capacity, and market value, thereby disrupting food and seed systems. Yield losses attributed to *M. vitrata* alone range from 20% to more than 80%, depending on varietal resistance, planting time, and pest management practices (Karungi *et al.*, 2000). In severe outbreaks, total crop failure has been observed, particularly in untreated fields. These losses disproportionately affect smallholder farmers who often lack access to effective pest control technologies, discouraging cowpea cultivation and limiting the adoption of improved varieties.

Sustainable cowpea production therefore, depends on effective management of post-flowering insect pests. Conventional calendar-based insecticide applications are often ineffective against pests such as *M. vitrata* due to their concealed feeding habits and also pose environmental risks (Jackai, 1995). Consequently, integrated pest management (IPM) strategies incorporating host plant resistance, biological control agents, botanical insecticides, and judicious use of synthetic chemicals are increasingly promoted. Cultural practices such as adjusting sowing dates and intra-row spacing have been shown to influence pest incidence. Early planting, in particular, enables crops to escape peak insect populations and has been associated with reduced pest infestation and improved yields (Nabirye *et al.*, 2003; Karungi *et al.*, 2000).

Despite these alternatives, synthetic insecticides remain widely used among cowpea farmers in the Sudano–Sahelian zone. However, indiscriminate pesticide use has resulted in environmental contamination, destruction of beneficial organisms, and increased health risks for farmers (Muhammad *et al.*, 2024; Oyewale *et al.*, 2014). Persistent pesticide residues pollute aquatic and terrestrial ecosystems, disrupt ecological balance, and adversely affect non-target organisms, including soil fauna, predators, pollinators, birds, and wildlife (Degri *et al.*, 2012; Muhammad *et al.*, 2018; Muhammad *et al.*, 2024). Moreover, intensive pesticide use has been linked to pest resurgence and the emergence of secondary pest species (Ahmed *et al.*, 2010). These challenges, combined with high costs, underscore the need for alternative, environmentally friendly pest management strategies.

No single control method is sufficient to manage the complex of cowpea pests. Microbial biopesticides, particularly entomopathogenic fungi and viruses, have shown promising results, especially in stored product protection (Ahmed *et al.*, 2010). The use of *Maruca vitrata* multinucleopolyhedrovirus (MaviMNPV) has demonstrated effectiveness in controlling *M. vitrata* populations (Muhammad *et al.*, 2018, 2019, 2021), and specific baculovirus formulations have been developed for this purpose (Tamo & Srinivasan, 2012). Integrating multiple control options such as cultural practices, host plant resistance, and minimal insecticide application has proven effective in managing *M. vitrata* infestations (Karungi *et al.*, 1999). Asante *et al.* (2001) further emphasized the effectiveness of combining improved cultivars, optimized planting dates, and well-timed, limited insecticide applications. A lot of research was carried out on the use of pesticides on CPSB in cowpea. No work was reported on the use of baculovirus (MaviMNPV) in the study area on CPSB. Consequently, this study was designed to evaluate the combined effects of intra-row spacings, sowing dates, and pesticide application on the management of selected post-flowering insect pests, particularly the spiny brown bug, *C. tomentosicollis* (Plate I), and the giant coreid bug, *A. curvipes* (Plate II).

MATERIALS AND METHODS

Study Area

Field experiments were conducted during the 2015 and 2016 rainy seasons at the Teaching and Research Farm of the College of Agriculture, Hassan Usman Katsina Polytechnic. The site lies between latitudes 11°07'49" and 13°22'57" N and longitudes 06°52'03" and 09°02'40" E, at an altitude of 619 m above sea level, within the Sudan savanna ecological zone (Ibrahim & Sani, 2012). The area experiences a unimodal rainfall pattern, averaging about 742 mm annually, with rainfall commencing in May/June and ending in September/October, with peak rainfall in August and September. The climate is hot and semi-arid, with mean temperatures ranging from 33.2 to 42.2°C and an average relative humidity of about 60% at 07:00 h. The soil type is predominantly sandy loam (MOANR, 2013).

Sources and Preparation of Pesticides

Neem kernel seed extract (NKE) was prepared from mature neem seeds collected after rainfall from neem forest reserves around Katsina. The seeds were depulped, washed, shade-dried, cracked, and the kernels ground into powder using an electric blender. A quantity of 5 kg ha^{-1} of the powder, together with 2 kg ha^{-1} of bar soap as an emulsifier, was wrapped in clean cloth and soaked overnight in water (Muhammad *et al.*, 2017, 2018, 2019). The mixture was thoroughly stirred and squeezed to obtain a milky suspension following the method described by Oparaeke *et al.* (2005a) and Oparaeke (2006). Liquid gum arabic was added at a rate of 2.7 kg in 6.75 L water ha^{-1} (Kwaifa *et al.*, 2012).

The *M. vitrata* multinucleopolyhedrovirus (MaviMNPV) suspension was obtained from IITA, Cotonou, Benin, and applied according to the protocol described by Sokame *et al.* (2015). The suspension was diluted to a concentration of 7.57 × 10^{11} and applied at 106 ml per hectare in 115 L of water. The synthetic insecticide Cyper diforce®, a class II insecticide containing cypermethrin (30 g L^{-1}) and dimethoate (250 g L^{-1}), was applied at 1.5 L ha^{-1} using a CP-3 knapsack sprayer fitted with a hollow cone nozzle (Muhammad *et al.*, 2019).

Treatments and Experimental Design

The experiment comprised three intra-row spacings, three sowing dates, three pesticide treatments (two biopesticides, NKE and MaviMNPV and one synthetic insecticide), and an untreated control. A split–split plot design was employed, with intra-row spacing as the main plot factor: 75 × 20 cm (SP_1), 75 × 30 cm (SP_2, commonly used by farmers), and 75 × 40 cm (SP_3). Sowing dates (2nd July, 23rd July, and 13th Aug.) constituted the sub-plot factor, while pesticide treatments NKE (P_1), MaviMNPV (P_2), Cyper diforce® (P_3), and control (P_0) were assigned to sub-sub-plots. Treatments were randomized and replicated three times. Each plot measured 6 m × 4.5 m (27 m^2) and consisted of six ridges spaced 0.75 m apart. The two central rows served as the net plot, with adjacent rows used for sampling and border rows for buffering (Kwaifa *et al.*, 2012). The experiment was repeated in 2016 using the same layout.

Agronomic Practices

The field was ploughed, harrowed, and ridged mechanically. The cowpea variety SAMPEA 7, known to be susceptible to M. vitrata, was used. Seeds were treated prior to planting with Allstar® 40 SD (20% metalaxyl and 20% imidacloprid) at a rate of one sachet per 4 kg of seed (Oparaeke *et al.*, 2005a). Planting was conducted at three-week intervals, with three seeds sown per hole and later thinned to two plants per stand. Single superphosphate fertilizer was applied at 25 kg ha^{-1} immediately after sowing. Mancozeb (80%) was applied at 1.782 kg ha^{-1} for disease control. Weeding was carried out at 3 and 6 weeks after sowing, and gaps were filled three weeks after emergence (Ogah, 2013; Muhammad *et al.*, 2018, 2019).

Pesticide applications commenced at 7 weeks after sowing, coinciding with the flowering stage of the crop. Extracts and synthetic insecticides were applied using CP-3 knapsack sprayers, while the viral suspension was applied using a hand-operated sprayer. Spraying was carried out between 06:00 and 07:00 h once weekly for four consecutive weeks (Oparaeke *et al.*, 2005a).

Data Collection

Assessment of Pod-Sucking Bug Populations

Populations of complex pod-sucking bugs were assessed at 8, 9, and 10 weeks after sowing. Insect counts were conducted early in the morning (06:00–07:00 h) under calm weather conditions. Mean populations of spiny brown bugs and giant coreid bugs were recorded per plot (Muhammad *et al.*, 2019).

Data Analysis

The collected data were subjected to analysis of variance (ANOVA). Treatment means were separated using the least significant difference (LSD) test at the 5% significance level in SAS (SAS, 2000). Data containing zero values were square-root transformed ($\sqrt{n} + 0.5$) prior to analysis to stabilize variance (Muhammad *et al.*, 2019).

RESULTS

Effect of intra-row spacings, sowing dates and pesticides on complex of pod sucking bugs (CPSB) populations in Katsina during 2015 and 2016 Cropping Seasons

Varying sowing dates significantly affect the CPSB population at 10 WAS during the 2015 cropping season. Cowpea sown on 13th Aug. recorded the lowest mean (1.22), compared with sowing on 2nd July and 23rd July, which were statistically at par (1.34 and 1.45, respectively).

Table 1: Effect of intra-row spacings, sowing dates and pesticides on post-spray populations of (Giant coreid bug, *Anoplocnemis curvipes* and (Spiny brown bug, *Clavigralla tomentosicollis*) sampled 8, 9 and 10 WAS during 2015 and 2016 cropping seasons in Katsina

Treatments	8 WAS	9 WAS	10 WAS	8 WAS	9 WAS	10 WAS	8 WAS	9 WAS	10 WAS
		2015			2016			Combined	
SP1; 75 x 20	1.36	1.44	1.35	1.62	1.59	1.29	1.49	1.52	1.32
SP2: 75 x 30	1.41	1.45	1.36	1.66	1.56	1.33	1.54	1.51	1.34
SP3: 75 x 40	1.40	1.36	1.31	1.52	1.54	1.33	1.46	1.45	1.32
Mean	1.39	1.42	1.34	1.60	1.56	1.32	1.50	1.50	1.33
LSD	0.233	0.100	0.147	0.151	0.506	0.233	0.132	0.244	0.089
Sowing dates (SD)									
SD1 (2nd July)	1.50	1.48	1.35a	2.03a	2.21a	1.22b	1.76a	1.84a	1.29b
SD2 (23rd July)	1.37	1.54	1.45a	1.56b	1.25b	1.50a	1.47b	1.39b	1.48a
SD3 (13th Aug.)	1.30	1.24	1.22b	1.22c	1.23b	1.22b	1.26c	1.24b	1.23b
Mean	1.39	1.42	1.34	1.60	1.56	1.32	1.50	1.50	1.33
LSD	0.212	0.616	0.147	0.234	0.257		0.167	0.284	0.128
Pesticides (P)									
P1: Neem seeds kernels extract	1.43	1.37	1.24b	1.47b	1.29bc	1.29b	1.45b	1.33b	1.26b
P2: MaviMNPV suspension	1.28	1.26	1.30b	1.53b	1.61b	1.30b	1.40b	1.44b	1.30b
P3: Cyper diforce	1.39	1.40	1.28b	1.22c	1.24c	1.21b	1.31b	1.32b	1.25b
P0: Control	1.47	1.64	1.53a	2.18a	2.12a	1.47a	1.83a	1.88a	1.50a
Mean	1.39	1.42	1.34	1.60	1.56	1.32	1.50	1.50	1.33
LSD	0.208	0.252	0.150	0.187	0.334		0.138	0.207	0.106
Interactions									
SD x SP	NS	NS	NS	*	NS	NS	NS	NS	NS
SD x P	NS	*	**	**	**	**	**	**	**
SD x P	NS	NS	NS	NS	NS	*	NS	NS	NS
SD x SP x P	NS	NS	NS	NS	NS	NS	NS	NS	NS

Means with the same letter(s) in the same column are not significantly different using LSD at 5 % level, NS -not significant, * significant at $P \leq .05$, **-highly significant at $P \leq .01$, WAS-weeks after sowing, SD-sowing dates, SP-Intra-row spacing, P-Pesticides, 2nd july; 02/07/2015 and 02/07/2016, 23rd July; 23/07/2015 and 23/07/2016, 13th Aug.; 13/08/2015 and 13/08/2016

Table 2: Combined Interaction between sowing dates and pesticides at 8 WAS on populations of (Giant coreid bug, *Anoplocnemis curvipes* and (Spiny brown bug, *Clavigralla tomentosicollis*) in Katsina during 2015 and 2016 cropping seasons

			Pesticides	
Sowing dates	P0	P1	P2	P3
SD1	2.76^{a}	1.33^{c}	1.78^{b}	1.49^{bc}
SD2	1.63^{bc}	1.40^{c}	1.30^{c}	1.24^{c}
SD3	1.24^{c}	1.24^{c}	1.22^{c}	1.22^{c}
LSD			0.361	

Key: P0- control, P1- Neem seeds kernel extract, P2- MaviMNPV suspension, P3- Cyper diforce, SD - sowing dates, SD1- 2nd July, 2015 and 2nd July, 2016; SD2- 23rd July, 2015 and 23rd July, 2016; SD3- 13th Aug., 2015 and 13th Aug., 2016

Table 3: Combined interaction between sowing dates and pesticides at 9 WAS on populations of (Giant coreid bug, *Anoplocnemis curvipes* and (Spiny brown bug, *Clavigralla tomentosicollis*) in Katsina during 2015 and 2016 cropping seasons

			Pesticides	
Sowing dates	P0	P1	P2	P3
SD1	2.76^{a}	1.33^{c}	1.78^{b}	1.49^{bc}
SD2	1.63^{bc}	1.40^{c}	1.30^{c}	1.24^{c}
SD3	1.24^{c}	1.24^{c}	1.22^{c}	1.22^{c}
LSD			0.361	

Key: P0- control, P1- Neem seeds kernel extract, P2- MaviMNPV suspension, P3- Cyper diforce, SD - sowing dates, SD1- 2nd July, 2015 and 2nd July, 2016; SD2- 23rd July, 2015 and 23rd July, 2016; SD3- 13th Aug., 2015 and 13th Aug., 2016

Table 4: Combined interaction between sowing dates and pesticides at 10 WAS on populations of (Giant coreid bug, *Anoplocnemis curvipes* and (Spiny brown bug, *Clavigralla tomentosicollis*) in Katsina during 2015 and 2016 cropping seasons

	Pesticides			
Sowing dates	**P0**	**P1**	**P2**	**P3**
SD1	1.34^{bc}	1.24^{c}	1.24^{c}	1.31^{bc}
SD2	1.95^{a}	1.32^{bc}	1.44^{b}	1.20^{c}
SD3	1.22^{c}	1.22^{c}	1.22^{c}	1.22^{c}
LSD			0.185	

Key: P0- control, P1- Neem seeds kernel extract, P2- MaviMNPV suspension, P3- Cyper diforce, SD - sowing dates, SD1- 2nd July, 2015 and 2nd July, 2016; SD2- 23rd July, 2015 and 23rd July, 2016; SD3- 13th Aug., 2015 and 13th Aug., 2016

Table 5: Effect of intra-row spacings, sowing dates and pesticides on total cowpea grain weight (kg ha^{-1}) during 2015 and 2016 cropping seasons in Katsina

Treatments	**2015**	**2016**	**Combined**
Intra-row spacing (cm) (SP)			
SP1: 75 x 20	87.43	184.97	210.51
SP2: 75 x 30	87.61	194.18	215.37
SP3: 75 x 40	84.41	212.29	220.10
Mean	86.49	197.15	215.33
LSD	22.838	70.142	48.159
Pesticides (P)			
P1: Neem seeds kernels extract	49.36^{b}	186.43^{b}	159.84^{b}
P2: MaviMNPV suspension	52.21^{b}	123.79^{b}	115.50^{bc}
P3: Cyper diforce	204.66^{a}	463.10^{a}	507.84^{a}
P0: Control	39.71^{b}	15.27^{c}	78.12^{c}
Mean	86.49	197.15	215.33
LSD	45.167	70.263	69.702
Interactions			
SD x SP	NS	NS	NS
SD x P	NS	**	**
SP x P	NS	NS	NS
SD x SP x P	NS	NS	NS

letter(s) in the same column are not significantly different using LSD at 5 % level, NS - not significant, ** - highly significant at $P \leq .01$, SD - Sowing dates, SP - Intra-row spacings, P - Pesticides

Table 6: Interaction between sowing dates and pesticides on total grain weight (kg ha^{-1}) during the 2016 cropping season in Katsina

	Pesticides			
Sowing dates	**P0**	**P1**	**P2**	**P3**
SD1	22.92c	224.51b	80.53c	264.08b
SD2	15.55c	93.59c	54.03c	600.16a
SD3	7.35c	241.18b	236.80b	525.05a
LSD			121.702	

Key: P0 - control, P1 - Neem seeds kernel extract, P2 - MaviMNPV suspension, P3 - Cyper diforce, SD - sowing dates, SD1- 2nd July, 2016; SD2- 23rd July, 2016; SD3- 13th Aug., 2016

Table 7: Combined interaction between sowing dates and pesticides on total grain weight (kg ha^{-1}) during 2015 and 2016 cropping seasons in Katsina

	Pesticides			
Sowing dates	**P0**	**P1**	**P2**	**P3**
SD1	133.40cd	225.59c	133.60cd	474.26b
SD2	69.22d	96.96d	60.63d	631.49a
SD3	31.73d	156.98cd	152.29cd	417.80b
LSD			121.880	

Key: P0 - control, P1 - Neem seeds kernel extract, P2 - MaviMNPV suspension, P3 - Cyper diforce, SD - sowing dates: SD1- 2nd July, 2015 and 2nd July, 2016; SD2- 23rd July, 2015 and 23rd July, 2016; SD3- 13th Aug., 2015 and 13th Aug., 2016

The effect during the 2016 cropping season significantly differed ($P \leq .05$) among sowing dates. Lower CPSB population was recorded at sowing cowpea on 13th Aug. across all sampling periods (1.22). This result, however, did not differ significantly from the CPSB population at 8 WAS (1.22). The highest population was recorded in cowpea sown on 2nd July (2.03) sampled 8 WAS. The combine effect also followed a similar trend, with the lowest CPSB population significantly (*P*≤ .05) recorded at 10 WAS (1.23). The highest mean was recorded at 9 WAS (1.84).

Similarly, the effect of pesticides did not differ significantly (P≥ 0.05) among the treatments. However, the effect was significantly different from the control (P≤ .05), which recorded the highest mean CPSB (1.53). The effect during the 2016 cropping season followed a similar trend, with cowpea sown on 13th Aug. Synthetic insecticide-treated plots consistently and significantly (P≤ .05) recorded lower CPSB means (1.21), but were at par with NKE and MaviMPV. The control plots consistently recorded higher CPSB means (2.18, 2.12, and 1.47) across all sampling periods. Furthermore, the combined result also showed a similar trend. (Table 1).

Interaction results

Result of the combined interaction effect between sowing dates and pesticides at 8 WAS on populations of (Giant coreid bug, *Anoplocnemis curvipes* and (Spiny brown bug, *Clavigralla tomentosicollis*) in Katsina during 2015 and 2016 cropping seasons showed that, combination of sowing date at 13th Aug. + pesticide spray produced the lowest mean CPSB population (1.22) while sowing on 2nd July + zero pesticide use (control) recorded highest means (2.34) Table 2.

Combined interaction between sowing dates and pesticides at 9 WAS on populations of CPSB in Katsina during 2015 and 2016 cropping seasons (Table 3) showed that cowpea sown on 2nd July + zero pesticide (control) significantly recorded high CPSB (2.76), which was significantly different (*P*≤ .05) from cowpea sown on 13th Aug. + pesticide use (1.22).

Combined interaction between sowing dates and pesticides at 10 WAS on populations of (Giant coreid bug, *Anoplocnemis curvipes* and (Spiny brown bug, *Clavigralla tomentosicollis*) in Katsina during 2015 and 2016 cropping seasons indicated that, cowpea sown on 13th Aug. + pesticide use recorded lowest CPSB means (1.22) which was significantly (*P*≤ .05) different with cowpea sown on 2nd July + zero pesticide application (control) (1.34) Table 4.

Effect of intra-row spacings, sowing dates and pesticides on total cowpea grain weight in Katsina during 2015 and 2016 Cropping Seasons

The effects of varying intra-row spacings, sowing dates, and pesticides on total grain weight in Katsina are presented in Table 5. There was no significant difference in yield due to varying sowing dates in 2015 or to combining. However, varying sowing dates from 2nd July to 13th Aug. significantly (P≤ .05) increased total cowpea seed weight by 41.41% in 2016. Statistically similar yields were obtained on 2nd July (148.01 kg ha-1) and 23rd July (190.83 kg ha-1). The highest seed weight was obtained on 13th Aug. (252.60 kg ha^{-1}). The effect of pesticides showed that significantly higher grain yield (P≤ .05) was obtained in Cyper diforce sprayed plots (204.66, 463.10 and 507.84 kg ha^{-1}) compared with NKE (49.36, 186.43 and 159.84 kg ha^{-1}) and MaviMNPV (52.21, 123.79 and 115.50 kg ha^{-1}), which were statistically at par in all the years and the combined. However, NKE and MaviMNPV were significantly (P≤ .05) better than the control, which recorded the lowest grain yield (39.16, 15.27, and 78.12 kg ha-1, respectively).

The results of the interaction between sowing date and pesticides on total grain weight in Katsina during the 2016 cropping season are presented in Table 6. The results showed that the highest grain weights were obtained in the pesticide-sprayed plots (P3) compared with the control (P0) across all sowing dates. However, the yield obtained in the Cyper diforce-treated plot was significantly (P≤ .05) higher than that in the control plot across all sowing dates. Varying sowing dates resulted in yields that were statistically similar in the control. A high interaction effect was obtained in Cyper diforce (P3) sprayed plot + cowpea sowing on 23rd July (SD2) (600.16 kg ha^{-1}), and the lowest effect was observed in the control (P0) + cowpea sowing on 13th Aug. (SD3) (7.35 kg ha^{-1}).

The results of the combined interaction effect between sowing dates and pesticides during the 2015 and 2016 cropping seasons in Katsina are presented in Table 7. Cyper diforce sprayed plots have consistently and significantly (P≤ .05) yielded higher grain yield than NKE and MaviMNPV, which were statistically similar across all sowing dates. The control plots yielded the lowest. The highest interaction effect was obtained in Cyper diforce (P3) treated plot + cowpea sowing on 23rd July (631.49 kg ha^{-1}), and the lowest effect was by control (P0) + cowpea sowing on 13th Aug. (31.73 kg ha^{-1}).

DISCUSSION

Effects of intra-row spacings, sowing dates, and pesticides on pod-sucking bug population and cowpea damage in Katsina during the 2015 and 2016 cropping seasons

The present study demonstrated that variation in intra-row spacing did not significantly influence pod-sucking bug (PSB) populations across the sampling periods. This suggests that plant density within the spacing ranges tested may not be a critical factor governing PSB abundance in cowpea. Conversely, staggered sowing dates altered crop phenology, which, in turn, affected the timing and intensity of pest infestations. Pod-sucking bugs typically infest cowpea crops from the early flowering stage, approximately six weeks after sowing, particularly in the cultivar evaluated (Oparaeke *et al.*, 2005; Oparaeke, 2006). The lack of a spacing effect observed in this study corroborates earlier reports by Ajao *et al.* (2016), who found no significant relationship between plant spacing and insect pest density or pod damage in cowpea fields in

Abeokuta. Similar conclusions were reached by Yusuf and Zakari (2016) in Kano, where insect pest populations were not significantly influenced by spacing (P > 0.05).

In contrast, planting date significantly affected PSB population dynamics in Katsina. A gradual reduction in mean PSB density was recorded as sowing was delayed from early July (2nd July) to late July (23rd July), while a further shift to mid-August (13th August) resulted in a marked and consistent decline in pest populations across both cropping seasons. Cowpea planted on 13th August experienced the lowest PSB infestation, indicating that crop establishment at this time coincided with periods of reduced pest pressure. Consequently, these crops suffered less damage. Cowpea planted on 2nd July flowered around 14th Aug. (6 WAS) to pod set on 21st Aug. (7 WAS). Cowpea planted on 23rd similarly flowered around 3rd Sept (6 WAS) and pod set around 7th Oct. (7 WAS) while cowpea sown on 13th Aug. flowered on 24th Sept. and pod set at & WAS (1st Oct.). This finding is at variance with the observations of Asante *et al.* (2001), who reported that cowpea planted in July often reaches flowering and podding stages during peak abundance of major post-flowering pests, spiny brown bug (*Clavigralla tomentosicollis*), giant coreid bug (*Anoplocnemis curvipes*), including the legume pod borer (*Maruca vitrata*). Varying sowing dates and the use of one or a combination of pesticides result in higher cowpea yields than the control. Cowpea sown on 2nd July podded between 21st Aug. – 11th Sept., while cowpea sown on 23rd podded between 10th Sept to 10th Oct. and that sown on 13th Aug. podded in between Oct. 1st to Oct. 22nd. The significant yield performance of the 23rd Aug planted cowpea could be attributed to lower PSB infestation and adequate rainfall, which allowed the crop to complete the reproductive phase. In contrast, cowpea sown on the 13th Aug podded during the onset of the dry season when rainfall duration and intensity have reduced. Absence of moisture greatly impacted the reproductive phase of the crop.

The effectiveness of pesticide application in managing cowpea insect pests has been widely reported in the literature. Numerous studies have highlighted the potential of botanically derived products such as neem, garlic, ginger, cashew nut shell, African pepper, and desert date in suppressing post-flowering pests of cowpea (Oparaeke *et al.*, 2000; Oparaeke *et al.*, 2005b; Ahmed *et al.*, 2007; Ahmed *et al.*, 2009; Degri *et al.*, 2012; Malgwi & Hamman, 2013; Oyewale & Bamaiyi, 2013). In the present investigation, neem seed kernel extract (NKE), *M. vitrata* multinucleopolyhedrosis virus (MaviMNPV), and the synthetic insecticide Cyper diforce were evaluated for their efficacy against PSBs. The results showed no significant differences among the pesticide treatments within 24 hours of application in terms of PSB population reduction. However, Cyper consistently produced lower pest densities, indicating superior control efficiency compared with NKE and MaviMNPV. Notwithstanding this difference, all pesticide treatments significantly reduced PSB populations when compared with the untreated control. These results align with the findings of Malgwi and Hamman (2013), who reported that although plant-based pesticides are effective, they generally exhibit lower efficacy than synthetic insecticides in cowpea pest control.

Comparable outcomes were reported by Ogah (2013), who demonstrated that extracts of *Azadirachta indica*, *Allium sativum*, and *Zingiber officinale* significantly reduced infestation levels and damage caused by post-flowering pests, particularly *Megalurothrips sjostedti* and *M. vitrata,* relative to untreated plots in Abakaliki, Ebonyi State. Similarly, Amatobi (2000) observed substantial mortality of post-flowering insect pests, including *M. sjostedti*, *Aphis craccivora*, and *M. vitrata*, following application of crude chilli pepper and tobacco leaf extracts, resulting in approximately 70% population reduction under greenhouse conditions.

The present findings are also consistent with Oparaeke *et al.* (2005b), who reported that mixtures of cashew nut shell, garlic bulb, African pepper (*Xylopia aethiopica*), and chilli pepper, *Capsicum* spp significantly reduced the population of pod-sucking bugs, flower bud thrip, and legume pod borer larvae, although their efficacy was lower than that of the synthetic insecticide (Uppercott). The comparatively better performance of Cyper diforce over NKE and MaviMNPV in this study further supports earlier reports on the effectiveness of both botanical and synthetic insecticides against cowpea pests (Oparaeke *et al.*, 2005; Degri *et al.*, 2012; Malgwi & Hamman, 2013).

Several studies have emphasized the potential of plant-based materials as environmentally friendly alternatives for cowpea pest management (Oparaeke *et al.*, 2000; Panhwar, 2002). The significant reduction in pest populations observed in neem-treated plots compared with the control confirms earlier findings by Malgwi and Onu (2004), who documented the insecticidal activity of plant extracts against multiple cowpea insect pests. The efficacy of NKE observed in this study may be attributed to its bioactive constituents, which are known to possess insecticidal and growth-disrupting properties against cowpea pests.

CONCLUSION

Post-flowering insect pests represent the most critical constraint to cowpea production in tropical agro-ecosystems. The pod-sucking bugs (*Clavigralla tomentosicollis* and *Anoplocnemis curvipes*) are particularly destructive due to their direct impact on reproductive structures. The insect caused damage mainly through its piercing and sucking, feeding on the sap. Heavy infestation often leads to empty pods and shrivelled grains. Understanding the diversity, biology, and damage patterns of these pests is essential for designing effective, sustainable pest management strategies to improve cowpea productivity and food security. Alternating sowing dates to escape the period of high pod population and minimise insecticide use is crucial for reducing high population and associated damage, thereby increasing yield and economic returns for farmers in the study area.

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DECLARATION OF CONFLICT OF INTEREST

The authors have no conflicts of interest to declare that are relevant to the content of this article.

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