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Integrating Insecticide Spray Time and Weeding Regime to Manage Insect Pests and Yield of Cowpea in the Southern Guinea Savanna of Nigeria

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Abstract

Insecticide treatments are recommended for the control of insect pests in cowpea (*Vigna unguiculata* (L) Walp) in Sub-Saharan Africa. Nonetheless, these have unfavorable effects on man and the environment, in addition to being costly for smallholder farmers. The goal of this study was to find the optimum insecticide spray time and weeding to manage insect pests and increase yield of cowpea. The experiment was designed as a randomized complete block in a split-plot arrangement with three replications. The main plots consisting of spray time of insecticide application while the sub-plots consisting of weeding regimes. Data collected includes insect pest's abundance, damage assessment and yield. The major insect pests observed were the cowpea aphids, thrips, maruca and pod sucking bugs. Insecticide sprays applied twice at 50 percent flowering and 50 percent podding, as well as a weeding regime applied either thrice or twice – at 3, 6, and 9 or at 3 and 6 weeks after sowing – effectively reduced insect population and damage, and increased yield of cowpea This recommendation can be incorporated into cowpea integrated pest management strategies among farmers in the study location.

Keywords: Cowpea, insect, insecticide, spraying time, weeding regime, pest management.

INTRODUCTION

Cowpea, *Vigna unguiculata* (L) Walp, is a popular crop in Nigeria and many other tropical countries because it is a low-cost source of protein. Humans can eat all parts of the plant, save the haulms, which are fed to domestic animals (Singh *et al*., 2003; Hall 2012 and Abudulai *et al*., 2017). It is indigenous to Africa and has become domesticated in parts of Southern, Eastern, and Western Africa, where a vast number of ancient cultivars and semi-wild varieties have been discovered (Kwaifa *et al*., 2012). Cowpea production is regarded as an

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important aspect of Africa's traditional cropping system (Isubikalu *et al*., 2000). It provides farmers and dealers many options for gaining revenue (Agbicodo *et al*., 2009). The crop promotes soil fertility by fixing nitrogen from the atmosphere and provides sufficient nutrients for crop growth and development.

Cowpea is cultivated on a global scale of 12.5 million ha^{-1} per year, according to conservative estimates. West Africa accounts for around 9.8 million hectares of this total, making it the world's greatest producer and consumer of cowpea (CGIAR 2001; FAOSTAT 2016). Kebede (2020) reported that Africa as a whole account for 22% of global grain legume production. Furthermore, the bulk of cowpea consumption and production is in sub-Saharan Africa (SSA) especially West and Central Africa. Nigeria produces cowpea grains annually at about 2.14 million metric tonnes (FAOSTAT, 2017).

Despite its importance, insect pests wreak havoc on cowpea yields at several phenological stages of the crop; from the vegetative stage to bud initiation, flowering, and podding, and even storage (Ojo *et al*., 2016; Agunbiade *et al*., 2018). Some of these pests include: phloem-feeding cowpea aphids, foliage beetles, flower thrips, legume pod borer, complex of pod sucking bugs – giant coreid bug, spiny brown bug, riptortus and green stink bug (Agunbiade *et al*., 2016). For the control of these pests, various management methods have been utilized. For example, weekly application of aqueous extracts of *Piper guineense* and *Aframomum melegueta* were effective against *Maruca vitrata* and *Clavigaralla tomentosicollis* (Oyewale *et al*., 2014). Also, the use of leaf and seed extracts of neem caused reduction in population of thrips, spiny brown bug and legume pod borer, which enhanced better cowpea yield. Cowpea intercropping with cereals like maize, sorghum, and millet has been utilized to reduce cowpea insect pests like aphids and thrips while intercropping alone does not completely control the pests (Nabirye *et al*., 2003; Hassan 2009). However, the efficacy of intercrop as a tool in insect pest management varied and success recorded in its usage is hinged on factors of the environment. As a result, just a small amount of pesticide is needed to provide efficient pest control. The adoption of resistant cultivars is another option for control. However, it is evident that no cowpea variety is resistant to all insect pests complex associated with it (Dzemo *et al*., 2010; Kusi *et al*., 2019). Most of the insect-resistant genotypes are immune to one or few insect pests, and when employed alone, they are ineffective. Furthermore, timing of planting has been manipulated in such a way that the duration of high pest density and critical crop stage does not coincide (Pulakkatu-Thodi *et al*., 2014; Abudulai *et al*., 2017). In agricultural systems, insects and weeds frequently cohabit and diminish production. Weeds reduce yields by 40 to 86 percent yearly, and insects cause production reductions of up to 80 percent annually in Nigeria (Li *et al*., 2004; Alabi *et al*., 2014; Adetunji *et al*., 2017; Osipitan 2017). In addition to the separate impacts of insects and weeds on crops, these two categories of pests, as well as their control strategies, can interact and have an impact on crop productivity. Weeds compete for nutrients and water, reducing crop yields and quality.

Nonetheless, insecticide spraying remains a reliable method for controlling insect pests of cowpea. This is due to the fact that it is efficient in preventing insect pests of cowpea from engaging in destructive behaviour. Insecticides, on the other hand, are costly, and their usage has negative impact on the biotic components of the environment (Damalas and Eleftherohorinos, 2011). As a

result, it is critical to understand the best insecticide spraying time and frequency for maximum effectiveness and a healthy environment. Also, because there is interplay between weed and insect population, weeding regime is an issue to consider. Understanding this interaction may be used to determine the best time to weed cowpea plots and when to apply insecticides to reduce insect pest infestation while maintaining a sustainable cowpea yield. As a result, cost-effective, ecologically acceptable, and long-term pest control solutions based on minimum pesticide spray treatments and weeding regimens are needed by farmers, particularly those with limited resources. However, to the best of the authors' knowledge, there are paucity of information on the combined effect of pesticide spray timing and manual weeding regimes on occurrence of insect pests in cowpea. In particular, we asked if the timing of insecticide application and weed control will affect the abundance of arthropod pests, vis-a-vis their interaction on cowpea yield? We based the times of insecticide spraying on phenological growth periods of cowpea. The study was conducted in two different locations with dissimilar agro-climatic condition in Southern Guinea Savanna of Nigeria. The objective of this work was to determine the appropriate combination(s) of insecticide spraying times and weeding regimes that would minimize insect pest population and damage to cowpea and increase its yield in Southern Guinea Savanna of Nigeria.

MATERIALS AND METHODS

Study Sites and Description of Cowpea Cultivar Used

Field experiments were conducted at two locations viz: Teaching and Research Farms, Kwara State University, Malete (KWASU) (Lat. 08°42′48.5″N; Long. 04°26′17.9″E), and National Centre for Agricultural Mechanization (NCAM), Idofian (Lat. 08°23′12°N; Long. 04°40′33°E), Kwara State, Nigeria in 2020 cropping season (Figure 1). Cowpea variety, IAR 48 (SAMPEA 7), a breeding line from Institute for Agricultural Research, Samaru, Zaria, Nigeria, with a national code – NGVU-96-17 was used. It is an erect, early maturing, consistent, high yielding and palatable cowpea variety.

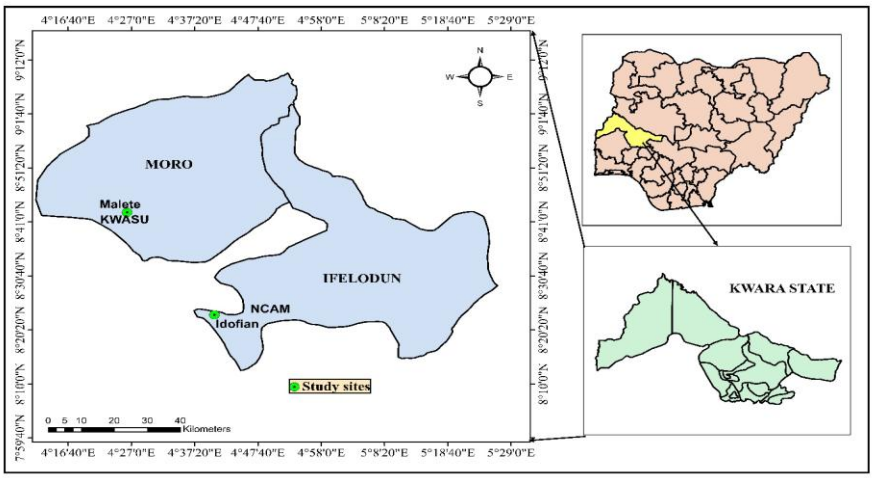


Fig. 1: The map showing the study locations

Layout of the Experiment

Treatments in this study comprised four insecticide spray times (based on cowpea growth stages) and five weeding regimes. The treatments were arranged in a split plot design with three replications. Insecticide spray times constituted the main plot treatments while weeding regimes were the sub-plot treatments. The main plot consisted of varying insecticide sprays times: no insecticide spray (control); one spray at 50% flowering; two sprays – first at 50% flowering and second at 50% podding; three sprays – first at vegetative stage, second at 50% flowering and third at 50% podding. Sub-plots were allocated to weeding regimes: weedy check (control); weeding at 3 weeks after sowing (WAS), weeding at 6 WAS, weeding at 3 and 6 WAS, and weeding at 3, 6 and 9 WAS. The insecticide, Lambda Super 2.5 EC (lambda-cyhalothrin), was sprayed at 0.025 kg a.i. in 200 liters of water. The size of each plot was 3 x 3 m and plants were spaced at 60 cm x 30 cm. The distance between replicates and subplots was 1 m.

Sampling for Insect Pest Infestation

Data on insects were collected a day before insecticide treatment application. Data collected were insect population, damage assessment and cowpea yield. Insects sampled included aphids, thrips, legume pod borer, and pod sucking bugs (PSBs). The data collection on population and severity of *Aphis craccivora* commenced on 14 DAS and continued on a weekly basis. Twenty (20) plants were randomly selected and tagged from the two central rows of each plot. Each tagged plant was systemically examined and level of aphid colony estimated. Due to often very high numbers, a categorical index was used to assess aphid population, where 0 = none; 1 = a few scattered individuals; 2 = a few isolated colonies; 3 = several isolated colonies; 4 = large isolated colonies; and 5 = large continuous colonies. Estimation of thrips and maruca infestations were carried out at the onset of flowering 50% podding. This was accomplished by randomly selecting 20 flowers and/or 20 pods from the two inner rows, submerging them in ethanol, and then sort and counting them in the laboratory. PSB populations were estimated by visually counting nymphs and adults of each sucking bug species detected in a 1m length of the two centre rows in each plot. After four weeks of data collection, the PSB populations (irrespective of type) were computed as a mean of the total number of PSB/m^2. Grain yield data was recorded at maturity during harvesting. Threshing of sundried pods was done; yield of grains was calculated from each net plot and converted to kilograms per hectare after weighing. The size of the net plot was 1 m^2 and formula used was:

$$\text{Grain Yield} = \frac{\text{Grain yield per net plot} \times 10{,}000\ m^2}{\text{Net plot size } (m^2)}$$

To determine the extent of PSB damage, 100 seeds from each plot were chosen at random. PSB-damaged grains with characteristic PSB feeding punctures and shriveled grains were identified and percentage damage was determined.

Statistical Analysis

The data from each site were subjected to an analysis of variance (ANOVA) for split plot design using STATA v16 (Stat Corp, 2018), with insecticide spray times serving as the main plots and weeding regime serving as subplots. The Tukey test was used to make mean comparisons at the 5% level of probability. Before performing the ANOVA, the yield, insect abundance, seed weight, and grain damage data were square root transformed to guarantee homogeneity of variances.

RESULTS

Impact of Insecticide Spray Times and Weeding Regime on Aphid Infestation of Cowpea

Results of the effects of weeding regime, spray times and locations on the mean impact of insecticide spray times and weeding regime population showed that aphid infestation was higher in cowpea planted at NCAM than Malete (Table 1). The main effects, spray times (P=0.0359) and locations (P=0.0039), significantly affected aphid infestation in cowpea. There was also a significant location and weeding regime interaction effect (P=0.0248) for aphid infestation. The other main effects and interactions had no discernible effect (P>0.05). When compared to other spray times, cowpea sprayed three times had the lowest aphid infestation in both locations. At Malete, the unprotected cowpea plots recorded the highest infestation than the other treatments. Similarly, at NCAM, aphid infestation was higher in unsprayed plots than in plots sprayed once or twice. However, it is interesting to note that those sprayed twice recorded the highest aphid infestation in NCAM compared to other sprays times. Among the weeding regimes in Malete, weeding done at 3 WAS had the lowest infestation while weeding at 6 WAS had the highest infestation. However, aphid infestation at NCAM under the weeding regime at 3, and 6 WAS had the lowest infestation, while weeding at 3 WAS had the highest infestation. For the location and weeding regime interaction effects, weeding at 3 WAS at Malete, had the lowest aphid infestation. In contrast, the same weeding at 3 WAS at NCAM had the highest aphid infestation while weeding regime at 3 and 6 WAS resulted in the lowest aphid number at NCAM (Table 1).

Table 1: Impact of insecticide spray times and weeding regime on aphids' infestation of cowpea

Location (L)	Weeding Regimes (WR)	Insecticide Spray Times (ST)				
		None	One	Two	Three	WR Mean
Malete	3	0.33	0.33	0.33	0.00	0.25
	6	1.00	1.33	0.00	0.67	0.75
	3 & 6	1.67	0.33	0.67	0.00	0.67
	3, 6 & 9	1.33	0.33	0.33	0.00	0.50
	Weedy check	0.33	0.33	1.00	0.33	0.50
	ST Mean	0.93	0.53	0.47	0.20	0.53
NCAM	3	1.33	1.33	1.33	1.00	1.25
	6	0.67	0.67	1.00	0.67	0.75
	3 & 6	0.33	1.00	1.00	0.33	0.67
	3, 6 & 9	1.00	1.00	1.00	0.33	0.83
	Weedy check	1.00	0.67	0.67	0.67	0.75
	ST Mean	0.87	0.93	1.00	0.60	0.85
Tukey (P < 5%)	Standard Error					
ST	0.10628*					
WR	0.11882					
L	0.07515*					
ST x WR	0.23765					
ST x L	0.15030					
WR x L	0.16805*					
ST x WR x L	0.33610					

Standard Error = Standard Error of the difference between treatment mean; *Significant at p < 0.05. One = spray once at 50% flowering; Two = sprays at 50% flowering and 50% podding; Three = sprays at vegetative stage, 50% flowering and 50% podding.

Impact of Insecticide Spray Times and Weeding Regime on Thrips Infestation

The density of thrips was strongly impacted by the primary impacts of insecticide spray times (P=0.0138), weeding regime (P=0.0001), and location (P=0.0050). For thrips infestation, there was also a significant location and pesticide spray times interaction impact (P=0.0010). The other main effects and interactions had no discernible effect (P>0.05). Cowpea planted at NCAM had a greater thrips infestation (64.80) than those planted at Malete (45.02), based on an average of pesticide spray times and weeding regime (Table 2). Across spray time, cowpea with no sprays at Malete produced the highest thrips infestation (55.80) while those protected thrice at Malete were lowest (26.01). At NCAM, cowpea with no sprays produced the highest thrips infestation (133.17). However, plots protected once had the lowest thrips infestation (42.64). Across weeding regime in the two locations, weeding done 3, 6, and 9 WAS recorded the highest thrips infestation while infestation of thrips was lowest in the weedy plot. The location and insecticide spray time interaction effects on thrips population resulted in producing the highest thrips infestation at both locations in no spray treatment (Table 2).

Table 2: Impact of insecticide spray times, weeding regime and location on thrips population of cowpea

Location (L)	Weeding Regimes (WR)	Insecticide Spray Times (ST)				
		None	One	Two	Three	WR Mean
Malete	3	79.74	55.35	55.95	19.45	49.98
	6	40.45	49.56	47.33	41.86	44.76
	3 & 6	71.74	96.24	45.43	33.41	59.29
	3, 6 & 9	93.70	65.29	92.16	30.69	67.73
	Weedy check	15.37	18.58	15.92	11.02	15.13
	ST Mean	55.80	53.88	48.16	26.01	45.02
NCAM	3	69.22	25.40	39.44	40.20	42.12
	6	173.71	48.02	54.32	52.42	75.34
	3 & 6	248.38	41.86	55.95	74.47	91.97
	3, 6 & 9	199.94	49.70	74.30	84.64	95.06
	Weedy check	39.82	51.55	14.82	31.25	32.83
	ST Mean	133.17	42.64	45.16	54.76	64.80
Tukey (P < 5%)	Standard Error					
ST	0.4615394*					
WR	0.5160168*					
L	0.3263577*					
ST x WR	1.032034					
ST x L	0.6527153*					
WR x L	0.7297579					
ST x WR x L	1.459516					

Standard Error = Standard Error of the difference between treatment mean; *Significant at p<0.05. One = spray once at 50% flowering; Two = sprays at 50% flowering and 50% podding; Three = sprays at vegetative stage, 50% flowering and 50% podding.

Impact of Insecticide Spray Times and Weeding Regime on *Maruca* spp. Infestation

The main effects and interaction (two-way and three-way) effects did not significantly affect maruca infestation on cowpea flowers. However, there were significant effects of maruca infestation on cowpea pods. Cowpea pod infestation was significantly affected by location ($P<0.0001$) and weeding regime ($P<0.0001$). There was significant 2-way interaction effect for location × insecticide spraying times ($P=0.0008$). There was also a significant location and weeding regime interaction effect ($P<0.0001$). Malete had a much reduced ($P<0.05$) maruca infestation in cowpea pods than NCAM, as seen in Table 3. Cowpea plants at NCAM exhibited greater pod infestation (9.43) than those planted at Malete when averaged across pesticide spray periods and weeding regime (0.25). Cowpea was protected with three rounds of pesticide treatments, which resulted in the lowest pod borer infestation at Malete (0.13) and NCAM (0.13), as anticipated (7.73). Among the weeding regimes in Malete, weeding done at 6 WAS had the highest pod infestation (0.58) while weeding done at 3, 6, and 9 WAS had the highest pod infestation at NCAM (12.42), however weedy check (control) at both locations had the lowest maruca infestation. For the location and weeding regime interaction effects, weeding done at 3 WAS at NCAM, significantly differ with a marginal infestation of 8.25. In addition, weedy plot at NCAM, significantly differ with a marginal infestation of 5.00.

Table 3: Impact of insecticide spray times and weeding regime on maruca infestation of cowpea

Location (L)	Weeding Regimes (WR)	Insecticide Spray Times (ST)				
		None	One	Two	Three	WR Mean
Malete	3	0.00	0.33	0.33	0.00	0.17
	6	0.67	0.67	1.00	0.00	0.58
	3 & 6	0.33	0.00	0.00	0.33	0.17
	3, 6 & 9	0.33	0.67	0.00	0.33	0.33
	Weedy check	0.00	0.00	0.00	0.00	0.00
	ST Mean	0.27	0.33	0.27	0.13	0.25
NCAM	3	6.00	10.00	11.00	6.00	8.25
	6	10.00	11.67	11.33	9.00	10.50
	3 & 6	10.33	13.67	10.67	9.33	11.00
	3, 6 & 9	13.33	12.67	13.33	10.33	12.42
	Weedy check	4.00	6.67	5.33	4.00	5.00
	ST Mean	8.73	10.93	10.33	7.73	9.43
Tukey (P < 5%)	Standard Error					
ST	0.278942					
WR	0.31186*					
L	0.19724*					
ST x WR	0.623733					
ST x L	0.394484*					
WR x L	0.44105*					
ST x WR x L	0.882092					

Standard Error = Standard Error of the difference between treatment mean; *Significant at $p<0.05$. One = spray once at 50% flowering; Two = sprays at 50% flowering and 50% podding; Three = sprays at vegetative stage, 50% flowering and 50% podding.

Impact of Insecticide Spray Times and Weeding Regime on Pod Sucking Bugs Infestation on Cowpea

The main effects, location (P=0.0140) and weeding regime (P=0.0083), had a substantial impact on cowpea pod sucking bugs. Insecticide spray times, however, had a significant impact on the occurrence of pod sucking bugs on cowpea (P=0.0596). The interaction between location and insecticide spray times was significant (P=0.0069). When averaged across insecticide spray times and weeding regime, sucking bug numbers were lower at NCAM (2.45) than Malete (3.20) (Table 4). Average of three sprays times at Malete had the lowest presence of pod sucking bugs while those that were spray once had the highest Cowpeas with no sprays at NCAM, on the other hand, had the lowest presence of pod sucking insect, while those sprayed three times had the most. It was observed that plots treated with hoe weeding only once at 3 WAS and the weedy check had significantly greater population of pod sucking bugs in both locations of NCAM and Malete. The interaction effect between three spray times and location was associated with the lowest population of pod sucking bugs in Malete, however at NCAM, this interaction led to the highest population of pod sucking bugs.

Impact of Insecticide Spray Times and Weeding Regime on Cowpea Pod Damage Rating

Pod damage rating was significantly different between insecticide spray times (P=0.0142) (Table 5). The interaction effect was significant for location and insecticide spray times (P=0.0016). There was also a significant location and weeding regime interaction effect (P=0.0075). Cowpea planted with no protection and one spray did not significantly differ. Cowpea plants that were sprayed twice and thrice did not significantly differ, but they differ significantly from those with no spray and one spray. For the location and weeding regime interaction effects, plots weeded at 3WAS at Malete, produced the highest pod damage rating. In contrast, plots weeded at 3, and 6 WAS and those weeded 3, 6, and 9 WAS at NCAM, produced the highest pod damage rating while the weedy check (control) produced the least pod damage. Plots that were not sprayed and those that were sprayed once at Malete had the greatest pod damage rating for the location and pesticide spray times interaction effects. However, no spray and plots sprayed once and twice at NCAM produced the highest pod damage rating.

Impact of Insecticide Spray Times and Weeding Regime on Cowpea Grain Damage

Cowpea grain damage was significantly different amongst the insecticide spray times (P=0.0313), and weeding regimes (P<0.0001) (Table 6). Averaging across weeding regime and insecticide spray times, cowpea planted at NCAM had higher grain damage (20.52) than those planted at Malete (19.10). Cowpeas treated with two insecticide sprays had the least grain damage (17.31), which was 26 percent less than those not protected (23.43), regardless of location or weeding regime. Across weeding regime, cowpea sprayed thrice at Malete produced the least grain damage (16.08) while those with no sprays at Malete recorded the highest grain damage (22.09). At NCAM, cowpea with two rounds of sprays produced the least grain damage (17.98), while those with no sprays were highest (24.80). Across spraying time, grain damage when weeding was done at 3,6WAS was lowest, while grain damage was highest on weedy plot at Malete. At NCAM, plots when weeding was done at either 3, 6 WAS or 3, 6, 9 WAS recorded the lowest grain damage while weedy plots recorded the highest grain damage.

Table 4: Impact of insecticide spray times and weeding regime on pod sucking bugs

Location (L)	Weeding Regimes (WR)	Insecticide Spray Times (ST)				
		None	One	Two	Three	WR Mean
Malete	3	2.93	7.07	5.27	1.87	4.28
	6	0.40	3.53	1.27	3.20	2.10
	3 & 6	1.87	4.40	1.67	1.80	2.43
	3, 6 & 9	2.73	6.20	2.33	2.40	3.42
	Weedy check	5.33	4.07	3.07	2.67	3.78
	ST Mean	2.65	5.05	2.72	2.39	3.20
NCAM	3	2.67	2.87	2.33	3.27	2.78
	6	1.73	1.27	2.07	2.60	1.92
	3 & 6	2.33	2.40	2.40	2.53	2.42
	3, 6 & 9	1.73	2.27	1.33	3.27	2.15
	Weedy check	1.67	4.33	2.80	3.20	3.00
	ST Mean	2.03	2.63	2.19	2.97	2.45
Tukey (P < 5%)	Standard Error					
ST	0.2979021*					
WR	0.3330647*					
L	0.2106486*					
ST x WR	0.6661294					
ST x L	0.4212972*					
WR x L	0.4710246					
ST x WR x L	0.9420492					

Standard Error = Standard Error of the difference between treatment mean; *Significant at $p < 0.05$. One = spray once at 50% flowering; Two = sprays at 50% flowering and 50% podding; Three = sprays at vegetative stage, 50% flowering and 50% podding.

Table 5: Impact of insecticide spray times and weeding regime on pod damage rating

Location (L)	Weeding Regimes (WR)	Insecticide Spray Times (ST)				
		None	One	Two	Three	WR Mean
Malete	3	1.33	1.33	0.33	0.67	0.92
	6	1.67	1.00	0.00	0.00	0.67
	3 & 6	1.00	1.00	0.00	0.67	0.67
	3, 6 & 9	1.00	1.00	0.33	0.67	0.75
	Weedy check	0.67	1.33	0.33	1.00	0.83
	ST Mean	1.13	1.13	0.20	0.60	0.77
NCAM	3	0.67	1.00	1.00	0.00	0.67
	6	1.00	0.67	0.67	0.33	0.67
	3,6	0.67	1.00	1.00	0.67	0.83
	3, 6 & 9	1.00	0.67	0.67	1.00	0.83
	Weedy check	0.00	0.00	0.00	0.00	0.00
	ST Mean	0.67	0.67	0.67	0.40	0.60
Tukey (P < 5%)	Standard Error					
ST	0.0927961*					
WR	0.1037492					
L	0.0656167					
ST x WR	0.2074983					
ST x L	0.1312335*					
WR x L	0.1467235*					
ST x WR x L	0.2934469					

Standard Error = Standard Error of the difference between treatment mean; *Significant at $p < 0.05$. One = spray once at 50% flowering; Two = sprays at 50% flowering and 50% podding; Three = sprays at vegetative stage, 50% flowering and 50% podding.

Table 6: Impact of insecticide spray times and weeding regime on grain damage of cowpea

Location (L)	Weeding Regimes (WR)	Insecticide Spray Times (ST)				
		None	One	Two	Three	WR Mean
Malete	3	12.82	32.15	11.02	17.31	17.47
	6	19.27	15.05	19.18	11.90	16.24
	3 & 6	20.16	17.72	11.97	11.90	15.21
	3, 6 & 9	15.60	17.89	22.28	13.69	17.22
	Weedy check	49.98	29.38	20.07	28.30	31.02
	ST Mean	22.09	21.90	16.56	16.08	19.10
NCAM	3	22.56	24.11	21.62	14.36	20.43
	6WAS	26.94	16.97	17.72	17.06	19.45
	3 & 6	22.37	18.32	11.49	18.66	17.47
	3, 6 & 9	17.72	16.73	16.65	18.84	17.47
	Weedy check	36.24	28.94	23.91	27.35	28.94
	ST Mean	24.80	20.70	17.98	19.01	20.52
Tukey (P < 5%)	Standard Error					
ST	0.1728741 *					
WR	0.1932792*					
L	0.1222405					
ST x WR	0.3865584					
ST x L	0.244481					
WR x L	0.273338					
ST x WR x L	0.5466761					

Standard Error = Standard Error of the difference between treatment mean; *Significant at $p < 0.05$. One = spray once at 50% flowering; Two = sprays at 50% flowering and 50% podding; Three = sprays at vegetative stage, 50% flowering and 50% podding.

Impact of Insecticide Spray Times and Weeding Regime on Cowpea Seed Weight

All main effects, insecticide spray times (P=0.0299), weeding regime (P<0.0001) and locations (P<0.0001), significantly affected the seed weight (Table 7). The location and insecticide spray times interaction effect (P<0.0001); location and weeding regimes interaction effect (P<0.0001) and weeding regimes and insecticide spray times interaction effect (P<0.0001) significantly affected the seed weight. In addition, the three-way interaction, location and insecticide spray times and weeding regimes interaction effect (P<0.0001) significantly affected the seed weight. The 100 seed weight in NCAM (14.82) was significantly higher than 100 seed weight in Malete (12.04). Cowpea spayed thrice with insecticide at Malete had the highest mean 100 seed weight while those with no spray had the lowest. In contrast, cowpea protected with two insecticide sprays at NCAM had the lowest mean 100 seed weight while those with no spray had the highest. At Malete, weedy plots with no spray had the least seed weight, regardless of location, insecticide spray times, or weeding regime impacts. At NCAM, however, the same weedy plots with no spray yielded the highest seed weight.

Impact of Insecticide Spray Times and Weeding Regime on Grain Yield of Cowpea

Cowpea yield was significantly different amongst the insecticide spray times (P = 0.0005), and weeding regimes (P < 0.0001) (Table 8). There were no significant two-way

and three-way interactions. Cowpeas grown at NCAM yielded more (794.68 kg/ha) than those planted at Malete (691.16 kg/ha) when all weeding regimes and insecticide spray times were averaged. Cowpea treated with two rounds of insecticide sprays generated the maximum yield (1179.92 kg/ha), which was nearly four times greater than those not protected (308 kg/ha) irrespective or weeding regime. Across weeding regime, cowpea with no sprays at Malete produced the lowest yield (280.56 kg/ha) while those protected twice were highest (1217.31 kg/ha). At NCAM, cowpea with no sprays produced the lowest yield (336.72 kg/ha) while those protected twice were highest (1143.12 kg/ha). Yield when weeding was done at 3, 6, and 9 WAS and 3 and 6 WAS was highest and that of when the plot was weedy check had lowest at Malete. In comparison at NCAM, plots when weeding was done at 3, 6, and 9 WAS and 3 and 6 WAS recorded the highest yield while weedy plots recorded the lowest yield.

Table 7: Impact of insecticide spray times and weeding regime on seed weight of cowpea

Location (L)	Weeding Regimes (WR)	Insecticide Spray Times (ST)				
		None	One	Two	Three	WR Mean
Malete	3	3.67	12.67	14.06	13.18	10.37
	6	11.42	14.59	13.69	14.82	14.44
	3 & 6	13.76	14.98	13.32	14.90	14.21
	3, 6 & 9	15.21	13.76	13.47	15.37	14.44
	Weedy check	1.61	5.29	14.21	13.25	7.51
	ST Mean	8.58	11.90	13.76	14.29	12.04
NCAM	3	12.53	15.37	14.29	14.52	14.14
	6	16.89	14.44	14.67	14.21	14.98
	3 & 6	15.76	15.37	15.37	15.37	15.44
	3, 6 & 9	16.81	15.05	14.52	14.82	15.29
	Weedy check	15.60	14.36	13.54	13.84	14.29
	ST Mean	15.44	14.90	14.44	14.52	14.82
Tukey (P < 5%)	Standard Error					
ST	0.0466725*					
WR	0.0521815*					
Location (L)	0.0330025*					
ST x WR	0.1043629*					
ST x L	0.0660049*					
WR x L	0.0737957*					
ST x WR x L	0.1475915*					

Standard Error = Standard Error of the difference between treatment mean; *Significant at $p < 0.05$. One = spray once at 50% flowering; Two = sprays at 50% flowering and 50% podding; Three = sprays at vegetative stage, 50% flowering and 50% podding.

Table 8: Impact of insecticide spray times and weeding regime on grain yield (kg /ha) of cowpea

Location (L)	Weeding Regimes (WR)	Insecticide Spray Times (ST)				
		None	One	Two	Three	WR Mean
Malete	3	97.22	297.22	873.79	443.52	377.52
	6	413.72	1032.34	1583.24	1156.00	996.67
	3 & 6	406.02	1799.46	1493.82	803.72	1049.11
	3, 6 & 9	719.85	1262.38	2011.52	1363.09	1298.16
	Weedy check	43.30	81.00	466.13	120.34)	144.96
	ST Mean	280.56	743.11	1217.31	689.59	691.16
NCAM	3	262.44	621.50	1057.55	547.56	588.55
	6	423.95	1165.54	1620.87	1011.24	1004.89
	3 & 6	311.52	1442.25	1407.75	1307.55	1045.23
	3, 6 & 9	498.63	1402.50	1681.82	1885.30	1299.60
	Weedy check	225.30	330.15	315.77	237.78	275.23
	ST Mean	336.72	923.69	1143.12	902.40	794.68
Tukey (P < 5%)	Standard Error					
ST	1.14977*					
WR	1.285491*					
L	0.813016					
ST x WR	2.570982					
ST x L	1.626032					
WR x L	1.817959					
ST x WR x L	3.635918					

Standard Error = Standard Error of the difference between treatment mean; *Significant at $p < 0.05$. One = spray once at 50% flowering; Two = sprays at 50% flowering and 50% podding; Three = sprays at vegetative stage, 50% flowering and 50% podding.

DISCUSSION

Aphids, thrips, maruca, and pod-sucking bugs were found to be economically relevant in cowpea production in the study area. These insect pests are important limiting factors in productivity in other places where cowpea is grown, particularly in the tropics, with typical yield losses ranging between 50 and 70% (Agunbiade *et al*., 2018). The management of cowpea pests in the tropics is mostly done by the use of synthetic insecticides and hand weeding. Farmers having limited resources may combine a typical IPM approach that includes suitable weeding regimes, planting density and dates, cultivar combinations, intercropping, appropriate crop husbandry, and indigenous materials with a limited budget (Abudulai *et al*., 2017).

Cowpea treated three times (at each of the 3 distinct plant physiological phases) had the least aphid infestation regardless of location. The untreated plots recorded the highest infestation at Malete but in contrast at NCAM aphid infestation was higher in unsprayed plots and those sprayed once or twice. In fact, plots sprayed twice contained the highest aphid infestation. At Malete, weeding at 3 WAS yielded the lowest infestation while weeding at 6 WAS yielded the highest. These results indicate that lower weed infestation may be associated with higher aphid population growth. This is consistent with the findings of Takim and Uddin (2010), who observed that the population of *Aphis craccivora* increased when the crops were weed-free mainly as a result of groundcover on the aphid optomotor

landing reaction. However, aphid infestation at NCAM was lowest under weeding at 3, and 6 WAS, while weeding at 3 WAS recorded the highest. This result contradicts earlier report that an increase in population density of aphid is directly related to increasing in weed density (Sheku *et al*., 2014); more aphids were recorded in uncontrolled plots than in the plots weeded once.

Megalurothrips sjostedti is thought to be responsible for up to 70% of yield loss. *M. sjostedti* alone was predicted to cause up to 70% yield loss in West Africa, depending on the severity of the infection (Ngakou *et al*., 2008). Their feeding action mostly causes flower buds and blooms to abort, leading to poor podding and yields (Alabi *et al*., 2004; Ngakou *et al*., 2008). Cowpea is reported to lose up to 80% of its flowers during development as a result of thrips and maruca infestations, which might negatively impair pod formation (Dzemo *et al*., 2010). The results of Kusi *et al*., (2019) indicated three insecticide applications, one at flower bud commencement, 50 percent blooming, and 50 percent podding, were shown to successfully control thrips infestations, corroborated this viewpoint. At Malete, cowpea with no sprays produced the highest thrips infestation while those sprayed thrice were lowest. At NCAM, cowpea with no sprays produced the highest thrips infestation, and however, those plots protected once had the lowest thrips infestation. This study corroborated claims that pesticide use decreases cowpea pest infestation and enhances crop yields significantly (Ebenezer, 2010; Mukendi *et al*., 2019). Across the weeding regime, irrespective of locations, the infestation of thrips when weeding at 3, 6, and 9 WAS were highest while plots left weedy was lowest, most probably because there were more flower buds on the weed-free plot (3, 6, and 9WAS) than the weedy plot. Regardless of location, protecting cowpea with three insecticide sprays resulted in the lowest pod borer infestations. This result was consistent with the findings that the first application of insecticide treatment at the initiation of flowers lowered the population of insects (*M. vitrata*), and the second application further whittled down the insect population, suggesting that applying insecticides three times could produce good yields of cowpea crop, comparable to the four and five spray regimes (Oyewale *et al*., 2014; Mukendi *et al*., 2019).

Cowpea plots sprayed thrice with insecticide at Malete had the least presence of pod-sucking bugs while those that were sprayed once had the highest. However, surprisingly at NCAM, cowpea with no sprays had the lowest presence of pod-sucking bugs while those that were sprayed thrice had the highest. The reason for this variation may be due to different biotic and environmental factors available in the two locations. Regardless, Kusi *et al*., (2019) found that spraying cowpea at 50% podding efficiently controlled this pest complex, indicating that efficient management of pod sucking bugs during the podding stage in cowpea may require just one insecticide application. Similarly, Mukendi *et al*., (2019) reported that spraying insecticide twice or thrice reduced the density of sucking bugs on cowpea. At both locations weeding at 6 WAS had the lowest pod infestation. Across locations and insecticide spray times, plots weeded at 3 WAS had the highest presence of pod-sucking bugs at Malete, while the plots left weedy were highest at NCAM. There were higher pod-sucking bugs at Malete in comparison with NCAM. This implies that weeding of cowpea once or unweeded at all supports the buildup of pod-sucking bugs, as weeds provide habitat for them to hide and survive in addition to their preferred cowpea plant. Moreover, Malete

supported a community of more diverse weed species than NCAM which could have provided a more suitable alternative habitat for the pod-sucking bugs. Although, it was expected that weedy plots support the buildup of natural enemies due to the high level of weed biomass, but this was not considered during the study.

At Malete, plots that were weeded at 3 WAS and weedy check produced the highest pod damage rating. In contrast, at NCAM plots weeded twice at 3 and 6 WAS and those weeded thrice – 3, 6, and 9 WAS produced the highest pod damage rating. Plots not sprayed and those sprayed once at Malete, produced the highest pod damage rating. This study corroborated reports that the second insecticide spray protects pods from pod borer and pod sucking bugs infestations (Oyewale *et al*., 2014; Kusi *et al*., 2019). However, the plots with no spray, plots sprayed once and twice at NCAM produced the highest pod damage rating. Cowpea planted at NCAM had higher grain damage than those planted at Malete. At NCAM, cowpea protected with two insecticide sprays produced the lowest grain damage and this was 26% lower than those not protected. Cowpea sprayed thrice at Malete produced the lowest grain damage, while those with no sprays recorded the highest grain damage. At NCAM, cowpea sprayed twice produced the least grain damage, while the unsprayed were the highest. Grain damage when weeding at 3, and 6WAS was lowest compared to the weedy check with the highest damage at Malete. However, at NCAM, plots with weeding either 3, and 6 WAS or 3, 6, and 9 WAS recorded the lowest grain damage while weedy plots recorded the highest. This result shows the import of insecticide application and weeding of plots in mitigating insect build-up in cowpea

NCAM has a substantially higher 100 seed weight than Malete. At both locations, no spray had the lowest 100 seed weight. Cowpea plots sprayed thrice with insecticide at Malete had the highest mean 100 seed weight while those with no spray had the lowest. In contrast, cowpea protected with two insecticide sprays at NCAM had the lowest 100 seed weight while those with no spray had the highest. At NCAM weeding at 3 and 6 and 3, 6 and 9 WAS had the highest seed weight, while at Malete weeding at 6 WAS and 3, 6 and 9 WAS had the highest seed weight. This finding supports the result of an earlier study that insecticide application significantly increased the average 100-grain weight (Ndiso *et al*., 2017) as a result of low pest density and infestation which invariably influence yield and yield parameters.

According to the findings, cowpeas planted at NCAM had more yield than those planted at Malete. Cowpeas plots sprayed twice with insecticide generated the highest yield, which was around four times greater than those not sprayed, regardless of location. This finding supported the findings of Dzemo *et al*., 2010; Mukendi *et al*., 2019 and Adigun *et al*., 2022 who found that two pesticide sprays applied at the start of flowering and podding might minimize insect infestations, grain damage, and enhance grain production in the tropics. At the two locations, the yield when weeding at 3, 6, and 9 WAS was highest and while the weedy plot was lowest. This result corroborated the findings of Li *et al*., 2004; Ajani *et al*., 2017 and Adeyemi *et al*., 2020 that uncontrolled weed development throughout the cowpea life cycle can result in yield losses ranging from 50% to 86 percent. It is therefore critical to do early weeding in cowpea to ensure a better yield. In the forest-savannah transitional zone of Southwest Nigeria, early weeding beginning at 3 WAS is vital for cowpea production, whereas the

key period for weed removal for optimum yield in cowpea is between 3 and 9 WAS (Adigun *et al*., 2014). In our study, spraying pesticides on cowpeas enhanced grain output considerably. The yield achieved when spraying three times, on the other hand, was not significantly different from the yield obtained when spraying twice, once during blooming and once during the podding periods. Similarly, the yield gained while weeding three times (3, 6, and 9 WAS) was not substantially different from the yield obtained when weeding twice (3 and 6 WAS). This indicates that a third pesticide spray may not be required in this region. Due to environmental issues, pesticide prices, and management expenses, careful selection of spray regimes is essential in the control of cowpea insect pests.

CONCLUSION

Two pesticide sprays applied at 50% flowering and 50% podding (two sprays) and weeding twice (3 and 6 weeks after sowing) or thrice (3, 6, and 9 weeks after sowing) were shown to successfully manage insect pest complex and boost yield in cowpea in the current study. Reduced pesticide treatment and weeding remain significant strategies for controlling cowpea insect pests in the field and preserving a healthy environment, according to the findings of this study. Aphids, thrips, maruca, and pod sucking bugs are the key limiting factors for cowpea production in the Southern Guinea Savanna of Nigeria. In plots where weeding was done three times – at 3, 6, and 9 WAS – and pesticide sprays were administered at 50 percent flowering and 50 percent podding (i.e., two sprays), the number of insect pests was lower, and the damage caused by insect pests of cowpea was greatly decreased.

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