Scholars Journal of Agriculture and Veterinary Sciences OPEN ACCESS
Abbreviated Key Title: Sch J Agric Vet Sci
ISSN 2348–8883 (Print) | ISSN 2348–1854 (Online)
Journal homepage: https://saspublishers.com

Developing a Sustainable Spraying Regime for Cowpea Seed Production in South West Nigeria

Olasoji JO[1*], Timothy MIJ[1], Dada AO[1], Owolade OF[1]

[1]Institute of Agricultural Research and Training, Obafemi Awolowo University, Moor Plantation Ibadan, Nigeria

DOI: 10.36347/sjavs.2023.v10i09.001 | **Received:** 12.06.2023 | **Accepted:** 19.07.2023 | **Published:** 15.09.2023

***Corresponding author:** Olasoji JO
Institute of Agricultural Research and Training, Obafemi Awolowo University, Moor Plantation Ibadan, Nigeria

Abstract **Original Research Article**

Cowpea (*Vigna unguiculata* L. Walp) production in Nigeria is burdened by insect pest infestations throughout its developmental stages. Farmers rely on the use of conventional insecticides for insect pest control; however, these insecticides are often wrongly used, thereby resulting in undesirable effects on seed yield and the ecosystem. Cowpea was cultivated under different insecticide application regimes and its effect on seed production was evaluated at three substations of the Institute of Agricultural Research and Training, located at Ibadan in Oyo state (Rain forest transiting to derived savannah), Ilora in Oyo state (Derived savannah) and Ballah in Kwara state (Southern Guinea savannah). The trial was conducted during the cowpea cropping seasons of year 2018 and 2019. Ten treatments included 10 sprays of 2.5 EC lambda-cyhalothrin and cowpea varieties Ife Brown and IT2246. The experimental layout was split-split plot in a randomised complete block design. The results show a reduction in percentage aphids infestation as the spraying regimes increased on both cowpea varieties. The lowest values of 1.53 and 1.58% on Ife Brown and IT2246 respectively, were recorded on 200m/ha of four regime spray. Similar results were recorded on the number of thrips, the population of *Clavigralla spp* and number of pods/plant. Average seed yield under 3 spraying regime increased for both Ife Brown and IT2246 with increase in concentration of pesticide across locations except Ibadan where the yield reduced when the concentration was increased to 600 ml/ha. The spraying regimes of Lambda-cyhalotrin at foliage, flowering and podding have considerable potential for managing the pest of cowpea, but their impact of cowpea grain yield varies significantly.

Keywords: Seed yield; insect pest; Lambda-cyhalotrin; spray regime; infestation.

INTRODUCTION

Cowpea *Vigna unguiculata* (L) is grown in tropical and sub-tropical climate, and consumed world-wide as source of nutrients and fiber in human diet (Baudoin, 2001). Cowpea plays a very important role in food security and income generation, not only due to its nutritional value but also due to its adaptability to poor agricultural soils, compatibility as an intercrop, and ability to fix atmospheric nitrogen (Rego *et al.*, 2015). Most cowpeas are grown on the African continent particularly in Nigeria and Niger which account for 66% of world production. Cowpea is a major source of protein in the diet of many people in sub-Saharan Africa. According to Kamar *et al*. (2014) cowpea supplies about 40 % of the daily protein requirements to the majority of Nigerians and has low density lipoproteins that are implicated in heart diseases (Singh and Basu, 2012). Nigeria is the world's largest producer of cowpea with 3.6 million tons of production (FAOSTAT Database 2021). However, the yield obtained from farmers' fields is generally low at an average of 500 kg ha−1 (Kusi *et al*. 2019). Cowpea production is greatly hindered by some factors among which are diseases caused by fungi, bacterial and viruses (Schwartz, 2005). Likewise, insect pest infestation has been reported to reduce cowpea yield by 75–80% (Ajeigbe *et al*., 2005). In most parts of West Africa, insect pests are the most important constraint to cowpea production (Karungi *et al*, 2000; Mkenda and Ndakidemi, 2014; Medugu and Okrikata, 2020).

Jackai and Adalla (1997) listed at least 20 major insect pest species in various cowpea producing regions of the world, and most damaging of all the insect pests are the flowering and post flowering insect pests. The major flowering and post flowering insect pests of cowpea in tropical Africa are the flower bud thrips, (*Megalurothrips sjostedti*), cowpea pod borer (*Maruca vitrata*) and a complex of pod sucking bugs out of which *Clavigralla tomentosicollis* is the dominant species (Jackai and Adalla, 1997). The use of conventional synthetic insecticides are the major method of controlling insect pests in cowpea, resulting in increased

cowpea yield by 50–200% (Alghali 1992; Kyamanywa 1996; Kamara *et al*. 2007). Kamara *et al*. (2007) reported a 75% grain yield increase with the application of dimethoate once at flowering, whereas Ajani *et al*. (2017) obtained an 82% grain yield increase with two sprays of cypermethrin. Complete crop failure may occur especially in situation where control measures are not applied. Without a breakthrough in the control of the more recalcitrant post flowering field pest of this crop, production of cowpea will be a slow and frustrating process. The most damaging of all pests are those occurring during flowering and podding stages of cowpea development (i.e post flowering pests PFPs). The use of conventional synthetic insecticide in cowpea production is the most widely known form of insect pests control. However, traditional cowpea grower in south west Nigeria misuse these insecticides due to the cost, non-availability and circulation of fake insecticide. Insect pests also respond differently to different insecticides in ways that could be unfavourable to the farmers Therefore, there is the need to determine the appropriate spraying regime that is economically sustainable and environmentally friendly.

MATERIALS AND METHODS

The trial was conducted during the cowpea planting seasons of year 2018 and 2019 at three substations of the Institute of Agricultural Research and Training, Moor Plantation located at Ibadan in Oyo state (Rain forest transiting to derived savannah), Ilora in oyo state (Derived savannah) and Ballah in Kwara state (Southern Guinea savannah). The experimental layout was split-split plot in a randomized complete block design with ten treatments spray of Lambda-cyhalothrin 2.5 EC.

Table 1: Treatment combinations of application rate and spraying regimes (frequency of application) of insecticide of cowpea varieties

Treatments	Spraying Regimes (SRs)	Concentration
01	2 Spraying Regimes (each at Flowering & Podding)	200ml/ha
02	2 Spraying Regimes (each at Flowering & Podding)	400ml/ha
03	2 Spraying Regimes (each at Flowering & Podding)	600ml/ha
04	3 Spraying Regimes (each at Foliage, Flowering & Podding)	200ml/ha
05	3 Spraying Regimes (each at Foliage, Flowering & Podding)	400ml/ha
06	3 Spraying Regimes (each at Foliage, Flowering & Podding)	600ml/ha
07	4 Spraying Regimes (each at Foliage, Flowering & 2 Podding)	200ml/ha
08	4 Spraying Regimes (each at Foliage, Flowering & 2 Podding)	400ml/ha
09	4 Spraying Regimes (each at Foliage, Flowering & 2 Podding)	600ml/ha
10	No Spray	

Two cowpea varieties Ife Brown and IT-2246 which are highly susceptible to insect pests were used for the trials. At 50% flowering, 30 flowers were picked at random at about 8 am and put into 30% alcohol. The flowers were dissected and thrips, *Megalurothrips sjostdti*i (Trybom) counted. Counts of adults, nymphs and egg batches of *Ootheca mutabilis* (Shalberg), *Aphis craccivora*, *Clavigralla tomentosicollis* (Stal.) and *Maruca testucalis* (Greyer) were done 5WAS in a 1 m X 1 m quadrant within the five inner rows of each plot between 7 am and 12 noon. Counting was done four times at 10 days' interval. Data was collected on the percentage aphids-infected plant, number of pods/plant, number of thrips/flower, number of *Clavigralla* sp/plot and grain yield. All the two years' data were pooled together for analysis using General Linear Model (GLM) procedure in statistical analysis system, SAS software package version 9.2(SAS institute, 2002) to compute mean squares for each character. Mean separation was done using Duncan Multiple Range Test (DMRT).

RESULTS

There was a reduction in percentage aphids infestation as the spraying regimes increased on both Ife Brown and IT2246 (Table 2). The lowest values of 1.53% and 1.58% on Ife Brown and IT2246 respectively, were recorded on 200m/ha of four regime spray. Crops managed with insecticides at 200m/ha, 2 regimes of spraying had the highest percentage aphids infestation of 24.55% and 17. 66% on Ife Brown and IT2246, and across all concentration of insecticide and were significantly higher than those managed with 3 and 4 regime sprays. Percentage Aphids infestation did not differ significantly between the 3 and 4 regime spraying on the two cowpea varieties. Cowpea variety IT2246 in Ilora stood out as percentage Aphid infestation was not different across all the spraying regime and concentration of insecticide. The number of thrips in cowpea flower dropped drastically with application of 200m/ha, 400m/ha, and 600m/ha of insecticide across all three spraying regimes as compared to no spray (Table 3). The trend was true at all three locations. Infestation of the cowpea varieties was generally lower at Ballah than Ibadan and Ilora. Observations from the two cowpea varieties Ife Brown and IT2246 showed that all spraying regimes and concentrations of insecticides drastically reduced the population of *Clavigralla* (Table 4). However, the three and four spraying regimes had a greater impact on population at Ibadan and Ilora. The trend at Ballah was slightly different, as the two-regime

insecticide spray at 600ml/ha on cowpea variety IT2246 was as effective as the three and four regime spray in keeping the population of *Clavigralla spp* down. Table 5 shows that the incidence and severity of brown blotch of cowpea was slightly reduced when managed with 200ml/ha, two regime spray, but in Ibadan, the incidence and severity of the disease on cowpea IT2245 was not different from that of the control plots, where no treatment was applied. Also, at ibadan, the most effective control was 400ml/ha and 600m/ha, 4 regime spray, giving values as low as 1.1 and 1.0 respectively. All the concentrations of the three and 4 regime sprays effectively reduced incidence and severity of brown blotch disease on IT2245. All concentrations of the three and four regime sprays, was effective at reducing the incidence and severity of the disease on the two cowpea varieties cultivated at Ilora and Ballah.

In all the three locations, the number of pods per plant was lowest on the two cowpea varieties managed with two spraying regimes (Table 6). The number of pods increased as concentrations increased within each spraying regime. Although there was an increase in the number of pods per plant as the spraying regime increased from three to four, the difference was not significant. In Ibadan and Ilora, 200ml/ha concentration of insecticide at 3 spraying regimes produced lower seed yield of Ife Brown than the other two concentrations within the spraying regime. Mean grain yield (Table 7) revealed that average seed yield of Ife Brown increased when sprayed twice with 400 ml/ha but reduced when the concentration was increased to 600 ml/ha in Ibadan and Ilora. However, in Ballah, the average seed yield of Ife Brown cowpea variety increased with increase in pesticide concentration. The average seed yield of IT2246 variety increased with pesticide concentration under two spraying regime across locations except Ballah where the yield reduced when the concentration was increased to 600 ml/ha. Furthermore, average seed yield of cowpea crops treated with fewer than 3 spraying regime increased for both Ife Brown and IT2246 with increase in concentration of pesticide across locations except Ibadan where the yield reduced when the concentration was increased to 600 ml/ha. The four spraying regime in Table 5 showed no particular pattern but it was noted that the average yield of both Ife Brown and IT2246 was highest with 400 ml/ha concentration in Ibadan. However, four spraying with 200 ml/ha concentration gave the highest yield of both varieties across locations (Table 7).

Table 2: Percentage aphids infestation on Ife Brown and IT2246 cowpea varieties under different insecticide spraying regimes

Spraying Regimes	Concentration	Ibadan		Ilora		Ballah	
		Ife brown	IT2246	Ife brown	IT2246	Ife brown	IT2246
2	200ml/ha	24.55b	17.66b	16.45b	15.67b	14.24b	13.00b
	400ml/ha	17.50b	11.45b	16.89b	14.66b	12.98b	14.67b
	600ml/ha	18.67b	14.67b	17.67b	16.87b	10.34b	15.90b
3	200ml/ha	6.80c	5.362	1.65c	1.78b	4.67c	6.34c
	400ml/ha	4.23c	3.7c	0.89c	1.67b	3.56c	4.55c
	600ml/ha	2.89c	4.89c	1.22c	1.89b	5.78c	4.45c
4	200ml/ha	1.53c	1.58c	0.60c	2.25b	1.22c	1.92c
	400ml/ha	1.67c	1.78c	0.87c	3.78b	1.78c	1.78c
	600ml/ha	1.78c	1.89c	1.56c	3.89b	0.66c	0.89c
No Spray		55.43a	65.46a	68.23a	75.23a	66.78a	56.59a

Values followed by the same letters are not significantly different P<0.05 DMRT

Table 3: **Effect of the different spraying regime and concentration of insecticide on the number of thrips/flower on Ife Brown and IT2246 cowpea varieties at different locations**

Spraying Regimes	Concentration	Ibadan		Ilora		Ballah	
		Ife brown	IT2246	Ife brown	IT2246	Ife brown	IT2246
2	200ml/ha	3.22b	2.00b	3.17	2.33	2.66b	1.56b
	400ml/ha	3.44b	2.33b	3.56	2.44	2.67b	1.33b
	600ml/ha	2.33b	2.67b	3.66	2.33	2.33b	1.67b
3	200ml/ha	2.67b	2.44b	3.51	2.34	1.33b	0.55b
	400ml/ha	3.33b	3.34b	3.45	1.34	0.67b	0.67b
	600ml/ha	2.66b	2.33b	2.33	2.33	0.33b	0.45b
4	200ml/ha	2.33b	2.67b	2.45	1.34	0.33b	0.67b
	400ml/ha	1.33b	2.15b	2.33	2.44	0.34b	0.33b
	600ml/ha	1.67b	2.33b	2.67	2.33	0.66b	0.67b
No Spray		14.76a	16.66a	12.33	14.00	8.83a	7.45a

Values followed by the same letters are not significantly different P<0.05 DMRT

Table 4: **Effect of the different spraying regime and concentration of insecticide on the population *Clavigralla spp* on Ife Brown and IT2246 cowpea varieties at different locations**

Spraying Regimes	Concentration	Ibadan		Ilora		Ballah	
		Ife brown	IT2246	Ife brown	IT2246	Ife brown	IT2246
2	200ml/ha	10.66b	14.44b	6.67b	6.67b	5.66b	5.67b
	400ml/ha	11.67b	10.66b	5.33b	5.33b	6.77b	4.56b
	600ml/ha	12.66b	9.87b	5.67b	5.67b	4.66b	3.67bc
3	200ml/ha	4.00c	3.56c	0.33c	0.33c	0.66b	1.00c
	400ml/ha	2.66c	2.43c	0.67c	0.67c	0.33c	0.33c
	600ml/ha	2.23c	2.45c	0.33c	0.33c	0.67c	0.33c
4	200ml/ha	2.88c	2.5c	0.33c	0.33c	0.67c	1.33c
	400ml/ha	2.56c	1.67c	0.67c	0.67c	0.57c	0.67c
	600ml/ha	2.15c	1.33c	0.56c	0.56c	0.45c	0.67c
No Spray		26.67a	22.66a	17.67a	17.67a	16.67a	15.56a

Values followed by the same letters are not significantly different P<0.05 DMRT

Table 5: **Effect of the different spraying regime and concentration of insecticide on the incidence and severity of brown blotch of cowpea**

Spraying Regimes	Concentration	Ibadan		Ilora		Ballah	
		Ife brown	IT2246	Ife brown	IT2246	Ife brown	IT2246
2	200ml/ha	3.9b(32.0b)	2.5a(21.5a)	3.8b(36.5b)	2.8a(26.9b)	3.1b(29.2b)	2.5b(18.8b)
	400ml/ha	3.9b(29.4b)	2.7a(23.6b)	3.4c(36.5c)	2.8a(29.2b)	3.1b(26.2c)	2.5b(16.2b)
	600ml/ha	3.7b(28.5b)	2.8a(22.2b)	3.3c(35.4c)	2.7a(27.3b)	3.0b927.3c)	2.4b(15.6b)
3	200ml/ha	2.1c(13.5c)	1.4b(10.2c)	2.2d(10.2d)	1.3b(11.2c)	1.2c(10.2d)	1.2c(6.2c)
	400ml/ha	2.2c(10.2c)	1.4b(8.5c0	2.2d(9.8d)	1.1b(8.2c)	1.0c(8.9d)	1.1c(5.2c)
	600ml/ha	1.2cd(6.3c)	1.2b(8.0c)	2.2d(8.2d)	1.2b(8.1c)	1.0c(8.9d)	1.1c(5.2c)
4	200ml/ha	2.0c(7.5c)	1.2b(8.2c)	2.1d(8.0d)	1.1b(7.2c)	1.0c(6.8d)	1.0c(4.4c)
	400ml/ha	1.1d(1.5e)	1.3b(7.5c)	2.2d(9.0d)	1.0b(6.5c)	1.0c(7.0d)	1.0c(4.8c)
	600ml/ha	1.0d(0.0e)	1.2b(7.0c)	1.8d(6.2d)	1.0b(5.6c)	1.0c(8.4d)	1.0c(3.2c)
No Spray		4.2a(95.6a)	4.5a(92.5a)	4.2a(75.2a)	4.3a(77.8a)	4.9a(79.8a)	3.8a(62.5a)

Values followed by the same letters are not significantly different P<0.05 DMRT
Value in parenthesis are the percentage incidence of brown blotch disease of cowpea

Table 6: **Effect of the different spraying regime and concentration of insecticide on the number of pods/plant of Ife brown and IT2246 cowpea varieties at different locations**

Spraying Regimes	Concentration	Ibadan		Ilora		Ballah	
		Ife brown	IT2246	Ife brown	IT2246	Ife brown	IT2246
2	200ml/ha	9.56c	6.23b	7.65c	5.56c	6.23c	9.25b
	400ml/ha	8.87c	8.36b	7.67c	5.78c	8.25c	9.56b
	600ml/ha	7.23c	9.56b	9.54c	6.66c	9.98c	8.36b
3	200ml/ha	18.33b	40.25a	33.63b	45.56a	10.36b	13.56a
	400ml/ha	23.45a	42.45a	39.55a	49.43a	11.56b	12.56a
	600ml/ha	23.5a	41.45a	40.76a	49.76a	9.63b	12.96a
4	200ml/ha	22.33a	42.33a	39.43a	47.27a	13.26a	13.55a
	400ml/ha	25.26a	43.67a	43.32a	48.20a	14.56a	13.55a
	600ml/ha	24.56a	43.33a	43.60a	53.56a	13.56a	13.88a
No Spray		2.26d	1.25d	3.56d	8.66d	0.20d	0.52c

Values followed by the same letters are not significantly different P<0.05 DMRT

Table 7: **Effect of the different spraying regime and concentration of insecticide on the mean grain yield of cowpea varieties under different spraying regimes**

Spraying Regimes	Concentration	Ibadan		Ilora		Ballah	
		Ife brown	IT2246	Ife brown	IT2246	Ife brown	IT2246
2	200ml/ha	128.49b	97.35b	152.67c	132.67c	232.56b	143.76b
	400ml/ha	136.68b	113.40b	136.67c	146.67c	256.67b	156.55b
	600ml/ha	132.44	118.20b	143.33c	143.33c	4301.55b	134.89b
3	200ml/ha	988.34a	577.20a	477.34b	487.34b	768.67a	943.84b
	400ml/ha	967.67a	577.70a	489.67ab	488.67ab	778.33a	933.45a
	600ml/ha	963.67a	566.25a	522.33a	512.33a	867.33a	978.45a
4	200ml/ha	944.67a	554.78a	583.77a	583.77a	897.15a	967.56a
	400ml/ha	1099.67	599.35a	563.89a	543.89a	889.96a	978.88a
	600ml/ha	1066.67a	578.67a	577.87a	569.87a	845.33a	957.00a
No Spray		68.00c	20.78c	34.90	15.90d	56.09c	12.89c

Values followed by the same letters are not significantly different P<0.05 DMRT

DISCUSSION

The findings from this study help to understand the reliance of many rural cowpea farmers on conventional synthetic insecticide for quick knock-down of insect pest of cowpea crop. For all the pest investigated in this study, there was a drastic drop in pest population, even with the application of the smallest concentration of insecticide in a two spraying regimes, and it agrees with Kusi *et al.*, (2019) who also reported a reduction in the abundance and damage of major cowpea pests after a two-regime spray in northern Ghana. Beyond recording a reduction in pest population, is the impact of pest control strategies on economic returns. Pest management practices on cowpea would be ideal with insect monitoring to determine economic threshold before intervention with insecticides. However, in a situation where pest monitoring is difficult, calendar schedule for application could be an ideal substitute. The pest status of insect pests: *Megalurothrips sjostedti*, *Aphis craccivora* and *clavigralla tomentosicollis* was further confirmed by the magnitude of yield reduction on untreated plots. Likewise, the efficacy of lambda-cyhalothrin to knock down a variety of insect pests might be due to its property as a double action insecticide, having both contact and systemic modes of operation (Nwadinigwe, 2010). A study by Oladapo *et al*., (2021) also shows that it is capable of improving formation of root nodules and other vegetative parameters in cowpea. The use of inappropriate concentrations of the insecticide, either higher or lower than recommended doses could be hazardous to crop production, this mostly results in a scenario where some of the insect population are able to survive exposure to insecticide (Alyokhin *et al.*, 2022), they tend to develop resistance to an otherwise lethal amount of insecticide and so is their progeny; for this purpose managing major pests of cowpea with different concentrations in a two time spraying regime could be undesirable in the long term. It is possible that a resurgence in pest population has resulted in the lower yield reported from those cowpea crops managed with two-spraying regime in this study.

Previous studies have shown that pest population and infestation is decided by several factors, some of which is environmental factor, which may differ at different locations even within the same agroecology, and varietal differences (Wallner, 2003; Walter *et al.*, 2018). Insect pests are cold blooded animals that thrive during the hot weather and can complete several reproduction cycles when temperatures are high (Björkman & Niemelä, 2015). The population of *M. sjostedti* on the two cowpea varieties, Ife-brown and IT2246 suggests that the latter is susceptible to a higher degree than the former. The observed difference could also be because of prevailing environmental condition at the time of planting or previous cropping history of the land, which could have resulted in a build-up or reduction in insect population. Thrips like many other arthropod pests can survive on alternative host plants or volunteer crops during off seasons, in wait for their preferred host crops (Abtew, 2015). Management of the major pests of cowpea in a three and four regime spray achieved the most in population management, more probably because the method did not give a chance for pest resurgence, rather than increased concentration of insecticide. Hence, higher concentration of insecticide and spraying regime than what was used in this study could be wasteful and hazardous to the environment and in the long run, the consumers, in the form of pesticide residue in cowpea grains and haulms.

CONCLUSIONS

Insecticide spray regime influenced the growth and yield of cowpea. However, the influence of insecticide application differed among spraying regimes. This study confirmed that pests (*Aphis cracivora*, *Megalurothrips sjostedti* and *Clavigralla tometicolis*) were a major impediment to cowpea production in south west Nigeria. The spraying regimes of Lambda-cyhalotrin at foliage, flowering and podding showed considerable potential for managing the pest of cowpea, but their impact on cowpea grain yield varied significantly Three spraying regime of 200ml/ha significantly reduced insect population of all the insect pest that was observed on Ife Brown and IT2246 cowpea crops and gave a higher grain yield than lower spraying regimes.

Acknowledgment

We are profoundly grateful to the of Agricultural Research and Training, Obafemi Awolowo University, Moor Plantation, Ibadan, Nigeria for the research grant. Special thanks also go to all the farmers selected across agro ecological zones in south western Nigeria for the trial.

Funding

The work was funded by the research grant from the Institute of Agricultural Research and Training, Obafemi Awolowo University, Moor Plantation, Ibadan.

Competing interests

The authors declare that they have no competing interests.

REFERENCES

- Abtew, A. B. (2015). The behavior, ecology and control of legume flower thrips, Megalurothrips sjostedti (Trybom) in cowpea *Vigna unguiculata* (L.) towards the development of an integrated pest management (IPM) program in Kenya. https://doi.org/10.3/JQUERY-UI.JS.
- Ajani, O. A., Adigun, J. A., Atayese, M. O., Popoola, A. R., & Daramola. O. S. (2017). Growth and Yield Performance of Cowpea (*Vigna unguiculata* L. Walp) as Affected by Insecticidal

Spraying Regime and Weed Control Methods. *Nigerian Journal of Ecology*, 16 (1), 22–35.

- Ajeigbe, H. A., Singh, B.B., & Oseni, T.O. (2005). Cowpea-cereal Intercrop Productivity in the Sudan Savanna Zone of Nigeria as Affected by Planting Pattern, Crop Variety, and Pest Management. *African Crop Science Journal* 13 (4), 269–279.
- Ajeighe, H. A., Adamu, R. S., & Singh, B. B. (2012). Yield performance of cowpea as influenced by insecticides types and their combinations in the dry savannah of Nigeria. *African Journal of Agric. Research, 7*(44), 5930-5938
- Alghali, A. M. (1992). "Insecticide Application Schedules to Reduce Grain Yield Losses Caused by Insect Pests of Cowpea in Nigeria." *Insect Science and Application*, 13, 725–730.
- Alyokhin, A., Chen, Y. H., Udalov, M., Benkovskaya, G., & Lindström, L. (2022). Evolutionary considerations in potato pest management. *Insect Pests of Potato: Global Perspectives on Biology and Management*, 429–450.
- Baudoin, A. (2001). Disease control principles. Page 330-332 in: Encyclopedia of plant pathology, Wiley, New York.
- Björkman, C., & Niemelä, P. (2015). Climate change and insect pests. *Climate Change and Insect Pests*, 1–279.
- Collinson, E. G., Ohaeri, G., Wadul-Mian, M., & Igene, J. O. (1992). Fungi association with stored unprocessed cowpea and groundnut varieties in Borno State, Nigeria. *Journal of Hygiene, Epidemology, Microbiology and Immunology* 36(4), 338-345.
- FAOSTAT Database. (2021). Available online: http://www.fao.org/faostat (accessed on 15August 2021).
- Ibrahim, B. I., & Kwaghe, T. T. (2007). The economic effect of spray pesticides on cowpea (*Vigna unguiculata*) production in Adamawa State of Nigeria. *International Journal of Agricultural Research*, 2(7), 647-650.
- Jackai, L.E.N., & Adalla, C.B. (1997). Pest Management Practices in Cowpea: A review. Pages 240-258 in Advances in Cowpea Research, edited by B. B. Singh, D. R. Mohan, Raj, K. E. Dashiell, and L. E. N. Jackai. Co-publication of International Institute of Tropical Agriculture (IITA) and Japan International Research Centre for Agricultural Sciences (JIRCAS). IITA, Ibadan, Nigeria
- Kamara, A. Y., Chikoye, D., Omoigui, L. O., & Dugje. I. Y. (2007). Influence of Insecticide Spraying Regimes and Cultivar on Insect Pests and Yield of Cowpea in the Dry Savannas of north-east Nigeria. *Agricultural Environment* 5 (1), 154–158.
- Kamar, N., Gworgwor, N. A., & Wabekwa, J. W. (2014), Varietal trial and physiological components determining yield differences among cowpea varieties in semiarid zone of Nigeria. Hindawi Publish Corporation. Ism Agronomy Http://Dx.Doi.Org/10.1155/2014/925450
- Karungi, J., Adipala, E., Ogenga-latigo, M.W., Kyamanywa, S., & Oyobo, N. (2000). Pest Management in cowpea. Part 1 Influence of planting time and plant density on cowpea field pests' infestation in eastern Uganda. *Crop Protection*, 19, 231-136
- Kusi, F., Nboyine, J. A., Abudulai, M., Seidu, A., Agyare, Y. R., Sugri, I., Zakaria, M., Owusu, R. K. Nutsugah, S. K., & Asamoah. L. (2019). Cultivar and Insecticide Spraying Time Effects on Cowpea Insect Pests and Grain Yield in Northern Ghana. *Annals o Agricultural Sciences* 64 (1), 121–127.
- Kyamanywa, S. (1996). Influence of Time of Insecticide Application on Control of Insect Pest of Cowpea and Grain Yield on Cowpea at Mtwapa, Coastal Province of Kenya. *African Crop Science Journal*, 4, 373–382.
- Medugu, M. A. & Okrikata, E. (2020). Bioactivity of Selected Plant Parts in the Control of cowpea Bruchid (*Callosobruchus maculatus* L.) on Stored Cowpea (*Vigna unguiculata* L. Walp.). *Equity Journal of Science and Technology*, 7(2), 100 – 104
- Mishan, E.J. & Quah, E. (2007). *Cost Benefit Analysis* (5 Ed.). Oxon: Routledge.
- Mkenda, P.A. & Ndakidemi, P.A (2014). Pesticidal Efficacy of Four Botanical Pesticides on Survival, Oviposition and Progeny Development of Bruchid, *Callosobruchus maculates* in Stored Cowpea, *Vigna unguiculata*. *InternationalJournal of Plant & Soil Scienc*e 3(12), 1504-1523
- Nwadinigwe, A. (2010). Effects of the Insecticide, Lambda-cyhalothrin on the Growth, Productivity and Foliage Anatomical Characteristics of *Vigna unguiculata* (L) Walp. *Bio-Research*, *8*(1), 583–587.
- Oladapo, B. O., Ekundayo, E. A., Ekundayo, F. O., & Gbaye, O. A. (2021). Effect of Lambda-Cyhalothrin and Dimethoate on the Growth Response of Cowpea Plants and the Surrounding Soil. *Annals of Science and Technology*, *6*(2), 1–13.
- Rego, A. D., Diop, F.I., Sadio, O., Da Sylva, M., Agbangba, C. E., Tour´e, O., Kane, A., Neyra, M., Ndoye, I. &. Wade. T. K. (2015). Response of Cowpea to Symbiotic Microorganisms' Inoculation (Arbuscular Mycorrhizal Fungi and Rhizobium) in Cultivated Soils in Senegal. *Journal of Plant Science*, 3, 32–42.
- Singh, B. B., Chambliss, O. L., & Sharma, B. (1997). Recent advances in cowpea breeding. In Singh, B. B., Mohan, D. R., Dashiel, K. E., Jackai, L. E. N. Advances in cowpea research (PDF), Ibadan, Nigeria: International Institute of Tropical Agriculture and Japan International Research Center for Agricultural Sciences.
- SAS Institute, (2002) SAS/STAT user's guide, Version 9.2, SAS Inst., Inc., Carg. Standards Australia (2014): What is a Net Benefit? Retrieved from www.standards.org.au/StandardsDevelopment on 6th March, 2023.
- Singh, J., & Basu, P. S. (2012). Non-nutritive bioactive compounds in pulses and their impact on human health: An overview. *Food and Nutrition Science, 3*(12),1664-1672
- Abtew, A. B. (2015). The behavior, ecology and control of legume flower thrips, Megalurothrips sjostedti (Trybom) in cowpea Vigna unguiculata (L.) towards the development of an integrated pest

management (IPM) program in Kenya. https://doi.org/10.3/JQUERY-UI.JS

- Alyokhin, A., Chen, Y. H., Udalov, M., Benkovskaya, G., & Lindström, L. (2022). Evolutionary considerations in potato pest management. *Insect Pests of Potato: Global Perspectives on Biology and Management*, 429–450.
- Björkman, C., & Niemelä, P. (2015). Climate change and insect pests. Climate Change and Insect Pests, 1–279.
- Kusi, F., Nboyine, J. A., Abudulai, M., Seidu, A., Agyare, Y. R., Sugri, I., Zakaria, M., Owusu, R. K., Nutsugah, S. K., & Asamoah, L. (2019). Cultivar and insecticide spraying time effects on cowpea insect pests and grain yield in northern Ghana. *Annals of Agricultural Sciences*, *64*(1), 121–127.
- Nwadinigwe, A. (2010). Effects of the Insecticide, Lambda-cyhalothrin on the Growth, Productivity and Foliage Anatomical Characteristics of Vigna unguiculata (L) Walp. *Bio-Research*, *8*(1), 583–587.
- Oladapo, B. O., Ekundayo, E. A., Ekundayo, F. O., & Gbaye, O. A. (2021). Effect of Lambda-Cyhalothrin and Dimethoate on the Growth Response of Cowpea Plants and the Surrounding Soil. *Annals of Science and Technology*, *6*(2), 1–13.
- Wallner, W. (2003). Factors Affecting Insect Population Dynamics: Differences Between Outbreak And Non-Outbreak Species. *Annual Review of Entomology*, *32*, 317–340.
- Walter, J. A., Ives, A. R., Tooker, J. F., & Johnson, D. M. (2018). Life history and habitat explain variation among insect pest populations subject to global change. *Ecosphere*, *9*(5), e02274.