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Minimizing Insecticide application for sustainable cowpea and livestock production

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Abstract

The use of synthetic insecticides in managing pests of many crops is on the ascendancy and cowpea is of no exception with up to ten insecticide applications per growing season reported. There have, however, been concerns of carry-over effect of these chemicals to humans and animals. The present study sought to conduct a survey with cowpea farmers who double in livestock raising to ascertain the effect of different spraying regimes on yield as well as the levels of pesticides residues in the haulm of cowpea. The study was carried out in the middle belt of Ghana during the minor rainy season of 2014. The experiments consisted of three spraying regimes; calendar spraying (spraying at scheduled periods without considering pest situation), farmers' practice (spraying 4 times at 10 ± 2 days' intervals depending on the farmer) and monitored spraying (spraying is done after assessment of pest numbers and damage). Four farms were selected and each farm represented a replicate. Randomised complete block design was used with the three treatments allotted to the fields of the four selected farms. The calendar and monitored spraying regimes performed significantly better than the farmers' practice spraying regime in aphids and thrips scores, thrips counts and Maruca pod borers in flowers. Besides, the farmers' practice regime had the highest numbers of pod sucking buds (PSB) counts and was significantly higher than the other treatments spraying regimes whilst the calendar spraying regime significantly reduced the PSB than the monitored spraying regime. Though the calendar spraying regime was better than the monitored regime in PSB numbers, it did not translate into yield as both performed equally in terms of grain and haulm yield but they however compared with the farmers' practice regime the levels of diamethoate, lamda cyhalothrin and diazinon in the haulm of cowpea exceeded the maximum residue limit (MRL) under the calendar regime but were within the MRL under the two regimes. Thus, the monitored spraying regime would be recommended as it might reduce both cost of production, pollution to the ecosystem and leaves no or less pesticide residues in the haulms as fodder for animals.

Keywords: Cowpea, Insect pests, pesticides, Grain and haulm yield, Amantin

INTRODUCTION

Cowpea (*Vigna unguiculata* L. Walp.) is of major importance to the livelihoods of millions of people in the tropics. Peasant or subsistence farmers derive food, animal feed, and cash, together with spillover benefits to their farmlands resulting from *in situ* decay of root, leaf and stem materials and effect of ground cover from the crop serving as an insurance crop to sustain production during droughts [1, 2, 3].

[4] reported a cowpea grain yield between 1.6 – 1.8 t ha^{-1} in Ghana with the highest production of cowpea coming from the savannah regions of northern Ghana. The Forest, Savannah transition, Savannah agro-ecological and Coastal zones in Ghana have two cropping seasons namely, major and minor, during which farmers grow cowpea for grain and fodder.

Cowpea haulms play a major role as a supplement for ruminants diets. [5] reported improved performance of sheep when cereal straws were supplemented with the haulm of cowpeas. Cowpea production, however, is considered too dicey an investment by many farmers because numerous insect pests damage the crop, from seedling emergence right to storage [6]. For a complete protection of the cowpea crop, application of appropriate insecticides is recommended and commonly practised in Ghana and other sub-Saharan African countries [7].

Farmers complain of insecticides residues in the haulm and the carry over effect of poisoning of small ruminants when consumed. Cowpea farmers who double in livestock raising have the perception that fodder from haulm of cowpea that contain pesticides residues could result in diarrhorea and other adverse effect to their animals. A survey was conducted with farmers in Amantin, Brong Ahafo of Ghana to ascertain whether the perception held by cowpea farmers were valid. Since these farmers do not feed the haulm to the animals until maturity (thus after grain harvest), there is the likelihood that if insecticides are not judiciously applied there could be insecticidal residues in haulms above the maximum residue limit. Hence, there is the need for proper use of insecticides for maximum cowpea yield and with minimal toxicity levels in the haulm and the environment [8,9].

Whilst there may be enough literature on protection of cowpea, there is limited information on the effects of the insecticidal residues in haulm which is used as fodder for ruminants livestock. This study aimed at providing evidence on the effects of three spraying regimes on insect pests numbers and damage to cowpea and ascertain the maximum residue limits of insecticides in cowpea haulm.

MATERIALS AND METHODS

Survey and interviews conducted

Thirty cowpea farmers who rear ruminants (sheep and goats) in addition at Amantin community were randomly selected. This was done with the assistance of Agriculture Extension Agents (AEA) of the Ministry of Food and Agriculture (MoFA). One on one interview with a structured questionnaires was conducted. Broadly all the farmers' knowledge and perceptions were sought on 1) appropriate use of pesticides in general 2) exact quantities (dosages) of pesticides needed for spraying per plot area measured 3) how many times the farmers apply insecticides till the harvest 4) describe observation of their livestock when fed with haulm of cowpea from the farm and other herbs (including grasses).

Land preparation, design and layout

Trials were set up at Amantin in the forest-savannah transitional zone during the minor growing season at Amantin, 1°19'W 7°54'N. Average annual rainfall, relative humidity and temperature for the area are 1,000 - 1,400 mm, 55 to 65% and 31 to 34^0C respectively. Four cowpea farmers who also reared sheep were selected for this trial. Thus, four farms were selected and each farm was divided into three blocks to accommodate the three spraying regimes. Each block measured 10 m x 10 m and three blocks were each separated by 2 m. Each farm represented a replication, thus obtaining four replications for each of the spraying regimes. The cowpea variety "Paditua" was used for the trial and spaced at 60 cm x 20 cm between and within rows for each treatment. Three seeds were planted per hill and was thinned to two, two weeks after emergence. Thinning was done in calendar and monitored treatment plots whilst farmers practice plots remained same. Manual hoeing was done to control weeds. No fertilizer was applied to the various treatment plots.

Treatments

Three to four insecticides, namely lambda cyhalothrin, Cypermethrin + dimethoate and chlorpyrifos were employed to control insect pests at different application rates as described below. The treatments were 1) Calendar spraying; where pre-flowering insecticide, Lambda Cyhalothrin[1]was applied 30 days after emergence (DAE) using application rate of 40 mls/15 litres. These insecticide applications continued thereafter at weekly interval for four weeks. Post-flowering application of Cymethoate[2] Super then followed at a rate of 60 mls/15 litres at the fifth week till pods matured for harvesting.

2) Monitored spraying; scouting for insect pests of cowpea began very early so that numbers did not go beyond the threshold before chemical intervention. For aphids, scouting was done by moving diagonally from one end of the field to another. Considering the two diagonals and randomly selecting 20 plants, if sampler encountered 4 cowpea stands that were infested with aphids, Lambda Cyhalothrin was applied. For Maruca, 10 flowers were plucked at random and inspected for hidden larvae. Observation of larvae from 2 out of 10 flowers plucked was an indication that chemical intervention would have to proceed immediately. At podding stage sucking bugs were also scouted: Scouting was also done by moving diagonally from one end of the field to another. Siting of a bug was enough of an indication that post-flowering

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[1] Trade name PAWA (ai)
[2] Trade name SUPER (ai)

application of Cymethoate Super at a rate of 60 mls/15 litres was to be applied.

3) Farmers' practice; this treatment was similar to calendar spraying except that decision on when to spray, type of insecticide and the dosage was the sole prerogative of the farmer. Sunpyrifos was applied 30 days after emergence as pre-flowering insecticide at the rate of 60mls/15litres and post-flowering application of Dursban using same rate of 60mls/15litres.

Data collection, harvesting and yield estimation

The data collected were Aphids score, *Thrips* score, *Maruca* pod borer on flowers, pod sucking bug count, percent *Maruca* pod borers on dry pods, percent *Maruca* pod sucking bug on dry seeds, percent pod sucking bug on dry pods, percent pod sucking bug on dry seeds, grain yield and haulm weight. For yield assessment, cowpea seeds were harvested 72 days post establishment from the central rows (i.e. 4 middle rows excluding the border rows) of each plot of area 2.4 m x 10 m. The seeds were conveyed to a barn for air drying. Threshing was done two weeks after harvesting. Haulm yield was determined from the materials in the same central rows. This was done by cutting with machete, 2 cm above ground level and weighed for each plot. Haulm samples were collected at harvest and sent to Ghana Standard Authority for pesticides residues analysis.

Pesticide Residues Analysis using Gas Chromatography

The extraction of pesticide residue was done according to the procedures of (Fillion et al. 2000). An aliquot of 10 mL was transferred to a clean 15 mL tube and evaporated to 0.5 mL under nitrogen water bath at 35 ºC. This was transferred into an ENVI-Carb SPE tube and eluted with 20 mg acetonitrile/ toluene (3 : 1). The elute was transferred to a clean 15 mg tube and 50 µL internal standard added and brought to a volume of 2.5 mg with acetone, of which 0.5 mL of this was used for gas chromatography analysis of the pesticide residues. Splitless injection of 1 µL was carried out at 270 ºC and splitless time 1.5 minutes. Column temperature was initially set at 80 ºC and held for 2 min, then increased at a rate of 35 ºC/min to 170 ºC and held for 13.5 min. This was followed by 10 ºC/min to 230 ºC, held 7 min, and was finally increased at rate of 10 ºC/min to 300 ºC for 3 min. The carrier gas flow rate was 2 mL/min. Pesticide residue was estimated as:

$$\text{Pesticide residue} = \frac{\text{peak height ratio in sample}}{\text{peak height ratio in standard}} + \frac{[\text{pesticide}]\text{ in standard}}{[\text{sample}]\text{ in final solution}}$$

Data analysis

Survey data was generated using calculations based on simple proportion from total farmers response.

However, data obtained field trials were subjected to analysis of variance where means of insects counts, haulm weight and yield were compared using PROC GLM; [10]. When significant differences were obtained (P < 0.05), means were separated with Student-Newman Keul's (SNK) test. Pesticide residues (mg/kg) in cowpea haulm under the three spraying regime were compared with maximum residue limits (MRLs) by the Ghana Standard Authority.

RESULTS

Figure 1 is a bar graph showing the percentages of male and female farmers who applied insecticides more than 5 times till harvest. The graph shows that 100% of male farmers and 100% of female farmers apply insecticides more than 5 times till harvest. Figure 2 is also a bar graph showing the percentages of male and female farmers who use the recommended dosage of insecticides for spraying. The graph indicates that 36.4% of male farmers and 25% of female farmers use 25% of female farmers use the recommended dosage of insecticides for spraying whilst 63% of male and 75% of female farmers do not use the recommended insecticides to spray.

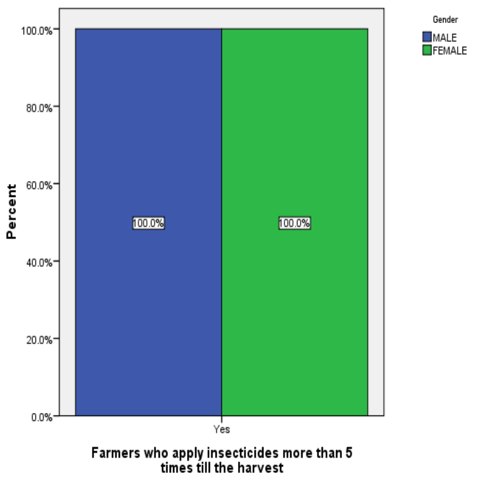

Figure 1

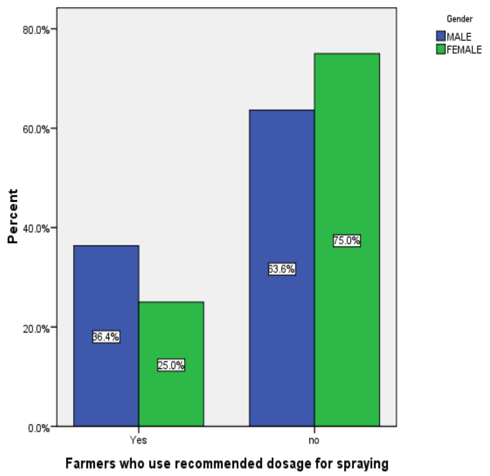

Figure 2

Figure 3 is a bar graph showing the percentage of male and female farmers who use the recommended dosage of insecticides to spray cowpea. The graph shows that 9.1% of male and 25% of female farmers use the recommended insecticide for cowpea whilst 90.9% of male farmers and 75% of female farmers do not use the recommended insecticide for spraying cowpea.

Figure 4 shows cowpea farmers who are literate above Junior High School (JHS) and Senior High School (SHS). The graph shows that 9.1% male farmers and 0% of female farmers are literate whilst 90.9% of male farmers and 100% of female farmers have no formal education.

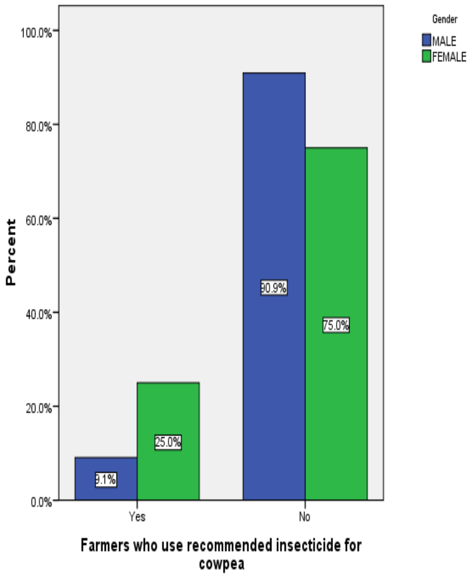

Figure 3

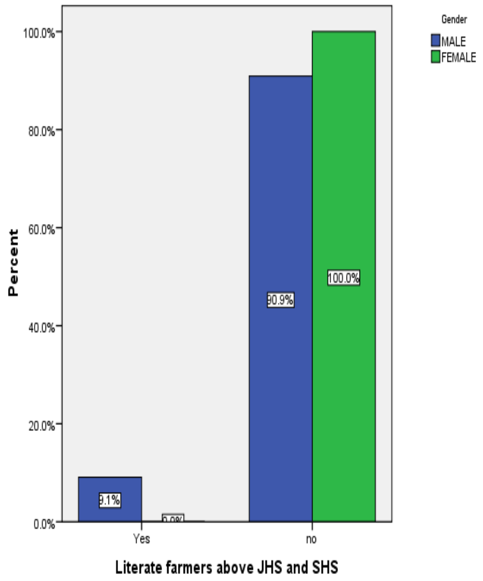

Figure 4

Figure 5 depicts percentages of male and female farmers who claimed animals had diarrhoea when fed with haulm of cowpea containing pesticides. The graph shows that 68.2% of male and 50% of female farmers claimed animals had diarrhoea when fed with haulm of cowpea containing pesticides residues whilst 31.8% of male and 50% of female farmers claim animals do not have diarrhoea when fed with haulm of cowpea containing pesticides residues.

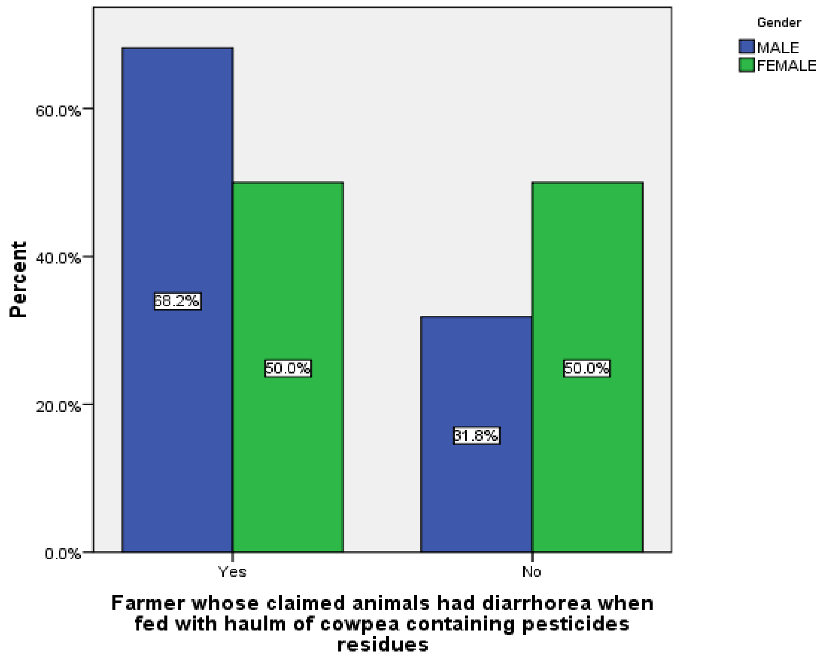

Figure 5

Insect pest numbers and damage to cowpea

The results of the pest populations on the three different insecticide applications are presented in Tables 1 and 2. There were significant (P<0.05) differences in the measured parameters namely; aphid score, thrips scores, thrips counts *and Maruca* pod borers on flowers (Table 2). Farmers' practice plots recorded the highest Aphids score (0.60 ± 0.04), thrips scores (0.55 ± 0.05) as well as thrips counts (4.00 ± 0.41) and were significantly poorer than the remaining treatments.

With the exception of PSB counts, there were no significant differences (P>0.05) in percent *Maruca* pod borers (MPB) on dry seeds, PSB damaged pod and MPB damaged on seeds (Table 3). Farmers' practice plots recorded the highest PSB counts with the least PSB counts being cowpea plots under calendar spraying

Similarly, there were no significant differences (P>0.05) in percent PSB dry seeds and haulm weight (Table 4). However, there were significant differences for yield for the three different spraying treatments. Farmers' practice plots recorded the highest yield while the least was from plots under monitored spraying (Table 4)

Table 1: Effect of insect pest on cowpea establishment under different spraying regimes at Amantin in minor rainy season of 2014.

Treatment Borer	Aphids score Mean ± s. e.	Thrips score Mean ± SE.	Thrips count Mean ± SE.	Maruca damaged pods Mean ± SE.
Calendar spraying	0.25 ± 0.05 b	0.26 ± 0.05 b	2.00 ± 0.00 b	0.15 ±0.03 c
Monitored spraying	0.30 ± 0.04 b	0.26 ± 0.05 b	2.25 ± 0.25 b	0.26 ± 0.03b
Farmers' practice	0.60 ± 0.04 a	0.55 ± 0.05 a	4.00 ± 0.41 a	0.55 ± 0.03 a
F-value	18.43	10.68	15.55	54.82
P	0.0007	0.0042	0.0012	0.0001

Note: Means with the same letters in the same column are not significantly different at P=0.05.

Table 2: Percent *Maruca* pod borers on dry seeds, PSB count, PSB damage Pod and MPB damage on seeds of *Paditua* cowpea under different spraying regimes at Amantin in the minor rainy season of 2014.

Treatment	%MPB dry seeds Mean ± SE.	PSB count Mean ± SE.	PSB damage Pod Mean ± SE.	MPB Damage on Seeds Mean ± SE.
Calendar spraying	10.00 ± 0.00 a	3.25 ± 0.25 c	72.50 ± 2.50 a	1.85 ±0.37 a
Monitored spraying	7.50 ± 0.25 a	4.75 ± 0.25 b	75.00 ± 2.89 a	0.82 ± 0.32 a
Farmers' practice	7.50 ± 4.79 a	6.75 ± 0.48 a	80.00 ± 0.00 a	1.11 ±0.89 a
F-value	0.21	26.12	3.00	0.82
P	0.8111	0.0002	0.1004	0.4701

Note: Means with the same letters in the same column are not significantly different at P=0.05.

Table 3: Percent PSB damaged dry seeds, yield and haulm weight of *Paditua* cowpea under different spraying regimes at Amantin in the minor rainy season of 2014.

Treatment	% PSB dry seeds Mean ± SE.	Grain yield (Kg/ha) Mean ± SE.	Haulm weight (Kg) Mean ± SE.
Calendar spraying	12.22 ± 0.65a	869.26 ± 3.22b	1.82 ± 0.09a
Monitored spraying	12.61 ± 0.86a	826.96 ± 17.65b	1.57 ± 0.05a
Farmers' practice	15.05± 1.00a	945.91 ± 15.11a	1.78 ±0. 02a
F-value	3.27	19.82	3.85
P	0.0858	0.0005	0.0619

Note: Means with the same letters in the same column are not significantly different at P=0.05.

Insecticidal residue in cowpea haulms

The dimethoate, lambda cyhalothrin and diazinon levels in the haulm of cowpea under the calendar spraying regime exceeded the maximum residue limits (MRLs) except for cypermethrin and chlorpyrifos, which were within the MRLs (Table 4). The levels of dimethoate, lambda cyhalothrin and diazinon in the farmers' spraying practice were similar (P> 0.05) to the calendar spraying method except that the cypermethrin level was significantly lower (P<0.05) than that in the calendar.

Table 4 Pesticide residues (mg/kg) in cowpea haulm under three spraying regime

Treatment	Cypermethrin	Dimethoate	Lambda cyhalothrin	Chlorpyrifos	Diazinon
Calendar	0.42^{a}	0.04^{a}	0.19^{a}	0.03^{ab}	0.08^{a}
Monitored	0.28^{ab}	0.016^{a}	0.10^{a}	0.02^{b}	0.03^{a}
Farmers' practice	0.18^{b}	0.023^{a}	0.02^{a}	0.09^{a}	0.09^{a}
MRLs	0.7	0.02	0.05	0.05	0.01
SEM	0.16	0.03	0.18	0.06	0.07

Note:*Within column means with common letters (a,b,c) are not significantly different (P> 0.05). Where MRLs = maximum residue limits and SEM = standard error of mean*

DISCUSSION

Results from the survey indicated that about 90% of the farmers no basic or secondary education. In many developing countries, farmers are illiterate or speak and read indigenous dialects. Pesticides labels are normally written in foreign languages [11]. For example, even though Ghana's official language is English, it is common to find pesticides on the market that are labelled in French or Chinese [12], a practice which exacerbates the inability of farmers to comprehend pesticides labels. This leads to unacceptable practises in handling and use of pesticides by some farmers such as tongue-testing of diluted insecticides to determine their potency [13]; [14]; [15]; [12].

Deducing from the survey results, it is evident that farmers generally do not take pains to conform with appropriate use of pesticides, exact quantities (dosages) required for spraying per plot area measured and the right time to apply insecticides (monitored spraying) for pests management. This study therefore lends support to the findings that almost 75% of all deaths linked with pesticidal poisoning occur in developing countries even though they use only 15% of global pesticide supply[16]; [17];[18]). Moreover cowpea farmers apply insecticides in excess of the recommended rates due to insects resistance, use insecticides meant for industrial crops such as cocoa and cotton for vegetables and cowpea, use empty pesticides containers for storing drinking water are practised in Ghana and often lead to pesticidal poisoning [13]; [15].

All the major insect pests of cowpea namely; the cowpea aphid , the flower bud thrips the legume pod borer and the sucking bug complex, of which *Clavigralla* spp, *Anoplocnemis* spp, *Riptortus* spp, *Mirperus* spp, *Nezara viridula* Fab and *Aspavia armigera* L were recorded in the study area; an observation which tallied with the reports of [19]) that these major insect pests of cowpea occur wherever the crop is cultivated in Ghana.

As observed in the legume yield, grain yield of cowpea varied among the different insecticide application regimes. Differences in the haulm weight were not significant which contrasts the stu who worked on similar cowpea varieties and obtained significant differences in haulm weights. The differences in the results of the two studies may be due to differences in the climatic conditions. [20]) reported 70% higher grain yield in similar experiments under calendar and monitored insecticides application for a particular cowpea variety.

Lambda cyhalothrin, Cypermethrin + dimethoate (conventional chemical) effectively controlled the major insect pests in the various treatments at the trial location, which conforms to reports of earlier cowpea researchers ([19] [21]). On grain yield, both calendar and monitored sprayings recorded high yields, 869.26 kgha^{-1} and 826.96 kgha^{-1} respectively and were significantly better than the farmers' practice which was 945.91 kgha^{-1}. The values for grain yield in this study compares favourably with yield from some other cowpea works conducted in Nigeria such as Bauchi [22] and Calabar [23] but was lower than the yield data reported in Ghana [4]. The significantly higher grain yield recorded by farmers' practice (945.91 kgha-1) at Amantin (compared with the other two treatments) may be attributed to less insect damage to cowpea in these trial locations. Yield differences due to different spraying regimes effects have been reported in Delta State, Nigeria from other previous studies for some cowpea [20].

Though Sunpyrifos and Dursban effectively controlled the major insect pests of cowpea under farmers' practice in this study, and grain yield was high, this chemical, like most other conventional chemicals has adverse side effect on the environment such as pollution, toxicity to mammals, users and consumers [24]. Moreover, most farmers in Ghana are resource-poor and require pest management strategies that are cost-effective, sustainable and maintain grain yield and haulm quality with less toxicity from chemical residue as feed to their ruminants. Improper use of pesticides may leave residues in the haulms of cowpea at levels that may be toxic to livestock and may indirectly affect human health when such animals or their products are consumed [25]; [26].

In west African countries including Ghana (personal experience) and from Uganda [27], it is reported that commercial farmers in these countries spray their farms from 8 to 10 times during the growing season. The present study which employed 3 times spray before harvest with monitored insect infestation/damage before spraying has advantages of reducing the number of pesticide applications (sprays) and still produce the desired grain yield, and environmental pollution is minimal. Findings in this study support the report of [4] who stated that significant differences did not exist in calendar spray and monitored sprays in terms of insect number and grain yield. The present study again lends support to the idea that cowpea farmers may spray only 3 times in order to reduce environmental pollution as well as chemical residue in fodder from cowpea haulms. The use of the monitored spraying regime with Cyhalothrin and Cypermethrin + dimethoate will ensure high and quality grain yield whilst reducing cost of production due to reduced insecticides application. This study recommends a further investigation on other types of agro-chemicals, its rates of application and shorter period of last spray to feeding is needed to completely document the effects of these chemicals on crops yield, residues quality and animal health.

CONCLUSION

Different insecticide application methods have a marked effect on the yield performance of cowpea. Pod sucking bugs which significantly influence the yield of cowpea were recorded in higher counts in farmers' practice plots than in cowpea plots under calendar and monitored spraying. However, insecticide residues in cowpea haulm under the calendar spraying regime exceeded the MRLs except for cypermethrin and chlorpyrifos. This is definitely a concern to farmers that insecticides residue may be left on crop residues such as cowpea haulms that are regularly used to feed ruminants and could harmfully affect the health of these animals.

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