African Journal of Biotechnology Vol. 8 (24), pp. 7182-7186, 15 December, 2009
Available online at http://www.academicjournals.org/AJB
ISSN 1684–5315 © 2009 Academic Journals

Full Length Research Paper

The impact of phosphate fertilizer as a pest management tactic in four cowpea varieties

Asiwe, J. A. N.

Agricultural Research Council, Grain Crops Institute, Private bag X1251, Potchefstroom, 2520, South Africa.
E-mail: AsiweJ@arc.agric.za. Fax: +27 18 294 7146.

Accepted 8 September, 2009

Insect pests constitute serious threat to cowpea production in sub-Saharan Africa. In some severe situations, total yield loss results. Chemical control, although most effective, is very costly, hazardous and unsustainable. Investigation of other control options such as cultural practices that are environment friendly is critically important. This paper reports the effects of four levels of phosphorus fertilizer application (0, 15, 30 and 45 kg P_2O_5 ha^{-1}) on insect population, damage and grain yield of four cowpea varieties (IT91K-180, IT95M-118, TVu 1890 and Vita 7) planted at research farm of International Institute of Tropical Agriculture (IITA), Nigeria. Data were collected on insect counts, pod evaluation index and damage by *Aphis craccivora, Megalurothrips sjostedti*, *Maruca vitrata* and pod-sucking bugs. Results indicated that damage by *A. craccivora*, *M. sjostedti* and *M. vitrata* were significantly ($P < 0.05$) lower at 30 and 45 kg P_2O_5 ha^{-1} and consequently higher grain yields were obtained.

Key words: Cowpea, grain yield, insect pests, pod evaluation index, phosphate fertilizer.

INTRODUCTION

Cowpea, *Vigna unguiculata* (L.) Walp, is one of the important staple food crops in sub-Saharan Africa. It is rich in protein, carbohydrate and vitamins (Bressani, 1985; Kholi, 1990). Cowpea is also important because it fixes atmospheric nitrogen (Asiwe et al., 2009) and excess of its nitrogen requirements are made available for subsequent crop uptake thereby reducing the cost of nitrogen fertilization. Cowpea is attacked by several insect pests from seedling to storage leading to zero grain yield in many instances in Sub Saharan Africa (Singh and Jackai, 1985; Jackai and Daoust, 1986; Asiwe et al., 2005). At Mokwa and Ibadan IITA research stations, zero yield or 100% crop failure due insect pests (especially Thrips, *Maruca* pod borer and pod-sucking bugs) are possible without any insecticide protection or yield enhancement (Ajeigbe and Singh, 2006). For this reason, insect pests pose the greatest challenge to cowpea production in sub-Saharan Africa. The most important insect pests of cowpea in Africa are aphids (*Aphis craccivora* Koch) (Homoptera: Aphididae), flower thrips (*Megalurothrips sjostedti* Trybom) (Thysanoptera: Thripidae), legume pod borer (*Maruca vitrata* Fabricius) (Lepidoptera: Pyralidae) and a complex of pod-sucking bugs (PSBs) (Singh et al., 1990; Dreyer et al*.,* 1994). Several management strategies are being employed in the suppression of these insect pests, including biological control (Kumar et al., 1980; Tamo et al., 1997), chemical control (Jackai et al., 1985; Amatobi, 1994; Jackai et al., 2001, Asiwe, 2009), host plant resistance (Singh, 1987; Fatokun et al., 1997) and cultural methods (Matteson, 1982; Karungi et al., 2000; Asiwe, 2004; Asiwe et al., 2005).

The use of fertilizers as a yield booster has been reported (Kang and Juo, 1979; Kang and Nangju, 1983; Kutu et al., 2009). Also, some macro-nutrients, nitrogen, phosp 1horus and potassium have received some attention in the study of plant resistance to insect pests. Fertilizers not only improve crop yield, but also influence crop suitability for insect development, depending on the type of fertilizer and pest species (Van Emden, 1966; Wooldbridge and Harrison, 1968; Kogan, 1994). For example, phosphorus is known to increase cowpea grain yield as well as influencing the contents of certain nutrients levels in the leaves (Kang and Nangju, 1983). We also know that it interacts with other soil nutrients such as nitrogen, sulphur and zinc to improve yield of other crops (Kang and Juo, 1979). Even though recent reports showed that, the application of phosphorus reduced the population densities and damage of pod-sucking bugs (Pitan et al., 2000) and *Empoasca dolichi* Paoli (Shri Ram et al., 1987, 1990) not much is known of the its effects on other insect pests of cowpea.

The soils in humid and semi-arid of West Africa are highly leached, eroded and are deficient in phosphorus (Mokwunye, 1979). Phosphorus deficiency in these areas is further worsened by farmers' practices of intensive cropping with little or no fallowing and removal of cowpea haulms or biomass due to the cut and carry method of harvesting by the farmers to feed their animals in kraals or for sale as fodder (Bottenberg, 1995). The eventual grazing of leftover crop residues by animals (IITA, 1998; Barzegar et al., 2002) further depletes the soil of organic material return to the soil. To evaluate the influence of phosphorus on insect pests of cowpea in such soils is therefore necessary. We know that other nutrients if deficient could limit cowpea growth and development (Carsky, 2003), therefore one important assumption in this work was that phosphorous is often most deficient and that cowpea can fix 80 - 90% of its nitrogen demand (Eaglesham et al., 1977). This paper reports the effects of applying different levels of phosphate fertilizer on insect counts, flower and pod damage as well as grain yield of four cowpea varieties.

MATERIALS AND METHODS

The experiment was conducted at the International Institute of Tropical Agriculture (IITA) Ibadan, in two cropping seasons: the first (April to July) and second (September to November), in 1999. Four cowpea varieties (Vita 7, IT95M-118, TVu 1890, IT91K-180) were chosen because of their differential susceptibility to cowpea insects. Vita 7 is susceptible to all cowpea insect pests and was therefore used as the susceptible check. IT95M-118 is a breeding line developed by IITA with low level of resistance to *M. vitrata,* while IT91K-180 is early maturing (65 days) and moderately resistant to *M. sjostedti* and *M. vitrata* TVu 1890 has low to moderate level of resistance to pod-sucking bugs (IITA,1987). Their average grain yield under full insecticide protection is about 0.8 - 1.0 t/ha. Plot sizes were 5 by 5 m (25 m^2) and consisted of 250 plants at the rate of two plants per stand. Four levels (0 kg P_2O_5 ha^{-1}, 15 kg P_2O_5 ha^{-1}, 30 kg P_2O_5 ha^{-1} and 45 kg P_2O_5 ha^{-1}) of single super phosphate fertilizer were applied, in a split-plot experimental design. Fertilizer levels were the main plots and the varieties the sub-plots. Each treatment was replicated three times. No insecticide was applied.

Three seeds were sown per stand in rows spacing of 1.0 m apart and 0.20 m apart within the row. Plant stands were thinned to two seedlings soon after germination. Fertilizer treatments were applied two weeks after planting (2WAP) as a side-dressing along the cowpea rows. In each plot, a one-metre row length was randomly staked out in each of the three middle rows and used as areas for sampling PSBs and pod counts. This was to ensure that during flower sampling, flowers were not picked from these areas so that data on pod counts would not be confounded.

Assessment of insect population and yield parameters

Damage caused by *A. craccivora* was assessed on cowpea plants taken from the three middle rows of every plot using a 9-point scale described by Jackai and Singh (1988). Damage of flowers by *M. sjostedti* was assessed in two ways: (a) by scoring visual damage symptoms observed on racemes, growing tips, stipules and flowers using a 9-point scale described by Jackai and Singh (1988) and (b) by direct counts of *M. sjostedti* (adults and larvae) in a sample of 10 flowers hand-picked randomly from the middle rows (outside the staked areas). The flower samples were put in vials containing 50 - 70% alcohol and subsequently examined in the laboratory. In the laboratory, the samples were dissected open for examination under an illuminated macro-projector to count the number of *M. sjostedti*.

Pod damage by *M. vitrata* was assessed by a technique known as Pod Evaluation index, (*Ipe)* described by Jackai (1995). *Ipe* measures two parameters: pod damage (PD) and pod load (PL). Pod damage measures the presence of *M. vitrata* frass and/or entry/exit holes of larvae while Pod load measures the degree of successful pod production. Each parameter was scored on a 9-points scale as described by Jackai and Singh (1988). Pod load was rated 1 (low) to 9 (high) and pod damage was rated 9 as high and 1 as low. An Index (pod evaluation index) was then derived from the following relationship:

Ipe = PL x (9-PD)

The population density of pod-sucking bugs was assessed by counting the pod bugs found within the sampling areas. This was done on weekly basis during the podding stage. Seed damage by pod bugs was determined as described by Gilman et al. (1982). Pod and flower counts were also taken weekly from the sampling areas in order to monitor their production. Grain yield was determined by harvesting pods of cowpea plants within two middle rows of each plot excluding the border plants. The pods were threshed and the grains weighed.

Data analysis

All the data collected were subjected to statistical analysis using SAS (SAS, 1990). Test for normality of data was done using SAS procedure. The data was found to be normal and did not require any form of transformation. Analysis of variance (ANOVA) was executed using SAS procedure. Pre-planned comparisons of checks (0 level of P and Vita 7 variety) with other factor levels were performed using Dunnett's method (SAS option). Interaction plots of least significant means (LSmeans) were used to examine the nature or pattern of interaction in cases where significant interactions were obtained between variety and P-levels.

RESULTS

Response of *Aphid craccivora* damage to P-levels and cowpea varieties

Significant difference ($P < 0.05$) was obtained in the severity of infestation by *A. craccivora* during the first season and the lowest damage was recorded on 30 kg P_2O_5 ha^{-1} treatment. During the second season, although mean aphid infestation was higher, significant differences ($P < 0.05$) were obtained only among the varieties (Table 1). Fertility level made no discernable difference in the population of this insect.

Response of *Megalurothrips sjostedti* infestation to P-levels and cowpea varieties

Significant differences ($P < 0.05$) were observed among

Table 1. Means of insect damage and pod production of four cowpea varieties at four P-levels.

Variety/P-level	Mean number							
	A. craccivora damage score (1-9)		*M. sjostedti* damage score (1-9)		Number of *M. sjostedti* per flower		*M. vitrata* Pod evaluation index (Ipe)	
	1999 first season	1999 second season	1999 first season	1999 second season	1999 first season	1999 second season	1999 first season	1999 second season
IT91K-180	2.50	3.17*	2.22*	2.57*	28.95*	134.06	42.46*	40.00*
IT95M-118	2.50	3.75*	3.10*	3.39*	25.40*	149.19	34.67*	30.58*
TVu 1890	0.33	2.67*	3.64*	3.38*	29.74*	105.18*	32.25*	34.00*
Vita 7	0.17	4.83	5.77	6.93	58.27	210.16	2.75	13.00
SE ±	0.14	0.30	0.19	0.11	5.8	21.00	2.210	3.60
0 kg (P_2O_5)/ha	0.25	2.67	3.80	4.72	30.12	145.86	19.29	19.58
15 kg (P_2O_5)/ha	1.95	3.0	3.72	4.2	32.73	157.65	24.54	24.66
30 kg (P_2O_5)/ha	0.01*	4.34	3.49	3.05*	28.47	137.04	34.42*	39.00*
45 kg (P_2O_5)/ha	0.33	4.42	3.68	3.79*	48.92*	153.69	33.87*	34.33*
SE ±	0.05	0.86	0.17	0.13	1.90	21.93	1.80	2.31

*Means of treatments are significantly ($P < 0.05$) different from that of control (Vita 7 or 0 kg (P_2O_5)/ha) using Dunnett's t-test, *SE* = Standard Error of means.

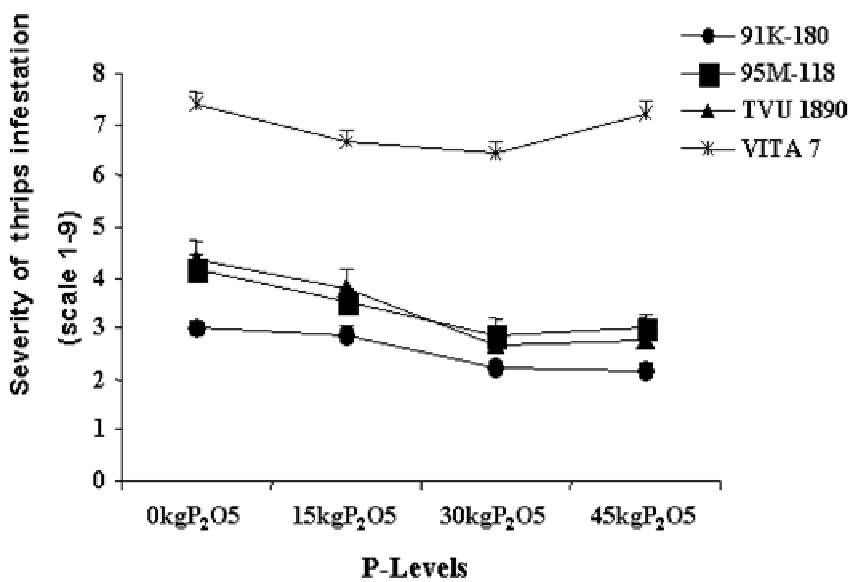

Figure 1. P-level x variety interaction effects on the severity of *Megalurothrips sjostedti* infestation. The interaction was not significant in the first season

the varieties (2.22-5.77) only in the first season (Table 1) but in the second season when infestation of *M. sjostedti* was higher, significant differences existed in both varieties (2.57-6.93) and P-levels (3.05-4.72). The interaction between them was also significant ($P < 0.05$) (Figure 1). Severity of damage (3.05) and number of *M. sjostedti* per flower (28.47) were lowest in the 30 kg P_2O_5 ha^{-1} treatment for all varieties. During both seasons, Vita 7 harboured the highest thrips density per flower and suffered the greatest damage (Table 1, Figure 1).

Responses of varieties to P-levels, *M. vitrata* and pod-sucking bug infestation

There were significant differences in the main and interactive effects of the cowpea varieties and P-levels for pod evaluation index (*Ipe)* during both seasons (Table 1). Variety x P-level interaction plot showed that *Ipe* values were higher at 30 kg and 45 kg P_2O_5 ha^{-1} in all the varieties (Table 1, Figure 2).

Pod sucking bug species recorded in this study were *C.*

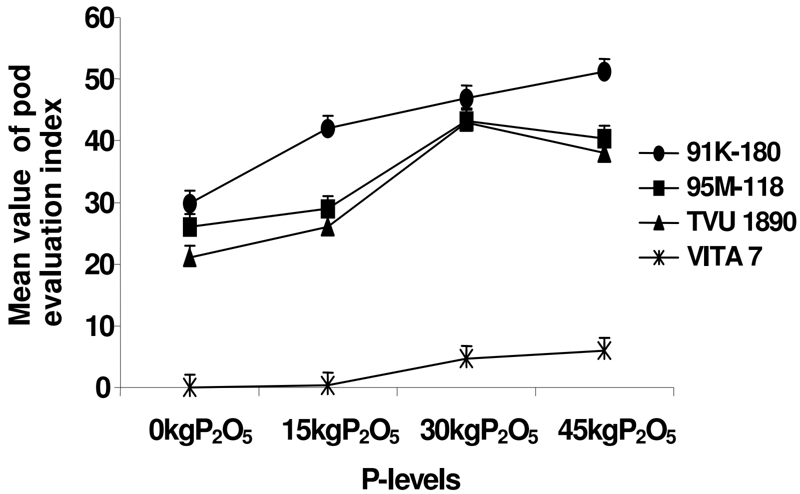

Figure 2. P-level x variety interaction effects on pod evaluation index, Ipe, during the first season. The interaction was not significant in the second season.

Table 2. Mean grain yield, number of pods per plant, seed damage index and number of pod-sucking bugs of four cowpea varieties at four P-levels.

Variety/P- level	Mean number							
	Number of pods per plant		Seed damage index (Isd)		Average number of pod sucking bugs per 1 m row-length		Grain yield (kg/ha)	
	1999 first season	1999 second season	1999 first season	1999 second season	1999 first season	1999 second season	1999 first season	1999 second season
IT91K-180	1.75*	2.55*	47.25*	49.14	8.00	7.90	393.33*	279.85*
IT95M-118	1.54*	1.28*	54.12	50.92	8.20	8.00	270.98*	257.59*
TVu 1890	1.38*	1.32*	50.99	53.70	8.40	8.30	229.47*	375.10*
Vita 7	0.90	0.97	61.44	61.57	8.40	7.50	162.96	45.09
SE ±	0.01	0.01	2.97	4.23	0.02	0.01	25.37	32.28.
No fertilizer								
(0 kg (P_2O_5)/ha))	1.24	0.16	53.43	59.71	8.20	7.90	271.31	172.41
15kg (P_2O_5)/ha	1.23	1.11	56.42	56.17	8.10	7.80	199.45	171.50
30kg (P_2O_5)/ha	1.58*	1.48*	44.49	51.76	8.10	7.80	281.16	290.56*
45kg (P_2O_5)/ha	1.54	1.41	50.09	47.50	8.00	8.20	288.69	312.09*
SE ±	0.01	0.01	3.69	4.72	0.02	0.01	8.62	11.24

*Means of treatments are significantly ($P < 0.05$) different from that of control (Vita 7 or 0 kg (P_2O_5)/ha) using Dunnett's t-test, *SE* = Standard Error of means.

tomentosicollis Stal., *C. shadabi* Dolling*., Anoplocnemis curvIpes* Fab., *Riptortus dentipes* Fab., *Mirperus jaculus* Thunberg, *Nezera viridula* (L.) *Acrosternum* sp. and *Aspavia armigera* Fab. Differences observed among the varieties and P-levels were not significant ($P < 0.05$) for PSB numbers (Table 2) during both seasons. However, within the varieties, Seed damage index (Isd) was significantly ($P < 0.05$) lower on IT91K-180 in the first season (Table 2).

Yield response of cowpea varieties to P-levels

Table 2 also shows that significant ($P < 0.05$) mean differences were obtained in the main effects. The nature of the variety x P-level interaction suggests that high flower production (Figure 3) was obtained among the varieties at the 30 kg P_2O_5 ha^{-1} and 45 kg P_2O_5 ha^{-1}. Grain yield varied significantly among the varieties during both seasons, whereas, among the P-levels, significant

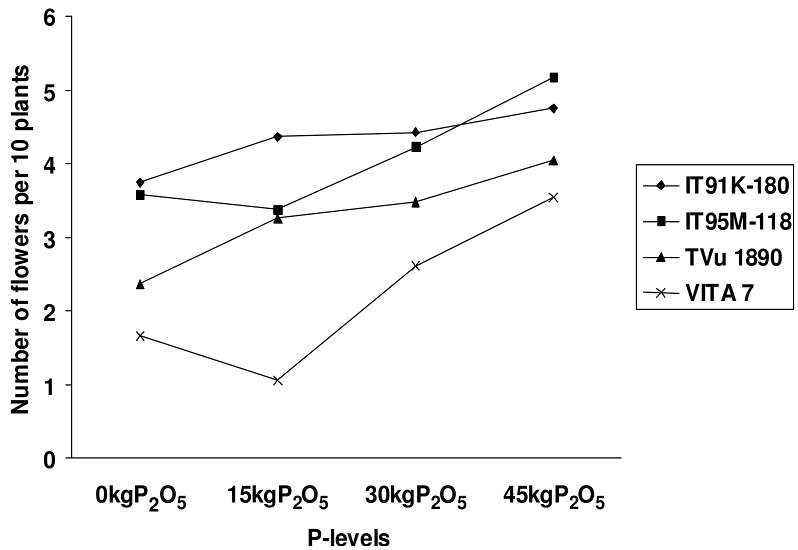

Figure 3. P-levels x variety interaction effects on number of flowers produced per ten plants during the first season.

differences were observed only in the second season (Table 2). Grain yield produced at 30 kg P_2O_5 ha^{-1} (290.56 kg ha^{-1}) and 45 kg P_2O_5 ha^{-1} (312.09 kg ha^{-1}) were higher than those produced at lower P-levels. Vita 7 produced the lowest grain yield during both seasons.

DISCUSSION

The infestations of aphids and thrips were not consistently high during both seasons. Severity of *A. craccivora* was higher during the second season than the first due to the carry-over effect from the first season into the second. Such carry-over effect was observed in flower thrips (Salifu, 1982).

However, Annan et al. (1977) found that about 20 kg P_2O_5 ha^{-1} was needed to reduce *A. craccivora* damage on a resistant cowpea variety. In this study the range is between 15 and 30 kg P_2O_5 ha^{-1}. The slight variation in the results obtained in this study and that of Annan et al., 1977 could be due to differences in variety used.

Higher dosage of phosphorus, especially, 30 kg P_2O_5 ha^{-1} reduced the severity of damage by *M. sjostedti*. This means that the increased nutrition enabled the plants to repair damage by thrips. However, the higher number of thrips in flowers obtained from plants fertilized at 45 kg P_2O_5 ha^{-1} was a function of increased flower numbers, a factor that was not used in determining pest load. This heavy thrips load in this P-treatment in part accounted for its lower pod production per plant than 30 kg P_2O_5 ha^{-1}.

The *Ipe* at 30 kg P_2O_5 ha^{-1} was higher because it exhibited a higher pod load with less damage by *M. vitrata* across the cowpea varieties. In addition, the reduced damage by *A. craccivora* and *M. sjostedti* at this P-application rate also contributed to its productivity in comparison with other P-levels. The slight drop of *Ipe* value in the 45 kg P_2O_5 ha^{-1} treatment as against 30 kg P_2O_5 ha^{-1} was influenced by the reduced pod load caused by increased flower and pod damage from thrips and *M. vitrata*, respectively. In addition, the drop of *Ipe* value obtained at the rate of 45 kg P_2O_5 ha^{-1} was possibly due to higher demand for other nutrients which were either unavailable or in limited proportion as to limit yield. Dense canopy associated with cowpea plots fertilized at 45 kg P_2O_5 ha^{-1} in part, had also contributed to the increased pod damage by *M. vitrata* by providing suitable micro-environment such as low temperature, high humidity and low light transmission. These factors created by dense canopy have been reported to enhance damage by *M. vitrata* (Oghiakhe et al., 1991). The significant low seed damage value for IT91K-180 is a new breakthrough which may be related to its earliness (65 days) or evasion and this needs further laboratory studies for confirmation. TVu 1890 was previously the only variety widely reported to have a low-moderate level of resistance to PSBs (Olatunde et al., 1991; Koona, 1999).

Although, the performance of all P-levels was better than the control (0 kg P_2O_5 ha^{-1}) in their yield components which suggests the role of phosphorus in cowpea grain production (Ntare and Bationo, 1992, Ankomah et al., 1995, Vadez et al., 1999, Waluyo et al., 2004), however, grain yields were lower than expected possibly due to the effect some nutrient antagonism since other macro-nutrients and micro-nutrients were not at optimum level. Several researchers have reported that the supply of P plays important roles in establishment, growth and function of nodules (Israel, 1987; Beck and Munns, 1984; Leung and Bottomley, 1987) and growth of host plants (Munns et al., 1981). The application of 30 kg P_2O_5 ha^{-1} promoted good nutrition and crop development which reduced pest damage; a level at which the supply of other soil nutrients necessary for crop performance were not critical. This finding is in conformity with past work on phosphorus nutrition in cowpea. Tenebe et al. (2000) reported that although grain yield increased with increasing P-levels, there was no accruing yield advantage if cowpea is fertilized with 40 kg P_2O_5 ha^{-1} and beyond. Similarly, the findings of Agboola and Obigbesan (1977) showed that 30 kg P_2O_5 ha^{-1} was the optimum rate of P application for maximum grain yield of cowpea.

Insect damage by aphids, thrips, Maruca pod borer and PSBs were lower on the new cowpea breeding lines (IT91K-180, IT95M-118 and TVu 1890) than on the susceptible Vita 7, thus indicating that they possess some levels of resistance to these pests. The high insect damage obtained on Vita 7 affected the number of flowers, pods per plant and grain yield produced. This supports the findings of Salifu (2001) who reported that Vita 7 is susceptible to all cowpea insect pests. Since most soils of sub Saharan Africa are prone to phosphorus deficiency, the results from this study would be useful in advising farmers the optimal application rate of phosphorus fertilizer for optimum yield and management of cowpea insect pests. In South Africa where crop rotation is commonly practiced and maize crop is heavily dosed with N and P fertilizers, extension agents will find the results from this study useful to advise their farmers to plant cowpea immediately after maize cropping so that cowpea will use the residual phosphorus left after maize uptake. Such residual P left after maize uptake is usually enough and above the critical level to improve the yield of cowpea and enhance resistance to insects. However, in other parts of sub Saharan Africa where farmers intercrop cereals with cowpea without the cereal component receiving any P-fertilizer, a generous application of P at 30 kg P_2O_5 ha^{-1} will not only improve the growth and development of the two companion crops in the intercrop but also enhance the resistance of cowpea to rebuild damages and/or compensate losses caused insects.

In conclusion, fertilizer provided good nutrition for the reduction of pest load and damage and consequently, enhanced grain yield of IT91K-180, IT95M-118 and TVu 1890. Application of 30 and 45 kg P_2O_5 ha^{-1} provided the best nutrition for effective reduction of cowpea pest load and damage with increased grain production. However, given the fact that yield difference between the application rate of 30 and 45 kg P_2O_5 ha^{-1} was not significant and higher cost involved of applying P at 45 kg P_2O_5 ha^{-1}, the optimal level of phosphorus application for cowpea production under no insecticide protection is 30 kg P_2O_5 ha^{-1}. In other words, phosphorous application above 30 kg P_2O_5 ha^{-1} will not result a corresponding increase in marginal return. The findings of this study also recommend that although P-application at 30 kg P_2O_5 ha^{-1} reduced pest load and increased grain yield, higher grain yield could be enhanced through integrated pest management, especially if this rate is applied in conjunction with other cultural practices such as crop rotation, inter-cropping, planting date manipulation, plant spacing and biological control.

ACKNOWLEDGEMENTS

We are grateful to the technical staff of former Cowpea Entomology Unit for their assistance and IITA for the financial support to this research work. Approved as journal article No. 01/125/JA by the International Institute of Tropical Agriculture (IITA), PMB 5320, Ibadan, Nigeria.

REFERENCES

Agboola AA, Obigbesan GO (1977). Effect of different sources and levels of P on the performance and uptake of Ife-Brown variety of cowpea. Ghana J. Agric. Sci. 10: 71-75.

Ajeigbe HA, Singh BB (2006). Integrated Pest Management in Cowpea: Effect of Time and Frequency of Insecticide Application on Productivity. Crop Protect. 25(9): 920-925. September 2006.

Amatobi CI (1994). Field evaluation of some insecticides for the control of insect pests of cowpea (*Vigna unguiculata* L. Walp.) in the Sudan savanna of Nigeria. Int. J. Pest Manage. 40: 13-17.

Ankomah AB, Zapata F, Hardarson G, Danso SKO (1995). Yield, nodulation and N_2-fixation by cowpea cultivars at different phosphorus levels. Biol. Fertil. Soil, 22: 10-15

Annan B, Ampong-Nyarko K, Tingey WM, Schaefers GA (1977). Interactions of fertilizer, cultivar selection, and infestation by cowpea aphid (Aphididae) on growth and yield of cowpeas. Int. J. Pest Manage. 43: 307-312

Asiwe JAN (2004). Impact of cultural practices in the management of major insect pests of cowpea (*Vigna unguiculata* (L.) Walp) Ph.D. Thesis, University of Ibadan, Ibadan, Nigeria. p. 188.

Asiwe JAN, Nokoe S, Jackai LEN, Ewete FK (2005). Does varying cowpea spacing provide better protection against cowpea insect pests? Crop Prot. 24(5): 465-471.

Asiwe JAN (2009). Insect mediated outcrossing and geneflow in cowpea *Vigna unguiculata* (L.) Walp): implication for seed production and provision of containment structures for GT Cowpea. Afr. J. Biotechnol. 8(2): 226-230, 19 January, 2009, ISSN 1684 5315 2009 ©Academic Journals. http://www.academicjournals.org/AJB

Asiwe JAN, Belane A, Dakora FD (2009). Evaluation of cowpea breeding lines for nitrogen fixatrion at ARC-Grain Crops Institute, Potchefstroom, South Africa. Paper presented at the 16th International Congress on Biological Nitrogen Fixation, Montana, USA, 14-19 June, 2009

Barzegar AR, Yousefi A, Daryoshenas A (2002). The effect of addition of different amounts and types of organic materials on soil physical properties and yield of wheat. Plant Soil, 247: 295-301.

Beck DP, Munns DN (1984). Phosphate nutrition of Rhizobium sp. Appl. Environ. Microbiol. 47: 278-282.

Bottenberg H (1995). Farmers' perceptions of crop pests and pest control practices in rainfed cowpea cropping systems in Kano, Nigeria. Int. J. Pest Manage. 41: 195-200.

Bressani R (1985). Nutritive value of cowpea. In: Singh SR, Rachie KO (eds). Cowpea Research Production and Utilization. John Wiley and Sons, Chichester, London. pp. 353-356.

Carsky RJ (2003). Response of cowpea and soybean to P and K on *terre de barre* soils in southern Benin. Agric. Ecosyst. Environ. 100: 241-249.

Dreyer H, Baumgartner J, Tamo M (1994). Seed damaging field pests of cowpea, *Vigna unguiculata* (L.). Walp. in Benin: Occurrence and pest status. Int. J. Pest Manage. 40: 252-260.

Eaglesham ARJ, Minchin FR, Summerfield RJ, Dart PJ, Huxley PA, Day JM (1977). Nitrogen nutrition of cowpea (*Vigna unguiculata*). 3: distribution of nitrogen within effectively nodulated plants, Exp. Agric.

13: 369-380.

Fatokun CA, Perrino P, Ng NQ (1997). Wide crossing in African *Vigna* species. In: Singh, BB, Mohan Raj Dashiell, KE Jackai, LEN (eds). Advances in Cowpea Research. Sayce Publishing, Devon, UK. pp. 50-57.

Gilman DF, McPherson RM, Newsom LD, Herzog DC, Willams C (1982). Resistance in soybeans to the southern green stink bug. Crop Sci. 22: 573-576.

IITA (1998). International Institute of Tropical Agriculture, IITA. Ann. Rep. Project 16. IITA, Ibadan, Nigeria. p. 69.

IITA (1987). International Institute of Tropical Agriculture, IITA. Ibadan, Nigeria. Ann. Rep. for 1986, p. 206.

Israel DW (1987). Investigation of the role of phosphorus in symbiotic nitrogen fixation. Plant Physiol. 84: 835-840.

Jackai LEN (1995). Legume pod borer *Maruca vitrata* (Fab.) and its principal host plant, *Vigna unguiculata* (L.) Walp. Use of selective insecticide sprays as aid in the identification of useful levels of resistance. Crop Prot.14: 299-306.

Jackai LEN, Daoust RA (1986). Insect pests of cowpeas. Ann. Rev. Entomol. 31: 95-119.

Jackai LEN, Goudou C, Asiwe JAN, Tayo BO (2001). Integrated control of the cowpea aphid using seed dressing and varietal resistance. Samaru J. Agric. Res. 17: 13-23.

Jackai LEN, Singh SR (1988). Screening techniques for host plant resistance to insect pests of cowpea. Trop. Grain Legume. Bull. 35: 2-18.

Jackai LEN, Singh SR, Raheja AK, Wiedijk F (1985). Recent trends in control of cowpea pests in Africa. In: Singh SR, Rachie KO (eds). Cowpea Research, Production and Utilization. John Wiley and Sons, Chichester, London, pp. 233-243.

Kang BT, Juo ASR (1979). Balanced phosphate fertilization in humid West Africa. Phosphorus Agric. 76: 75-85.

Kang BT, Nangju D (1983). Phosphorus response of cowpea, *Vigna unguiculata* (L). Walp. Trop. Grain Legume Bull. 27: 11-16.

Karungi J, Adipala E, Kyamanywa S, Ogenga-Latigo MW, Oyobo N, Jackai LEN (2000). Pest management in cowpea. Part 2. Integrating planting time, plant density, and insecticide application for pest management of cowpea field insect pests in Eastern Uganda. Crop Prot. 19: 237-245.

Kholi KS (1990). Kohinoor -a nutritious fodder cowpea for animals. Indian Farming 39: 15-29.

Kogan M (1994). Plant resistance in pest management. In: Metcalf, R and Luckmann (eds.), Introduction to pest management, John Wiley and Sons, Inc. New York, pp. 73-128.

Koona P (1999). Anatomical and biochemical bases of resistance of wild and cultivated vigna species to the coreid bug *Clavigralla tomentosicollis* Stal. (Hemiptera: Coreidae*).* Ph.D. thesis. University of Ibadan, Nigeria, p. 213.

Kumar NG, Thontadarya TS, Kulkarni KA (1980). Some natural enemies of the pod borer, *Cydia ptychora* Myrick (Lepidoptera: Tortricidae). Curr. Res. 9: 146-147.

Kutu FR, Deale W, Asiwe JAN (2009). Assessment of maize and dry bean productivity under different intercropping systems and fertilizer regimes. Paper Accepted for presentation at 9th International Conference of African Crop Science Society, Cape Town, South Africa, September, 2009.

Leung K, Bottomley PJ (1987). Influence of phosphate on the growth and nodulation characteristics of *Rhizobium trifolii.* Appl. Environ. Microbiol. 53: 2098-2105.

Matteson PC (1982). The effect of intercropping and minimal permethrin application on insect pests of cowpea and their natural enemies in Nigeria. Trop. Pest Manage. 28: 372-388.

Mokwunye U (1979). Phosphorus needs of soils and crops of the savanna zones of Nigeria. Phosphorus Agric. (Special Issue), 76: 87-95.

Munns DN, Hohenberg JS, Righetti TL, Lauter DT (1981). Soil acidity tolerance of symbiotic and nitrogen fertilized soybeans. Agron. J. 73: 407-410

Ntare BR, Bationo A (1992). Effect of phosphorus on yield of cowpea cultivars intercropped with pearl millet on Psammentic Paleustalf in Niger. Fertilizer Res. 32: 143-147.

Oghiakhe S, Jackai LEN, Makanjuola WA (1991). Cowpea plant architecture in relation to infestation and damage by the legume pod borer, *M. vitrata* Fab. (Lepidoptera: Pyralidae). 1. Effect of canopy structure and pod position. Insect Sci. Appl.12: 193-199.

Olatunde GO, Odebiyi JA, Jackai LEN (1991). Identification of sources of resistance in cowpea *Vigna unguiculata* L. Walp. to *Clavigralla tomentosicollis* Stal. (Hemiptera: Coreidae*).* Insect Sci. Appl. 12: 455-461.

Pitan ORO, Odebiyi JA, Adeoye GO (2000). Effects of phosphate fertilizer on cowpea pod-sucking bug population and damage. Int. J. Pest Manage. 46: 205-209.

Salifu AB (1982). Biology of cowpea flower thrips and host plant resistance. M.Sc. Thesis, University of Ghana, Legon, Ghana. p. 115.

Salifu AB (2001). Bases of resistance among cowpea genotypes to the bean flower thrips, *Megalurothrips sjostedti* (Trybom) (Thysanoptera: Thripidae). Nig. J. Entomol. 18: 68-79.

SAS Institute (1990). SAS/STAT® User's Guide, Fourth Edition, Cary, NC, USA.

Shri Ram, Gupta MP, Maurya RP (1987). Role of major plant nutrients (NPK) in the management of insect pests of cowpea, *Vigna unguiculata* (L.). Int. J. Trop. Agric. 5: 209-214.

Shri Ram, Patil BD, Purohit ML (1990). Role of fertilizer (phosphorus and potassium) and soil insecticide in the pest management of fodder *cowpea, Vigna unguiculata* (L.) Walp. Indian J. Entomol. 52: 627-636.

Singh SR (1987). Host plant resistance for cowpea insect pest management. Insect Sci. Appl. 8: 765-769.

Singh SR, Jackai LEN (1985). Insect pests of cowpea in Africa: their life cycle, economic importance, potential for control. In: Singh SR, Rachie KO (eds). Cowpea research, production and utilization. John Wiley and Sons, Chichester, and London. pp. 217-231.

Singh SR, Jackai LEN, Dos Santos JHR, Adalla CB (1990). Insect pests of cowpea. In: Singh, S.R. (ed.) Insect pests of tropical food legumes, Chichester, John Wiley & Sons, Chichester and UK. pp. 43-90.

Tamo M, Bottenberg H, Arodokoun D, Adeoti R (1997). The feasibility of classical biological control of two major cowpea insect pests. In: Singh, BB, Mohan Raj Dashiell, KE Jackai, LEN (eds) Advances in cowpea research. Sayce Publishing, Devon, UK pp. 259-270.

Tenebe VA, Kushwaha S, Singh BB (2000). The influence of sources and levels of phosphorus on the grain yield and protein content of cowpea, *Vigna unguiculata* (L.) Walp. varieties. Proc. Third World Cowpea Res. Conf., Ibadan Nigeria. 4-7th September, 2000.

Vadez V, Lasso JH, Beck DP, Drevon JJ (1999). Variability of N_2-fixation in common beans (*Phaseolus vulgaris L.*) under P deficiency is related to P use efficiency. Euphytica, 106: 231-242.

Van Emden, HF (1966). Plant insect relationships and pest control. World Rev. Pest Control 5: 115-123.

pWaluyo SH, Lie TA, Mannetje L (2004). Effect of phosphate on nodule primordia of soybean (*Glycine max*) in acid soils in rhizotron experiments Indonesian J. Agric. Sci. 5: 27-44.

Wooldbridge AW, Harrison FP (1968). Effect of soil fertility on abundance of green peach aphid on Maryland tobacco. J. Econ. Entomol. 61: 387-391.