Effect of phospho-compost on growth and yield of cowpea (*Vigna unguiculata*)

K. G. OFOSU-BUDU, D. OBENG-OFORI, K. AFREH-NUAMAH & R. ANNOBILL

(K. G. O.-B. : Agricultural Research Station, Kade, University of Ghana, Legon, Ghana; D. O.-O. , K. A.-N. & R. A. : ARPIS Sub-Regional Centre for West Africa, University of Ghana, Legon, Ghana)

ABSTRACT

The effect of phospho-compost on the growth and yield of cowpea (*Vigna unguiculata*) was studied at Juaboso in the Western Region of Ghana. It was a factorial experiment arranged in a randomized complete block design with four replications. Phospho-compost, prepared from phosphate rock, cocoa pod husk, sawdust and poultry manure, was applied at the rate of 560 g plot^{-1} (875 kg ha^{-1}) and worked into soil before planting. Phosphate rock was applied at the rate of 195 g plot^{-1} (300 kg ha^{-1}) 1 week before planting. The triple superphosphate was applied as band placement of 90 g plot^{-1} (130 kg ha^{-1}), 7 days after sowing. These application rates were equal to 60 kg P_20_5 ha^{-1}. Phospho-compost significantly ($P < 0.05$) increased number of leaves, number of nodules, plant biomass, number of pods per plant, and grain yield more than the control. Grain yield on the phospho-compost-treated plot was 25.8 per cent higher than the control. Phospho-compost treatment had a profit margin of ¢3,295,000.00 ($387.65). This figure compared favourably with the treatment using conventional triple superphosphate fertilizer, which recorded ¢3,422,000.00 ($402.59) profit. The controls had a profit margin of ¢2,515,000.00 ($295.88). The results of the study indicate that the use of phospho-compost (which is locally prepared) can significantly increase the yield of cowpea. Resource-poor farmers can use phospho-compost to improve the fertility of soil for higher productivity of cowpea.

Original scientific paper. Received 27 Jul 04; revised 18 Oct 06.

RÉSUMÉ

OFOSU-BUDU, K. G., OBENG-OFORI, D., AFREH-NUAMAH, K. & ANNOBILL, R.: *Effet de phospho-compost sur la croissance et le rendement de dolique* (Vigna unguiculata). Une étude était entreprise à Juaboso dans la région de l'Ouest du Ghana pour faire des recherches de l'effet de phospho-compost sur la croissance et le rendement de dolique. C'était une expérience factorielle arrangée dans un dessin de bloc complet choisi au hasard avec quatre réplications. Phospho-compost, préparé de roche du phosphate, de l'écale de cosse de cacao, de sciure de bois et de fumier de volaille, étaient appliqués à raison de 560 g/lot (875 kg/ha) et mélangés avec le sol avant la plantation. La roche du phosphate était appliquée à raison de 195 g/lot (300 kg/ha) une semaine avant la plantation. La triple superphosphate était appliquée comme un placement en bande de 90 g/lot (130 kg/ha), sept jours après les semailles. Ces taux d'application étaient équivalent à 60 kg $P_2 O_5$/ha. Phospho-compost augmentait considérablement ($P < 0.05$) le nombre de feuilles, nombre de nodules, biomasse de plante, nombre de cosse par plante et le rendement de graine plus que le contrôle. Le rendement de graine sur le lot traité de phospho-compost était 25.8% plus élevé que sur le lot de contrôle. Le traitement de phospho-compost avait une marge bénéficiaire de ¢3,295,000.00 ($387.65) et ce chiffre se comparait favorablement avec le traitement appliquant l'engrais conventionnel la triple superphosphate, qui donnait un bénéfice de ¢3,422,000.00 ($402.59). Les lots de contrôle avaient une marge bénéficiaire de ¢2,515,000.00 ($295.88). Les résultats de l'étude indiquent que l'application de phospho-compost (qui est préparé localement) peut augmenter considérablement le rendement de dolique. Les pauvres agriculteurs ingénieux peuvent appliquer phospho-compost pour améliorer la fertilité du sol pour une productivité plus élevée de dolique.

Ghana Jnl agric. Sci. **40**, 169-176

Introduction

Cowpea is a leguminous short-day crop, which originated in the semi-arid areas of West Africa, where it has been cultivated for human consumption since ancient times (Cobley, 1974; Smartt, 1979; Purseglove, 1984; Rowland, 1993). It is one of the widely cultivated grain legumes in Ghana, especially in the savanna and transitional zones (CRI, 1994). It is mostly grown by peasant farmers with smallholdings (0.4-2.0 ha).

In the compound farming systems in northern Ghana, cowpea forms an important part of the traditional farming culture. However, commercial production of cowpea in Ghana is restricted to some parts of the Volta, Northern, Upper, and Brong-Ahafo regions (CRI, 1994). The nutritional value of cowpea lies in its high protein content, which is 20-25 per cent, and is twice the protein value of most cereals (Kay, 1979). The crop can be readily used as a substitute for meat and fish, which are expensive in most West African countries. Thus, cowpea is a very important primary source of vegetable protein in Ghana and other West African countries.

The yield of cowpea in Ghana, as in other West African countries, averages 360 kg ha^{-1}, the lowest in the world (IITA, 1993). Some major constraints to cowpea production in the country is declining soil fertility and attack by pests and diseases. Most farmers use their fertile lands for cultivating cocoa, plantain, cocoyam, yam, vegetables and other food crops. However, cowpea, like cassava, is usually cultivated on depleted soils in most communities in Ghana.

Fertilization using organic and inorganic fertilizers is rarely practised by cowpea farmers in Ghana. This is because cowpea, being a leguminous crop, is able to fix atmospheric nitrogen into the soil for plant use (Wrigley, 1981; Palaniappan, 1985). Also, the high cost of fertilizers prevents farmers from using them. Applying triple superphosphate had been shown to increase the growth and yield of cowpea (Singh & Lamba, 1971). However, this source of phosphorus is expensive and as a result cowpea farmers do not use it.

Phosphate rock, which is cheaper, has been shown to increase the yield of cowpea (Ankomah *et al.*, 1996). However, it has a slow rate of dissolution and, therefore, has to be applied several weeks before planting (Kanabo & Gilkes, 1988). Well-prepared compost, if applied properly, could improve soil fertility and subsequent yield of most crops (Wolf, 1977; Sinnadurai, 1992). When phosphate rock is added to compost materials before composting, the phosphorus in the phosphate rock will be available for plant growth at the end of the 14-week composting period (Ofosu-Budu, Quaye & Danso, 2002).

This study determined the potential of phosphate rock and phospho-compost in increasing the productivity of cowpea in the Juaboso-Bia District of the Western Region of Ghana.

Materials and methods

Study site

The study was at Juaboso in the Juaboso-Bia District in the Western Region of Ghana during the minor growing season from September 2001 to January 2002. The Juaboso-Bia District is in the north-western part of the Western Region. The district lies between latitude $6^0 6'$ N and $7^0 0'$ and $2^0 15'$ W. The district shares borders with Dormaa District in the northern Asunafo District and Sefwi Wiawso District to the east, Aowin-Suaman District to the south, and La Cote d'Ivoire to the west. The district has rainforest vegetation and, therefore, experiences two rainfall regimes. It is a leading food-producing district in Ghana and is considered to be the food-basket of the Western Region.

Preparation of phospho-compost

The phospho-compost was prepared using phosphate rock from Togo, cocoa and pod husk, sawdust, and poultry manure. The materials were moistened to 60 per cent and heaped in a compost structure with the bottom cemented (Ofosu-Budu *et al.,* 2002). Phosphate rock was added at the rate of 10 kg 300 kg^{-1} of agricultural waste materials. The materials were turned weekly until maturity period. It took about 3 months for the compost to mature.

Treatments

The experiment was a randomized complete block design. The four types of soil amendments were as follows: S_0 - No soil amendment; S_1 - Phosphate rock; S_2- Phospho-compost; S_3 - Triple superphosphate.

The four replications each comprised four experimental plots. The size of an experimental plot was 3.2 m × 2.0 m (6.40 m^2), and the plots were separated from each other by 1.0 m path. The blocks were also separated from each other by 1.5 m path.

Agronomic and other cultural practices

The land was prepared and fenced to keep away vertebrate pests and to reduce pilfering. The phospho-compost was applied at the rate of 560 g $plot^{-1}$ (875 kg ha^{-1}) and worked into the soil before planting. The phosphate rock was applied at the rate of 195 g $plot^{-1}$ (300 kg ha^{-1}) 1 week before planting. The triple superphosphate was applied as band placement of 90 g $plot^{-1}$ (130 kg ha^{-1}), 7 days after sowing. These application rates recorded 60 kg P_20_5 ha^{-1} (Panwar & Yadav, 1980). Seeds of the cowpea cultivar ‘Asontem’ were sown in rows. Between-row and within-row spacing was 60 and 20 cm, respectively. Three seeds were planted in a hill, which were later thinned to two seedlings per stand after germination.

Weeding and other routine cultural practices were applied when necessary. Insect pests were controlled using a combination of neem seed extract and cymethoate (cypermethrin + dimethoate). Neem seed extract was applied at 50 g l^{-1} of water. Cymethoate was applied at the rate of 2.5 ml l^{-1} of water (0.75 l ha^{-1}) as recommended by the manufacturers. Three insecticide applications were at 21, 35 and 49 days after sowing, using 15-l Knapsack (Model CP 15) spraying equipment.

Data collected

Data collected included the following:

1. number of leaves produced per plant;
2. number of days to flowering;
3. number of nodules per plant at flowering;
4. number of days to pod maturity;
5. weight of shoot biomass;
6. nitrogen and total phosphorus content of shoots;
7. number of pods per plant;
8. 100-grain weight;
9. grain yield per hectare; and
10. insects associated with the crop at various crop growth stages, and their importance.

Determination of shoot biomass

At 6 weeks after sowing, two plants from each plot were uprooted and the roots cut at soil level. The shoots were put into brown paper bags and oven-dried at 700 °C to constant weight. The weight was recorded. The biomass was analysed for total nitrogen and total phosphorus. The roots were washed and the number of nodules counted. Total nitrogen of soil from the experimental plot was determined by the micro kjedahl method (Black, 1965). To determine total phosphorus content, the soil sample was digested using perchloric acid ($HClO_4$). The digests were then cooled, diluted with distilled water and filtered into 250 ml flasks. The filtrate was then topped up to volume and 5 ml aliquot taken for phosphorus determination using the Watanabe & Olsen (1965) modified technique.

Determination of yield

An area of 3.84 m^2 in the centre rows was demarcated and harvested (IITA, 1979). The harvested pods were dried, shelled and the grains sun-dried to moisture content of 12 per cent. The grains were weighed and the yield per hectare was estimated.

Determination of cost-potential benefits

The cost associated with preparing and applying soil amendments was determined based on current market prices. The cost of seeds, labour, land preparation, planting, applying insecticides, and of maintaining experimental plots was similar (fixed costs) for all treatments. Yields recorded were estimated on per hectare basis. The value (yield) was multiplied by ¢3,500,000.00 ($411.76), being the cost of one metric tonne of cowpea to obtain total output. Net profits (returns) were determined as the total output from each treatment minus the cost of production. The data were subjected to a two-way Analysis of Variance (ANOVA). For significant differences, means were separated using Least Significant Difference (LSD).

TABLE 1

Chemical Properties of Soil Used for the Study

Parameter	*Level*
*p*H (H_20 1:1)	6.65
*p*H (C_aCI 1:2)	6.34
Percent organic carbon (g kg^{-1})	16.40
N (g kg^{-1})	1.00
P (mg kg^{-1})	20.00
K (cmol kg^{-1})	0.205
C_a (cmol kg^{-1})	24.00
M_g (cmol kg^{-1})	11.69
ECEC (cmol kg^{-1})	35.27

Results

Composition of soil and phospho-compost

The soil used for the study is Oxisol or Ultisol (USDA). Table 1 shows the chemical composition. The soil used had a *p*H of 6.5 (slightly acidic) and is unlikely to benefit from phosphate rock fertilization because the PR will not dissolve to release phosphorus into the soil solution. The calcium content was high. For chemical analysis of the phospho-compost, the proportions of nitrogen, phosphorus and potassium (the three major nutrients) were recorded as 11.0 g kg^{-1}, 28.8 g kg^{-1} and 3.1 cmol kg^{-1}, respectively.

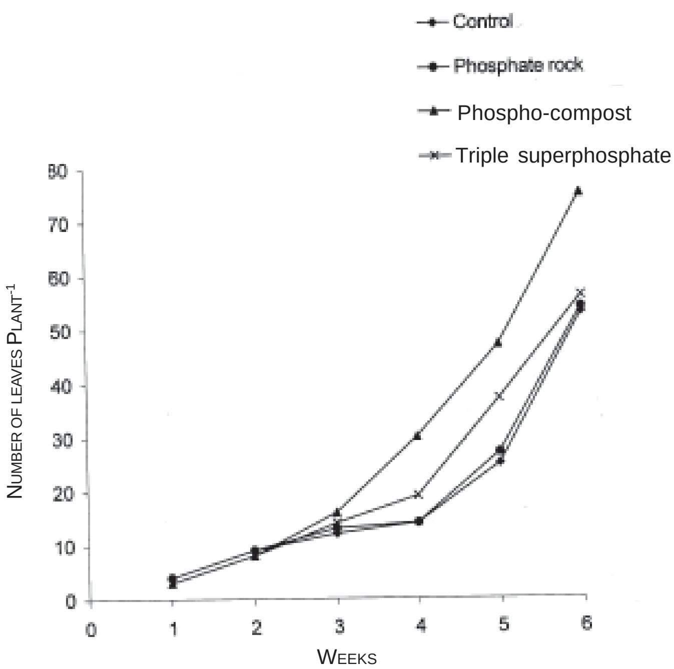

Fig. 1. Effect of soil amendments on leaf development of cowpea.

Leaf production

The number of leaves produced per plant varied consistently with age for all treatments. Soil amendment influenced the number of leaves produced per plant (Fig. 1). Phospho-compost-treated plants recorded the highest number of leaves per plant, with the no soil amendment plots recording the lowest.

Whole plant biomass and number of nodules

The ANOVA indicated that soil amendment significantly ($P < 0.05$) increased whole plant biomass (Table 2). Phospho-compost-treated plants recorded the highest whole plant biomass whilst the controls recorded the lowest. Similarly,

TABLE 2

Effect of Soil Amendments on Whole Plant Biomass, %N and %P of Plant Biomass, and Number of Nodules Per Cowpea Plant

Soil amendment	*Plant biomass*	*%N of plant biomass*	*%P of plant biomass*	*Number of nodules/plant*
No soil amendment	14.1±0.3	1.9±0.0	1.6±0.0	13.8±0.0
Phosphate rock	14.5±0.5	2.0±0.0	1.6±0.0	14.0±0.6
Phospho-compost	17.8±0.4	2.1±0.0	1.7±0.0	18.8±0.5
Triple superphosphate	16.6±0.3	2.0±0.0	1.7±0.0	17.3±0.5
LSD	1.1	0.09	0.03	1.9

Means ± SE of four replicates

soil amendment significantly ($P < 0.05$) increased %N and %P of whole plant biomass, and the number of nodules per plant. Phospho-compost-treated plots recorded the highest %N, %P, and number of nodules per plant whilst the lowest were recorded on the controls.

Days to flowering and maturity

The soil amendments did not significantly ($P > 0.05$) influence the number of days to flowering and maturity (Table 3).

Yield parameters

The ANOVA indicated that soil amendment significantly ($P < 0.05$) increased the number of pods per plant. Triple superphosphate-treated plots recorded the highest number of pods per plant, whilst no soil amendment plots recorded the least (Table 4). The 100-grain weight was not significantly ($P > 0.05$) different among the treatments (Table 4). Soil amendment significantly increased grain yield (Table 4). The grain yield of phospho-compost-treated plots compared favourably with that of triple superphosphate-treated plots.

Insects associated with the crop at different crop growth stages

The effects of the different treatments on insects associated with the crop growth stages have been analysed for publication (Annobill, Afreh-Nuamah & Obeng-Ofori, 2006).

Cost/benefit analysis

The application of soil amendment greatly increased profit margin (Table 8). The triple superphosphate treatment recorded the highest profit margin of $402.59 (¢3,422,000.00). The phospho-compost treatment had profit margin of $387.65 (¢3,295,000.00), which compared

TABLE 3

Effect of Soil Amendments on Days to 50% Flowering and Maturity of Cowpea

Soil amendment	*Days to flowering*	*Days to pod maturity*
No soil amendment	45.5±0.5	69.0±0.4
Phosphate rock	44.8±0.3	68.8±0.2
Phospho-compost	45.3±0.4	68.5±0.3
Triple superphosphate	44.5±0.3	68.6±0.3
LSD	0.7	0.9

Means ± SE of four replicates

TABLE 4

Effect of Soil Amendments on the Yield of Cowpea

Soil amendment	*Number of pods/plant*	*100-grain weight (g)*	*Grain yield in tones/ha*
No soil amendment	9.9±0.4	12.8±0.1	1.32
Phosphate rock	11.6±0.2	12.8±0.2	1.34
Phospho-compost	14.5±0.2	12.9±0.2	1.65
Triple superphosphate	15.3±0.2	12.9±0.1	1.70
LSD	0.70	0.20	0.10

Means ± SE of four replicates

TABLE 5

Costs for the Production of Cowpea in the Juaboso-Bia District of Ghana

Cost	*Cedis/ha*
Cost of seeds	179,000.00
Cost of labour	1,482,000.00
Cost of applying soil amendment	150,000.00
Cost of insecticide application	150,000.00
Cost of insecticide	294,000.00
Cost of phosphate rock	300,000.00
Cost of triple superphosphate	273,000.00

TABLE 6

Total Cost of Inputs for the Different Treatments

Soil amendment	*Cost (cedis/ha)*
No soil amendment	2,105,000.00
Phosphate rock	2,555,000.00
Phospho-compost	2,480,000.00
Triple superphosphate	2,528,000.00

favourably with the triple superphosphate treatment.

Discussion

During the first 2 weeks after planting, no differences were recorded in the number of leaves per plant among the treatments. Because nitrogen was not immediately available owing to slow mineralization of the phospho-compost as there was no basal nitrogen application. The increased vegetative growth of plants treated with phospho-compost compared to the other treatments may be attributed to the higher organic matter content of the manure. Phospho-compost may have improved the soil structure, increased water holding capacity and supplied nutrients, which are essential for the growth and development of the plants. This confirms the findings by several workers who reported that incorporating organic matter into the soil promoted vegetative growth of crop plants (Sinnadurai, 1992; Rowland, 1993; CRI, 1994). Wolf (1977) also reported that nitrogen

TABLE 7

Total Output Returns for the Different Treatments

Soil amendment	*Output returns (cedis/ha)*
No soil amendment	4,620,000.00
Phosphate rock	4,690,000.00
Phospho-compost	5,775,000.00
Triple superphosphate	5,950,000.00

One metric tone of cowpea sells at ¢3,500,000.00

TABLE 8

Net Returns (Profit) for the Different Treatments Determined by the Prevailing Market Prices

Soil amendment	*Net returns in dollars*
No soil amendment	295.88 (¢2,515,000.00)
Phosphate rock	251.12 (¢2,135,000.00)
Phospho-compost	387.65 (¢3,295,000.00)
Triple superphosphate	402.59 (¢3,422,000.00)

is directly responsible for vegetative growth of plants, and indicated that adequate amounts of nitrogen may be obtained from organic matter derived from compost or farmyard manure.

The phospho-compost treatment recorded the highest plant biomass, indicating that the plants in the phospho-compost-treated plots took advantage of the increased nutrients to grow vigorously. Kayitare (1993) observed that a good balance between nitrogen and phosphorus improved dry matter accumulation more in French beans than in plants in unfertilized plots. Soil amendment also significantly influenced %N and %P content of whole plant biomass and number of nodules per plant. Phospho-compost-treated plots recorded the highest %N, %P and number of nodules per plant, indicating that phosphorus was important for fixation of nitrogen. Thus, nitrogen may be ineffective without adequate amounts of phosphorus (CIAT, 1976), but nitrogen is also necessary for assimilating phosphorus.

Adu-Gyamfi, Fujita & Ogata (1990) indicated that by increasing the phosphorus concentration in the culture medium, its concentration tended to increase in all the plant parts. No soil amendment influenced days to flowering and maturity. Though phospho-compost promoted the vegetative growth of the crop, it did not significantly affect the days taken by the plants to flower and reach maturity.

The number of pods per plant was significantly increased by soil amendment. Triple superphosphate-treated plots had greater number of pods than phospho-compost-treated plots. It is unlikely that the increased vegetative growth of phospho-compost-treated plots was responsible for the reduced number of pods per plant. This finding is contrary to that of Wolf (1977) who indicated that compost contains high amounts of trace elements not found in mineral fertilizers. Consequently, when applied to crops, they lead to enhanced growth properties and higher grain yield. Generally, it is known that plants treated with soil amendment grow vigorously because of supply of enough nutrients, which help them to compensate for damaged parts (Kayitare, 1993).

Higher yields in soil amendment-treated plots resulted in greater net profits. Although triple superhosphate treatment recorded the highest net profit, phospho-compost, with its favourable effect on vegetative growth, may have a special place in cultivating high-value leafy vegetables. It will also be useful in areas with serious weed problems because the formation of closed canopy could help to suppress weed growth. In all, phospho-compost significantly increased vegetative growth, plant biomass, number of pods per plant, and grain yield; which compared favourably with triple superphosphate. Its use in the cowpea cropping system will provide an avenue for using industrial and agricultural wastes such as sawdust, cocoa pod husk, and animal manure. The benefits of the phospho-compost treatment extend beyond the short-term economic returns. It is available locally and is cheaper than the conventional synthetic fertilizers. In this era of great advocacy by environmentalists for the adoption of organic farming technology, the use of phospho-compost in cowpea production by resource-poor farmers should be encouraged.

Acknowledgement

This work forms part of an M Phil programme of the last author. It was funded by the Dutch Direct Research Support (DSO) under the West African Sub-regional Centre at the African Regional Post Graduate Programme in Insect Science (ARPPIS). The authors are grateful to staff of the Juaboso-Bia District Directorate of the Ministry of Food and Agriculture for their assistance in diverse ways; and to Mr E. Asante of the Department of Crop Science, University of Ghana, Legon, for assisting in the statistical analysis of the data.

REFERENCES

Adu-Gyamfi, J. J., Fujita, K. & **Ogata, S.** (1990) Phosphorus fractions in relation to growth in pigeon pea (*Cajanus cajan*) at various levels of P supply. *Soil Sci. Pl. Nutr*. **36** (4), 531-543.

Ankomah, A. B., Zapata, F., Handenson, G. & **Danso, S. K. A.** (1996) Yield, nodulation and N_2 fixation by cowpea cultivars at different phosphorus levels. *Biol. Fert. Soils* **22**, 10-15.

Annobill, R. K., Afreh-Nuamah, K. & **Obeng-Ofori, D.** (2006) Management of insect pest complex of cowpea (*Vigna unguiculata*) with phosphorus-enriched soil and neem seed extract. *Ghana Jnl agric. Sci.* **39** (1), 103-113.

Black, C. A. (ed.) (1965) *The methods of soil analysis. Agronomy.* Wisconsin. Madison, USA. 1178 pp.

Centre for International Tropical Agriculture (1976) Bean production systems. In *CIAT Annual Report* 1975. Centre for International Tropical Agriculture, Cali, Colombia. pp. 128-136.

Cobley, L. S. (1974) *An introduction to the botany of tropical crops.* 2nd edn. Longman, London. 155 pp.

Crops Research Institute (1994) *Maize and legume production guide*. Ghana Grains Development Project, Crops Research Institute, Kumasi, Ghana. 45 pp.

International Institute of Tropical Agriculture (1979) *Recommendation for cowpea international trials. Explanation of crop management, layout of trials, data collection.* Grain Legume Improvement Programme, IITA, Ibadan, Nigeria. pp. 2-17.

International Institute of Tropical Agriculture (1993) *Annual Report of the IITA.* Ibadan, Nigeria. pp. 56-80.

Kanabo, I. A. K. & **Gilkes, R. J.** (1988) A comparison of mixed and band applications on the dissolution of North Carolina phosphate rock and on bicarbonate soluble soil phosphorus. *Fert. Res.* **15**, 3-12.

Kayitare, S. (1993) *Using cultural practices to control the bean fly* (Ph D Thesis). Department of Crop Science, University of Ghana, Legon, Ghana. 196 pp.

Kay, D. E. (1979) *Food legumes, crop and product digest*, No. 3. Natural Resources Institute, Chattan, UK. 214 pp.

Ofosu-Budu, K. G., Quaye, A. & **Danso, S. K. A.** (2002) Composting of agricultural and agro-industrial residues in Ghana. *W. Afr. J. appl. Ecol.* (in press).

Panwar, K. S. & **Yadav, H. L.** (1980) Response of short-duration pigeon pea to early planting and phosphorus levels in different cropping systems. In *Proceedings of the International Workshop on Pigeon Peas (ICRISAT)* **2**, 15-19.

Palaniappan, S. P. (1985) *Cropping systems in the tropics: Principles and management*. Wiley Eastern Ltd, New Delhi, India. 215 pp.

Purseglove, J. W. (1984) *Tropical crops: Dicotyledons*. Vol. 1 and 2. ELBS Series, Longman Groups Ltd, London. pp. 321-328.

Rowland, J. (1993) Grain legumes. In *Dry farming in Africa* (ed. J. Rowland). CTA/ Macmillan Press Ltd. 180 pp.

Singh, S. R. & **Lamba, P. S.** (1971) Agronomic studies on cowpea FS-68: Effect of soil moisture regimes, seed rates and levels of phosphorus on growth and yield. *Hargena Agric. Univ. J. Res.* **1** (3), 1-7.

Sinnadurai, S. (1992) *Vegetable cultivation*. Asempa Publishers, Accra, Ghana. 208 pp.

Smartt, J. (1979) The evolution of pulse crop. *Econ. Bot.* **32**, 185-198.

Watanabe, F. S. & **Olsen, E. R.** (1965) Text of ascorbic method for determining P in water and $NaHCO_3$ extracts from soil. *Soil Sci. Ann. Proc.* **29**, 677-678.

Wolf, R. (1977) *Organic farming: Yesterday's and tomorrow's agriculture*. Rodale Press Inc. 344 pp.

Wrigley, G. (1981) Legume intercropping. In *Tropical agriculture,* 4th edn. Longman, London. 496 pp.