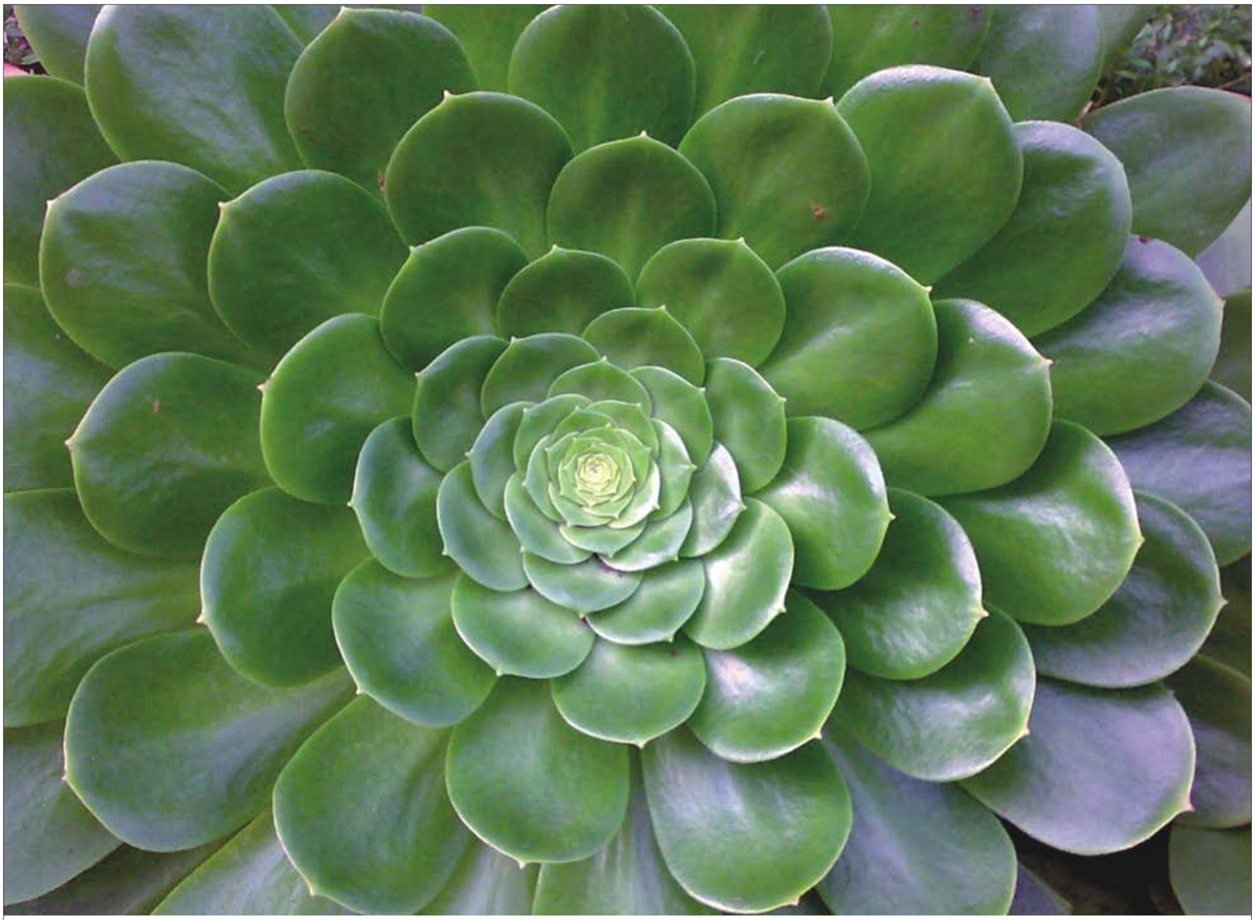

Journal of
Plant Sciences

ISSN 1816-4951

Academic
Journals Inc.

www.academicjournals.com

Journal of Plant Sciences 10 (5): 167-178, 2015
ISSN 1816-4951 / DOI: 10.3923/jps.2015.167.178

Effect of Phosphorus Fertilizer on Dry Matter Production and Distribution in Three Cowpea (*Vigna unguiculata* L. Walp.) Varieties in Ghana

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ABSTRACT

Dry matter production and its partition are the best measure and index of the total performance and response of a crop to growth conditions. Two-season experiment was conducted in soil with low available phosphorus (P) to study dry matter production and partitioning among the cowpea plant as influenced by either variety or phosphorus application using triple super phosphate (46% P_2O_5). In the present study IT89KD-347-57 consistently produced the highest number of leaves. The number of leaves per plant did not differ significantly ($p>0.05$) with phosphorus application; however, 60 kg ha^{-1} rate consistently yielded the greatest number of leaves. Asomdwee and Asetenapa recorded the highest and lowest leaf area of 1731.22 and 769.27 cm^2, respectively. Leaf area also increased consistently with P application, with 20 kg ha^{-1} been the optimal rate for greater leaf area. However, leaf area did not differ significantly ($p>0.05$) with P application. Net assimilation rate was not significantly influenced by P and therefore, 0 kg ha^{-1} rate yielded the highest NAR. Dry matter production increased with age of plant regardless of the levels of P applied, with 60 kg ha^{-1} yielding the mean highest value. Dry matter accumulation in the stem was consistently higher than the remaining plant parts regardless of the levels of P applied. However, dry matter production and partitioning among above ground parts were significantly ($p<0.05$) affected by cowpea variety but not P application. The results in this study indicate that dry matter production among cowpea is totally dependent on varietal differences but not phosphorus application.

Key words: *Vigna unguiculata*, phosphorus, leaf area index, net assimilation rate, total dry matter

INTRODUCTION

Phosphorus (P) is a major essential nutrient required by plants for growth and reproduction. It is, however, one of the most immobile, inaccessible and unavailable nutrients present in soils (Narang *et al*., 2000). Low level of soil P and N are the major constraints to crop growth and production in nutrients depleted sandy soil of Sub-Saharan Africa (Nyoki and Ndakidemi, 2014). Phosphorus plays major role in plant growth, development and consequent determination of yield of the crops. It is found in every living plant cell and is involved in several key functions including energy metabolism, nitrogen fixation, synthesis of nucleic acids and membranes, photosynthesis, respiration and enzyme regulation. These processes require inorganic phosphate from ADP (Nyoki and Ndakidemi, 2014). Phosphorus is also needed for the transformation of sugars and starches, nutrient movement within the plant (Brady, 2002), phospholipids, ATP and it makes about 0.2% of plant's dry weight (Schachtman *et al*., 1998). Successful production systems based on legumes, therefore, require P inputs either from soil reserves or from added fertilizer (Ndakidemi *et al*., 2006). Other workers (Singh *et al*., 2011; Tomar *et al*., 2004; Rani, 1999) reported that shoot development, plant leaf area and dry matter of the legume plants increased with P application. It has also been reported that shortage of inorganic phosphate in the chloroplast reduces photosynthesis (Rubio *et al*., 2001). Application of phosphorus is, therefore, recommended for cowpea production on soils low in P not only to enhance their growth and yield but also nitrogen fixation (Nkaa *et al*., 2014). In Ghana, legumes do not usually receive any form of P fertilizer, they therefore, entirely rely on the natural available soil P and other nutrients for nitrogen fixation and growth and this has resulted in lower yields. One of the options of reducing low yields due to soil P content is to determine the best level of P application so as to increase yield and returns from cowpea.

Cowpea (*Vigna unguiculata* L. Walp.), considered as "Poor man's meat" and "Rich man's vegetable" (Singh and Singh, 1992), is a major grain legume in Sub-Saharan Africa. It also plays an important role in providing soil nitrogen. It does not, therefore, requires a high rate of nitrogen fertilization; its roots have nodules in which rhizobia inhabit and help to fix nitrogen from the air into the soil in the form of nitrates (Nkaa *et al*., 2014). Cowpea fixes atmospheric nitrogen up to 240 kg ha^{-1} and leaves about 60-70 kg nitrogen for successive crops (Nkaa *et al*., 2014). Cowpea can be grown under rain fed conditions as well as by using irrigation during the dry season, with rainfall pattern of 500-1200 mm $year^{-1}$ and temperature of 28-30°C (Madamba *et al*., 2006). It is a drought tolerant crop and adapts well to sandy and poor soils. However, best yields are obtained in well-drained sandy loam to clay loam soils with pH between 6 and 7 (Nkaa *et al*., 2014). Crop productivity depends not only on dry matter accumulation but also on its effective partitioning to the seed; this is a key to yield stability (Kumar *et al*., 2010). Dry matter partitioning is the end result of the flow of assimilates from source organs to vegetative and reproductive sinks (Marcelis, 1996). Its production is reported to increase by phosphorus application while its distribution is also affected. This work, therefore, sought to determine the effects of P fertilizer on dry matter production and distribution in plant parts of three varieties of cowpea in Ghana.

MATERIALS AND METHODS

Experimental site and design: The experiment was conducted at the teaching and research farms of Kwame Nkrumah University of Science and Technology (KNUST), Kumasi from June to August (major cropping season) and repeated from October to December (minor cropping season). The experimental site was within the semi-deciduous forest vegetational zone of Ghana with a bimodal rainfall distribution with one peak in July and the other in September and an average annual rainfall of 1422.40 mm for the experimental year. The annual average relative humidity was 83.75% (9 h GMT) and 58.83% (15 h GMT). The annual ambient temperature ranged from 22.08-31.58°C with an average annual sunshine duration of 4.94 h. The weather parameters were lower than the optimum rainfall pattern and sunshine for good growth and development of cowpea as per the standards described by Madamba *et al*. (2006).

A 3×4 factorial design with 3 cowpea varieties and 4 levels of P fertilizer using triple super phosphate (46% P_2O_5) was used in the present study. The treatments combination was arranged in randomized complete block design with four replications. The cowpea varieties were Asetenapa (IT81D-1951), Asomdwee (IT94K-410-2) and IT89KD-347-57 and levels of P were 0 (Control), 20, 40 and 60 kg ha^{-1} P_2O_5. Planting was done at a distance of 0.60×0.20 m yielding a plant density of 240 plants per plot corresponding to 166,666 plants per hectare. All agronomic practices were carried out. The fertilizer was applied 21 Days After Planting (DAP).

Soil analysis: Soil chemical analyses were done on depths of 0-15 and 15-30 cm according to methods described by Tel and Hagarty (1984). Soil organic carbon was determined using modified Walkley and Black wet oxidation method. The percent organic carbon was multiplied by 1.724 (Van Bemmelen factor) to get percent organic matter. Soil pH was determined by the use of pH meter. The modified Kjeldahl method was used to determine total nitrogen. Available phosphorus was determined by the Bray-1 test method while the exchangeable base cations were extracted using ammonium acetate at pH 7.0. Calcium and magnesium were determined using the Ethylene Diamine Tetraacetic Acid (EDTA) titration method while potassium and sodium were determined by the flame photometer method.

Plants parameters measured: Number of leaves borne on each plant was counted and the mean value calculated and expressed as number of leaves per plant. The Leaf Area (LA) was estimated by the disc method on dry weight basis at different growth stages of 30, 45 and 60 DAP using the method described by Watson (1952). Leaf Area Index (LAI) was then determined from LA using instantaneous approach at 30, 45 and 60 DAP. This was done using the relation:

$$\text{LAI} = \frac{\text{Leaf area of number of plants per meter sequare}}{1\text{m}^2 \text{ of land}}$$

Five randomly selected plants from destructive sampling area at 30, 45 and 60 DAP were used for dry matter content determination per leaves, stem and reproductive parts. Average total dry matter per plant was then calculated. Net Assimilation Rate (NAR) was calculated using the relation below according to the formula described by Harper (1983).

$$\text{NAR} = \frac{W_2 - W_1}{T_2 - T_1} \times \frac{\text{InLA}_2 - \text{InLA}_1}{\text{LA}_2 - \text{LA}_1} \left(\text{g m}^{-2} \text{ day}^{-1}\right)$$

where, W_1 and W_2 are total dry weight (above ground) at sampling periods T_1 and T_1, respectively and LA_1 and LA_2 are leaf areas at sampling periods T_1 and T_2, respectively.

Harvested plants (above ground parts) from the net plot area were allowed to dry to a constant weight and recorded as total biomass of the plant. All the data collected were statistically analysed and where the F-values were found to be significant, the treatment means were separated using Duncan's multiple range test.

RESULTS AND DISCUSSION

Soil analysis: The soil at the experimental site was well drained, sandy loam overlying reddish-brown and gravelly light clay and belongs to the Kumasi series, Ferric Acrisol developed over deeply weathered granite rocks (Asiamah, 1998). The soil was slightly acidic with low available P, total N, exchangeable cations and very low organic matter. The available P varied between 5.65 and 5.22 mg kg^{-1} which are lower than 7.0 mg kg^{-1} established by Aune and Lai (1995) as the critical soil available P level required for proper growth and development of cowpea; thus, the soil was depleted. This could be attributed to the fact that the site was used for continues crop cultivation, characterized by regular mechanized tillage and excessive inorganic fertilizer application, which has aided in soil degradation through rapid soil organic matter depletion. Soil organic matter influences physical properties relating to water absorption, available water content and nutrient retention. Therefore, the low organic matter content in the soil used for the study could be a contributing factor to the amount of dry matter accumulated in the plants (Ayodele and Oso, 2014). Soil management practices must, however, aim at raising the level of soil organic matter and preventing its rapid depletion.

Number of leaves per plant: The number of leaves per plant differed significantly ($p<0.05$) with variety in both seasons. The IT89KD-347-57 consistently produced the highest number of leaves while Asetenapa and Asomdwee produced similar low number of leaves throughout the experimental period (Table 1). The number of leaves per plant did not differ significantly ($p>0.05$) with phosphorus application, however, P application rate of 60 kg ha^{-1} consistently recorded the greatest number of leaves (Table 1). Ayodele and Oso (2014) observed that P application increased the number of leaves of cowpea and this is contrary to the result in this study. In the present study, as the plant matures beyond 45 days, the number of leaves declined significantly for all varieties and at all levels of P application during the major season. Meanwhile, the number of leaves increased with age of the plant during the minor season. There was, however, significant difference between numbers of leaves in the different growing seasons, with the major growing season recording the highest leaf count. This could be attributed to poor growth conditions during the minor season.

Leaf area and leaf area index: At 45 and 60 DAP, varietal effect on Leaf Area (LA) was significant ($p<0.05$) for both seasons. At 45 DAP during both seasons; Asomdwee and Asetenapa recorded statistically similar leaf area which was significantly lower than that of IT89KD-347-57 during the minor season (Table 2). Leaf area increased consistently throughout the experimental period and was directly proportional to the age of the plant, with Asomdwee recording the highest

Table 1: Effect of variety and phosphorus application on number of leaves per plant

	No. of leaves per plant					
	30 DAP		45 DAP		60 DAP	
Treatments	Major season	Minor season	Major season	Minor season	Major season	Minor season
Varieties						
Asetenapa	11.50	13.30	28.1	16.2	21.5	18.2
Asomdwee	11.50	12.80	28.4	15.6	24.2	17.5
IT89KD-347-57	13.60	16.70	34.1	21.5	29.7	24.2
LSD (5%)	1.45	2.60	3.7	2.6	3.7	2.9
P levels (kg ha^{-1} P_2O_5)						
0	10.9	13.30	27.3	16.1	22.1	18.2
20	12.2	14.70	29.8	17.8	24.7	20.0
40	12.4	13.50	30.7	18.1	25.8	20.4
60	13.4	15.60	32.9	19.0	27.8	21.4
LSD (5%)	NS	NS	NS	NS	NS	NS
CV (%)	16.9	25.3	17.1	20.0	20.3	19.9

NS: Non significant, DAP: Day after planting, LSD: Least significant difference, CV: Coefficient of variation

Table 2: Effect of variety and phosphorus application on leaf area and leaf area index

	Leaf area (cm^2)						Leaf area index					
	30 DAP		45 DAP		60 DAP		30 DAP		45 DAP		60 DAP	
Treatments	Major Season	Minor season	Major season	Minor season	Major season	Minor season	Major season	Minor season	Major season	Minor season	Major season	Minor season
Varieties												
Asetenapa	769.27	971.24	1116.00	1089.04	1511.65	1171.54	1.23	1.55	1.79	1.74	2.42	1.87
Asomdwee	862.19	1083.95	1252.00	1151.83	1731.22	1224.17	1.38	1.73	2.00	1.84	2.77	1.96
IT89KD-347-57	814.71	1217.29	960.00	1415.56	1241.11	1535.06	1.31	1.95	1.54	2.26	1.99	2.46
LSD (5%)	NS	NS	151.50	233.99	326.88	234.45	NS	NS	0.24	0.37	0.52	0.38
P levels (kg ha^{-1} P_2O_5)												
0	790.92	973.39	1060.00	1072.62	1381.50	1141.93	1.27	1.56	1.70	1.72	2.21	1.83
20	944.64	1288.88	1228.00	1326.44	1395.11	1361.61	1.51	2.06	1.96	2.12	2.23	2.18
40	735.45	1068.69	1011.00	1227.54	1405.08	1307.88	1.18	1.71	1.62	1.96	2.25	2.09
60	790.54	1032.34	1139.00	1248.65	1796.95	1429.61	1.26	1.65	1.82	2.00	2.88	2.29
LSD (5%)	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
CV (%)	23.1	28.5	19.0	26.7	30.4	24.9	23.1	28.5	19.0	26.7	30.4	24.9

NS: Non significant, DAP: Day after planting, LSD: Least significant difference, CV: Coefficient of variation

leaf area of 1731.22 cm^2 and Asetenapa recording the least, 769.27 cm^2. The leaf area did not differ significantly ($p>0.05$) with phosphorus fertilizer application (Table 2). This observation is, however, contrary to that of Ayodele and Oso (2014). Leaf area also increased consistently with the application of P as the plants grew. There was a sudden rise in leaf area with application rate of 60 kg ha^{-1} at 60 DAP. However, the optimal rate of P application for greater leaf area was 20 kg ha^{-1} and this was consistent throughout the experimental period. This result compares favourably with the observation by Ayodele and Oso (2014) which reported highest leaf area with 20 kg ha^{-1} application.

Leaf Area Index (LAI) increased proportionally with age of the crop in all varieties, with Asomdwee and Asetenapa recording the highest and lowest LAI of 2.77 and 1.23, respectively (Table 2). However, varietal effect on leaf area index was significant ($p<0.05$) at 45 and 60 DAP. The leaf area index did not differ significantly ($p>0.05$) with P application at all the sampling times and seasons (Table 2). Leaf area index was directly proportional to age of plants in both growing seasons with P application rate of 20 kg ha^{-1} been the optimal rate for good and consistent LAI. Thus, an indication that the cowpea varieties utilised the phosphorus fertilizer applied judiciously in growth and development processes (Nkaa *et al*., 2014).

Number of primary branches per plant: In the present study IT89KD-347-57 consistently produced the highest number of primary branches than the other varieties (Table 3). Treatment effect of Asomdwee was also significantly greater than that of Asetenapa for both season at 45 and 60 DAP sampling. However, there was a significant ($p<0.05$) varietal difference in the number of primary branches per plant throughout the experimental period. The variation in number of primary branches could partly be due to genetic makeup of the varieties (Magani and Kuchinda, 2009) and weather conditions (Jeuffroy and Ney, 1997). Application of P fertilizer did not significantly affect number of branches. However, greater number of branches was recorded at 60 kg ha^{-1} throughout the experimental period (Table 3). This could be attributed to the fact that phosphorus is required in large quantities in shoot tips where metabolism is high and cell division is rapid (Ndakidemi and Dakora, 2007). This result is; however, contrary to that of Ayodele and Oso (2014), which reported maximum number of branches at 40 kg ha^{-1} rate. The number of primary branches remained constant from 45 DAP at all levels of P in the minor season.

Table 3: Effect of variety and phosphorus application on number of primary branches

	No. of primary branches per plant					
	30 DAP		45 DAP		60 DAP	
Treatments	Major season	Minor season	Major season	Minor season	Major season	Minor season
Varieties						
Asetenapa	1.3	1.1	1.7	1.1	2.0	1.1
Asomdwee	1.6	1.4	2.4	1.5	2.7	1.5
IT89KD-347-57	2.5	2.4	3.3	2.6	3.6	2.7
LSD (5%)	0.3	0.3	0.3	0.4	0.3	0.4
P levels (kg ha^{-1} P_2O_5)						
0	1.7	1.4	2.3	1.5	2.6	1.5
20	1.8	1.6	2.4	1.7	2.8	1.7
40	1.9	1.6	2.5	1.7	2.8	1.7
60	2.0	1.9	2.6	2.1	2.9	2.1
LSD (5%)	NS	NS	NS	NS	NS	NS
CV (%)	20.9	28.6	15.7	28.3	14.1	29.0

NS: Non significant, DAP: Day after planting, LSD: Least significant difference, CV: Coefficient of variation

Net assimilation rate: Net Assimilation Rate (NAR) recorded for each variety declined significantly with age of the crop in both seasons. It was, therefore, not significantly ($p<0.05$) influenced by cowpea variety (Table 4). However, Asomdwee and IT89KD-347-57 recorded statistically similar NAR but significantly different from Asetenapa in the major growing season at both 30-45 and 45-60 DAP. The higher NAR values of Asomdwee and IT89KD-347-57 in the major season at 45 DAP suggest that the leaves of the two varieties were more efficient in producing dry matter than Asetenapa in the major season (Table 4). In the minor season, NAR was in order Asetenapa>Asomdwee>IT89KD-347-57. This indicates that apart from solar radiation, NAR could be influenced by water supply which was limited during the minor season (Fageria *et al*., 2006). The reduction in NAR between sampling periods agrees with the report by Addo-Quaye *et al*. (2011) attributing it to the fact that the plants had sufficient leaf area but there were; however, many leaves which had reduced assimilatory activity (Fageria *et al*., 2006). Phosphorus fertilizer application had no significant ($p>0.05$) effect on NAR at both seasons (Table 4). Higher NAR rates were, therefore, recorded at P application rate of 0 kg ha^{-1}. The NAR increased as P application rates decline but at an irregular pattern. Also, NAR with P application was inversely proportional to the age of the crop.

Dry matter production, distribution and total biomass: Total Dry (shoot) Matter (TDM) produced per plant was significantly ($p<0.05$) affected by cowpea variety in the present study (Table 5). Generally, TDM production increased progressively over time regardless of the varietal differences. During the major cropping season, TDM of Asetenapa was statistically different from Asomdwee and IT89KD-347-57 at 30 DAP. At 45 DAP, TDM of Asomdwee and IT89KD-347-57 did not differ but were significantly higher than that of Asetenapa in the major cropping season. At 60 DAP, similar effect was observed for Asomdwee and IT89KD-347-57 as against Asetenapa. During the minor season, IT89KD-347-57 recorded the highest TDM production at 30 and 45 DAP while Asomdwee gave the highest TDM at 60 DAP. These results, therefore, show that the varieties have unequal or irregular growth pattern as well as dry matter production potential. This is because aside of growth conditions (environment), dry matter production is influenced by genotype (variety), therefore, the production of different dry matter content at different stages of the crop and different cropping seasons in the present study attests to the fact that these varieties have different growth potentials. This compares favourably with the report by Addo-Quaye *et al*. (2011)

Table 4: Influence of variety and phosphorus application on net assimilation rate

	Net assimilation rate (g^{-2} day^{-1})			
	30-45 DAP		45-60 DAP	
Treatments	Major season	Minor season	Major season	Minor season
Varieties				
Asetenapa	3.24	4.52	1.36	3.44
Asomdwee	3.74	4.14	1.13	2.99
IT89KD-347-57	3.70	3.35	1.12	0.17
LSD (5%)	NS	NS	NS	0.63
P levels (kg ha^{-1} P_2O_5)				
0	3.77	4.39	1.25	2.46
20	3.64	3.87	1.23	2.08
40	3.48	3.95	1.05	2.04
60	3.35	3.79	1.28	2.23
LSD (5%)	NS	NS	NS	NS
CV (%)	18.1	33.2	34.8	39.5

NS: Non significant, DAP: Day after planting, LSD: Least significant difference, CV: Coefficient of variation

Table 5: Effect of variety and phosphorus application on total (shoot) dry matter production and total biomass over three sampling periods

	Total (shoot) dry matter production (g plant^{-1})							
	30 DAP		45 DAP		60 DAP		Total biomass (kg ha^{-1})	
Treatments	Major season	Minor season	Major season	Minor season	Major season	Minor season	Major season	Minor season
Varieties								
Asetenapa	8.86	6.83	12.67	13.05	15.38	18.39	2631.0	2468.0
Asomdwee	7.45	6.93	14.84	13.45	19.41	18.50	2980.0	2680.0
IT89KD-347-57	8.02	8.09	15.04	14.64	18.00	15.04	3612.0	3052.0
LSD (5%)	0.83	0.69	1.27	0.81	1.51	0.96	509.7	283.9
P levels (kg P_2O_5 ha^{-1})								
0	7.65	7.18	13.82	13.35	16.85	16.86	2591.0	2417.0
20	7.97	7.39	14.52	13.78	17.62	17.37	3023.0	2679.0
40	8.14	7.19	14.29	13.80	17.50	17.33	3175.0	2857.0
60	8.67	7.36	14.09	13.93	18.42	17.67	3510.0	2981.0
LSD (5%)	NS	NS	NS	NS	NS	NS	588.6	327.8
CV (%)	14.1	13.2	12.4	8.2	11.9	7.8	23.0	14.4

NS: Non significant, DAP: Day after planting, LSD: Least significant difference, CV: Coefficient of variation

that cowpea varieties have different capacities for dry matter production. Dry matter production increased throughout the sampling periods and seasons (Table 5). This is in agreement with Das *et al.* (2008) that dry matter production in plant gradually increases with crop age and attains maximum at maturity.

Phosphorus fertilizer application did not significantly affect total dry (shoot) matter production in the present study; however, dry matter production increased over time regardless of the different levels of P applied (Table 5). Treatment effect of 20, 40 and 60 kg ha^{-1} rates produced higher but not significant dry matter than the control (0 kg ha^{-1}) with 60 kg ha^{-1} rate yielding the mean highest DM and this compares favourably with reports by Magani and Kuchinda (2009). These reports; however, contradict that of Das *et al.* (2008), which indicated that 30, 60, 90 and 120 kg ha^{-1} P_2O_5 on chickpea showed a marked influence on the total dry matter accumulation.

Total biomass yield significantly ($p<0.05$) differed with cowpea variety for both seasons. In both seasons, total biomass of Asomdwee and Asetenapa varieties were similar but significantly lower than that of IT89KD-347-57 variety which produced the highest biomass of 3612 kg ha^{-1} (Table 5).

In the present study, total biomass increased with increased P application rate, with 60 kg ha^{-1} yielding the highest biomass (Table 5). This result agrees favourably with the observations by Singh *et al.* (2011) but contrary to that of Ayodele and Oso (2014), who reported maximum biomass at 40 kg ha^{-1}. However, P fertilizer application significantly influenced total biomass yield in both seasons.

Generally, within 30-45 DAP, Dry Matter (DM) accumulation in the leaf and stem increased for both seasons. However, there was a greater accumulation in stem than in the leaf (Fig. 1-3). For all the sampling periods in the major cropping season, Asetenapa partitioned greatest DM in leaf followed by IT89KD-347-57 and Asomdwee while in the minor season, Asetenapa again recorded the highest followed by Asomdwee and IT89KD-347-57. Between 45 and 60 DAP, there was a decline in DM in the leaf of all varieties in the major season; however, the reverse was recorded in the minor season. From 45-60 DAP in both seasons, DM in stem increased but the marginal increase was however, lower compared to the increase from 30-45 DAP (Fig. 4). Asomdwee variety translocated highest DM into the reproductive part followed by Asetenapa and IT89KD-347-57 (Fig. 1-3). This could be attributed to phenological difference among the varieties. Similar trend was observed in the minor season (Fig. 1-3). Dry matter accumulation in reproductive parts increased with time for both seasons in all varieties (Fig. 1-3). Dry matter distribution in the above ground parts such as leaves, stem and reproductive parts varied significantly with the varieties. Dry weight of leaves increased rapidly from 30-45 DAP in all three varieties of cowpea. This could be attributed to production and formation of new leaves. However, there was a decline from 45-60 DAP, which may be due to mutual shading, competition, leaf senescence and translocation of photosynthates to other plant parts as reported by Patil *et al.* (2002).

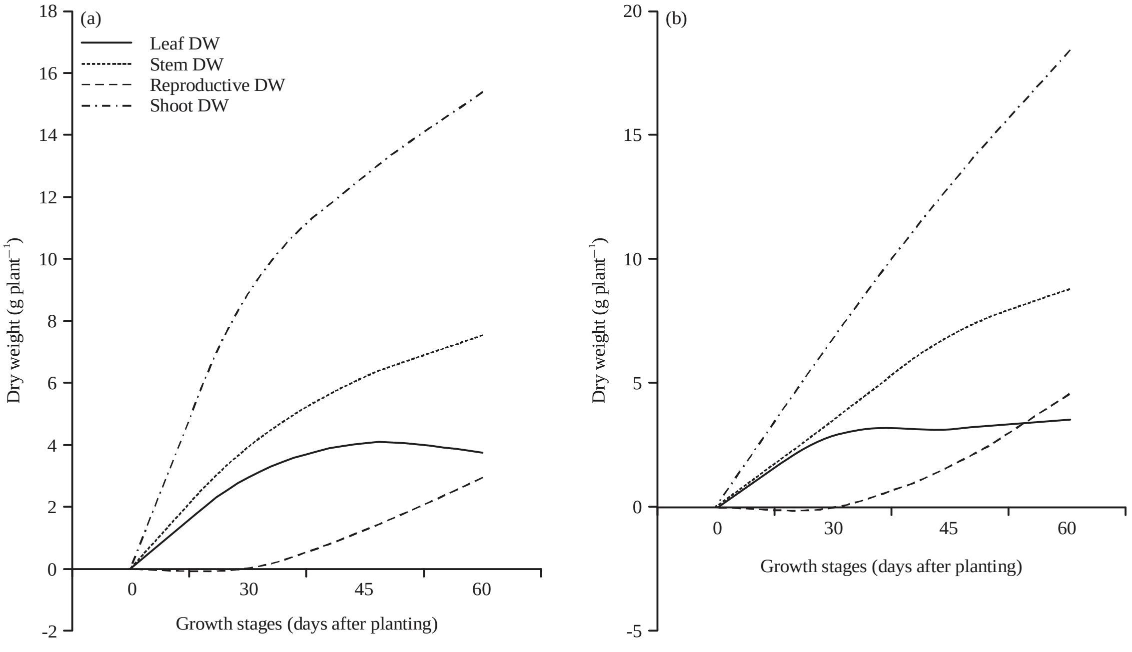

Fig. 1(a-b): Dry matter production and distribution in Asetenapa variety during the (a) Major and (b) Minor growing seasons

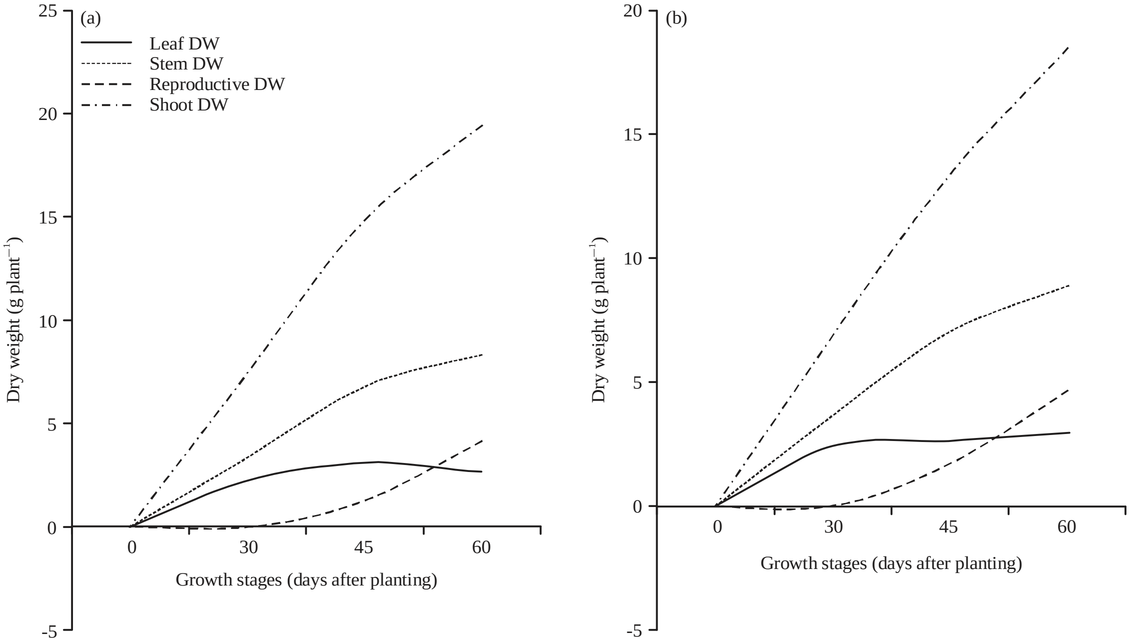

Fig. 2(a-b): Dry matter production and distribution in Asomdwee variety during the (a) Major and (b) Minor growing seasons

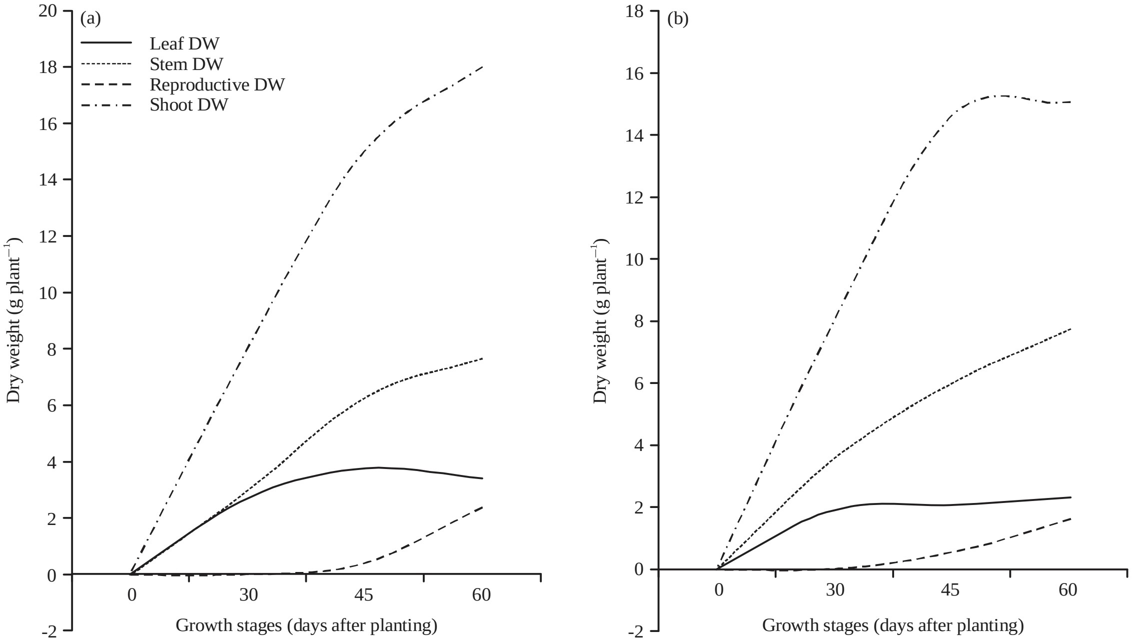

Fig. 3(a-b): Dry matter production and distribution in IT89KD-347-57 variety during the (a) Major and (b) Minor growing seasons

During the major season for all the sampling periods, leaf dry matter decreased with decreasing P rates. In a similar work, Moot *et al.* (2007) reported that phosphorus deficiency leads to early senescence of older leaves and stunting of new leaves, thereby, reducing leaf dry weight. This result compares favourably with the result in the present study. The initial soil analysis of low P level in the soil used for the experiments corroborates the report of Moot *et al.* (2007). Similar trend was observed in the minor season except between 40 and 60 kg ha^{-1} rates. Dry matter accumulation in the stem was higher in the control (0 kg ha^{-1}) than in the P application rates for both seasons. It consistently increased with age of the crop (Fig. 4). This agrees favourably with report by Fageria *et al.* (2006) that phosphorus deficient plants usually have more DM partition to stem and roots than shoots, probably as a result of higher export rates of photosynthates to the stem and roots. Dry matter partition to the reproductive parts in both seasons was in the order of 60>40> 20>0 kg ha^{-1}. The increased dry matter accumulation in reproductive parts indicates a better translocation of the available photosynthate towards seed (Acquaah, 2007). Almost all the P rates resulted in higher translocation of photosynthate to the reproductive parts over the control (0 kg ha^{-1}). However, the variation in dry matter distribution among the above ground parts confirms that dry matter partitioning among the sinks of a plant is primarily regulated by the sinks themselves but not prevailing environmental and growth conditions (Marcelis, 1996).

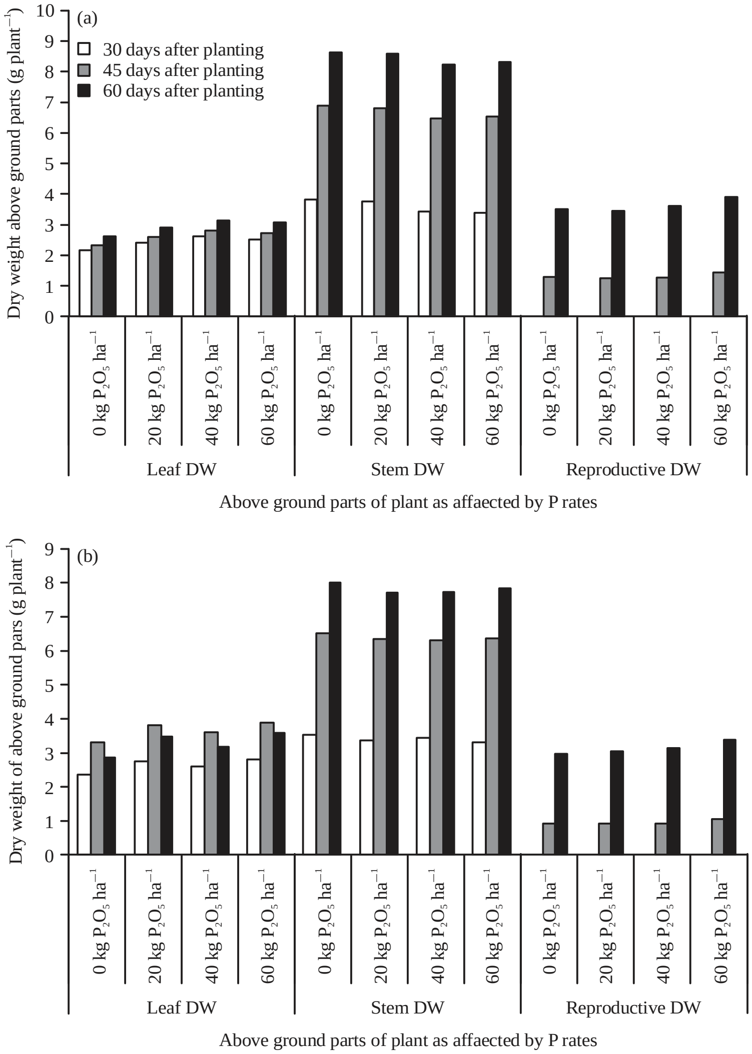

Fig. 4(a-b): Dry matter accumulation of above ground parts of cowpea plant as affected by phosphorus rate in the (a) Major growing season and (b) Minor growing season

CONCLUSION

In the present study, the varieties had unequal and inconsistent dry matter production and distribution potential. The performance of each of the varieties did not follow any rank order in both seasons. Dry matter production and partition varied among the varieties. Phosphorus rates did not influence dry matter production and distribution. However, there was marginal increase in dry matter production in P levels than the control. Dry matter response to P application rates was a reflection of its effects on vegetative growth such as number of leaves, leaf area, number of primary branches and net assimilation rate.

The observed variations in the performance of the cowpea varieties used could provide a basis for selecting cowpea lines with greater agronomic efficiency in P deficient soil to reduce fertilizer cost. These variations could also be important for selecting varieties suitable for a range of soil P conditions as well as for release to farmers on large scale production. It could therefore, be concluded that variety IT89KD-347-57 and 60 kg ha^{-1} P_2O_5 rate are ideal for soils low in P and thus, recommended for farmers in the semi-deciduous forest vegetational zone of Ghana for enhancement of cowpea yield.

ACKNOWLEDGMENT

We are grateful and also dedicate this work to our supervisor, the late Dr. Eric Asare of the Department of Crop and Soil Sciences, Faculty of Agriculture, Kwame Nkrumah University of Science and Technology for his substantial advice, guidance, support and constructive suggestions during this study.

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