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PERFORMANCE OF THREE COWPEA (*Vigna unguiculata* (L) Walp) VARIETIES IN TWO AGRO-ECOLOGICAL ZONES OF THE CENTRAL REGION OF GHANA I: DRY MATTER PRODUCTION AND GROWTH ANALYSIS

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ABSTRACT

A study on the performance of three cowpea varieties was conducted during the 2008 minor rainy season to compare the effects of location and plant density on growth at two locations, Cape Coast (Coastal savanna) and Twifo Hemang (Transition zone) in Ghana. Three density levels: low, medium and high (125 X 10^3, 1667.7 X 10^3 and 250 X 10^3 plants ha^{-1}, respectively) and the cowpea varieties Ayiyi, Bengpla and UCC-Early were used. The three varieties and three densities were factorially combined and replicated four times in a randomized complete block design. In order to obtain location effect, data were analyzed as a split-split plot design with location as the main plot, density as sub-plot and variety as sub-sub plot. Results from growth analysis indicated that leaf area index, net assimilation rate, crop growth rate, and total dry matter yields were higher at Twifo Hemang than Cape Coast. The variety Ayiyi produced the highest dry matter yield across locations, followed by Bengpla and UCC-Early, respectively. Total dry matter production increased linearly with increasing plant density across locations.

Keywords: cowpea varieties, dry matter production, plant density, growth analysis, Ghana.

INTRODUCTION

Cowpea is a food grain legume that plays a critical role in the lives of millions of people in Africa and other parts of the developing world. Both the grain and the haulm are valuable dietary proteins for the African human population and their livestock (Fatokun, 2002). The grain contains between 20-25 percent of protein, about twice the protein content of most cereals (Kay, 1979). The crop is also a valuable and dependable commodity that produces income for many small holder farmers and traders in Sub-Saharan Africa (Langyintuo, 2003). It's a deep rooted crop and does well in sandy soils and more tolerant to drought than soybean (Dadson, *et al*., 2003, cited by Lauriault and Kirksey, 2007). It forms a major component of the tropical farming system because of its ability to improve marginal lands through nitrogen fixation and as a cover crop (Sanginga *et al*., 2003; Abayomi, 2008). The crop can fix about 240 kg ha^{-1} of atmospheric nitrogen and make available about 60-70 kg ha^{-1} nitrogen for succeeding crops grown in rotation with it (CRI, 2006, cited by Aikins and Afuakwa, 2008). Cowpea cover crops have also been shown to suppress nematode in tomato production system by Roberts *et al*., (2005).

In Ghana, cowpea is one of the widely cultivated legumes, mainly in the savanna and transitional zones (CRI, 2006). The yields of the crop in Ghana, however, are among the lowest in the world, averaging 310 kg/ha (IITA, 1993, cited by Ofosu-Budu *et al*., 2007). Hence, efforts have been made to improve cowpea production in Ghana through various means including the introduction of new varieties such as those used in this study. At present however, there are no growth analysis data on cowpea in the Central Region of Ghana. Thus, various problems pertaining to their adaptability and cultural practices required for optimum utilization of the growing season require investigation. It is, therefore, important to know how various factors affect the growth and development of these new varieties in order to interpret the observed yields in these different environments. In order to obtain information on some of the factors that affect growth and yield of cowpea, a study was undertaken to assess the location and plant density effects on growth of three varieties of cowpea. Such information would provide an understanding of the growth and development of the crop throughout the period of growth.

MATERIALS AND METHODS

Study sites

The study was carried out during the 2008 minor season (September to December) at the Teaching and Research Farm of the University of Cape Coast and Twifo Hemang, about 64 km North-West of Cape Coast. The area of Cape Coast has a bimodal rainfall pattern, the major season (April to July) with maximum rainfall in June and the minor season (September to November) with the maximum in October. The mean annual rainfall for the period 1999 to 2008 ranged between 800mm to 1000mm, with a mean monthly temperature of about 26.5^{o}C. The soils of the experimental site belong to the Benya series which is a member of the Edina-Benya-Udu compound association developed over Sekondian material. The soil is medium to fine textured and moderately well drained (Asamoa, 1973). Twifo Hemang falls within the moist semi-deciduous rainforest zone with a mean annual rainfall for the period 1998 to 2007 ranging between 1156 to 2169mm, well distributed in two wet seasons separated by a short dry spell in August. Temperatures are usually between 25°C to 28°C. The soils have been classified as forest alfisols belonging to the Swedru Series (Obeng, 1971).

Planting materials

Three varieties of cowpea: Ayiyi, Bengpla, recommended by the Crops Research Institute, Ghana and a newly developed strain UCC-Early from the University of Cape Coast were used for the study. Ayiyi is an aphid resistant line (IT83S-728-13), introduced from IITA in 1987. It is upright, but has a sprawling growth habit. Seeds are white with brownish helium, medium maturing (between 65 to 70 days). Its average grain yield is about 1,255 kg ha^{-1}, but has a potential of about 2.6 tons ha^{-1}. Bengpla, an early maturing line (IT83S-818) was also introduced from IITA in 1987. It has an erect growth habit. The seeds are white with black-eyes, but smaller in size than California Black-eye cultivar. It matures between 60 to 65 days. It has a mean grain yield of about 1,023 kg ha^{-1} and a potential of 1.8 tons ha^{-1}. The UCC-Early variety has determinate semi-erect growth habit and with ovate leaves. It has light brown pod colour and reddish seed coat. It matures at about 62 days after planting.

Experimental procedure and treatments

Seeds of the varieties previously described were planted at the two locations after the experimental sites have been disc-ploughed and disc-harrowed. The site of Cape Coast had previously been cropped with cowpea (UCC-Early) strain. Planting was done between 23rd and 27th September and between 8th and 12th October 2008 at Cape Coast and Twifo Hemang, respectively. The design was RCBD with a factorial combination of three varieties and three densities replicated four times. However, in order to obtain information on the effects of location, the results from both locations were analyzed as a split-split plot design with location as the main block, density as subplots and variety as sub-subplots. The plots measured 7.0m x 6.4m in size, and in each case the final harvested area for grain yield was 9.0m^2. Means were tested for significance by an F-test and further separated by the least significant difference (Little and Hills, 1978). Details of treatment combinations are given in Tables 1 and 2.

Table-1. Treatment details.

Treatment code	Treatment description
V1D1	Bengpla planted at 80cm x 20cm
V1D2	Bengpla planted at 60cm x 20cm
V1D3	Bengpla planted at 40cm x 20cm
V2D1	UCC-Early planted at 80cm x 20cm
V2D2	UCC-Early planted at 60cm x 20cm
V2D3	UCC-Early planted at 40cm x 20cm
V3D1	Ayiyi planted at 80cm x 20cm
V3D2	Ayiyi planted at 60cm x 20cm
V3D3	Ayiyi planted at 40cm x 20cm

Table-2. Expected plant population at three density levels.

Density	Spacing (cm)	Plants per hill	Expected number of plants per:	
			m^2	Ha
Low (D1)	80 X 20	2	12.5	125000
Medium (D2)	60 X 20	2	16.7	166667
High (D3)	40 X 20	2	25.0	250000

Data collection

The growth of the crop was analyzed over a period. Using the stratified sampling method, plants from an area of 1m^2 were carefully uprooted from each plot. The roots were carefully washed to remove remaining soil. Plants from each plot were placed in polythene bags and tied. Samples from the 36 plots were sent to the laboratory for growth analysis. Fresh weight for each plot sample were taken and recorded. For each sample also, the roots were cut using a pair of secateurs and put in an envelope and labelled. There were three weekly samplings taken at Cape Coast and four at Twifo Hemang starting from 26th October and 4th November 2008, respectively. Leaf area was determined from three plant samples and by the cork borer or disc method (Edje, 1988). Other growth analysis parameters were computed on the net plot (sample area of about 1m^2) basis according to well established formulae as shown below:

$$(i)\,Leaf\ Area\ Index\ (LAI) = {}^{L}/_{P}$$

where L is leaf area and P, the ground area

$$(ii)\,Net\ Assimilation\ Rate\ (NAR\ or\ E, gm^{-2}day^{-1}) = \frac{(W_2 - W_1)}{(t_2 - t_1)}\ X\ \frac{(\log_e L_2 - \log_e[L_1])}{(L_2 - L_1)}$$

Where L_1 and L_2 are the leaf area at times t_1 and t_2 and W_1 and W_2 are the total dry weights at times t_1 and t_2, respectively.

$$(iii)\,Crop\ growth\ rate\ (CGR, gm^{-2}day^{-1}) = \frac{W_2 - W_1}{P(t_2 - t_1)}$$

Where W_1 and W_2 are the total plant dry weights at times t_1 and t_2, respectively, and P, land area.

RESULTS AND DISCUSSIONS

Total dry matter production

The results of total dry matter production from 30 days after planting are presented in Table-3 and Figure-1. Total dry matter yield in Cape Coast was significantly higher than Twifo Hemang on the first sampling occasion. The latter two samplings however, did not show any significant differences in dry matter production between the locations. Similarly, Kamara (1976) did not find any significant differences in dry matter production when cowpea plants were subjected to excess and deficient moisture regimes.

Total dry matter accumulation followed a similar pattern at both locations. There was a linear increase in total dry matter yield from the first week of sampling to the time of final sampling (Figure-1). According to Blackman (1968), during the juvenile stages of the plant vigorous exponential vegetative growth occurred. Leaf area index thus increased which in turn led to increasing light interception by the leaves resulting in increasing rate of photosynthesis and hence dry matter yield.

Dry matter yield on the first sampling occasion showed no significant variations among the varieties, but subsequent samplings revealed significant differences among them. Bengpla and Ayiyi recorded significantly higher dry matter yield than UCC-Early. Haizel (1972) and Turk *et al*. (1980), also found that cowpea varieties have different capacities for dry matter accumulation. For example, Haizel (1972), found Arauca, a spreading variety to have a higher dry matter yield than the Black Mottled variety, an erect type. The high dry matter values of Bengpla (an erect type) and Ayiyi (semi-erect) also suggested that these varieties could provide high dry matter yields when used as fodder.

Table-3. Total dry matter production.

Main effect	**Weekly samplings** (DAP)		
	30	37	44
Location (L)			
Cape Coast	114.4	156.1	204.1
Twifo Hemang	73.1	151.6	216.1
	**	ns	ns
Variety (V)			
Bengpla	90.8	165.8	214.2
UCC-Early	91.2	127.2	184.1
Ayiyi	94.7	168.5	231.9
	ns	**	**
Density (D)			
Low	79.1	126.6	187.7
Medium	91.4	157.4	216.4
High	106.2	177.5	226.1
	*	**	ns
Interactions			
L X V	ns	ns	ns
L X D	ns	ns	ns
V X D	ns	ns	ns
L X D X D	ns	ns	ns
C.V (%)	31.7	34.2	29.2

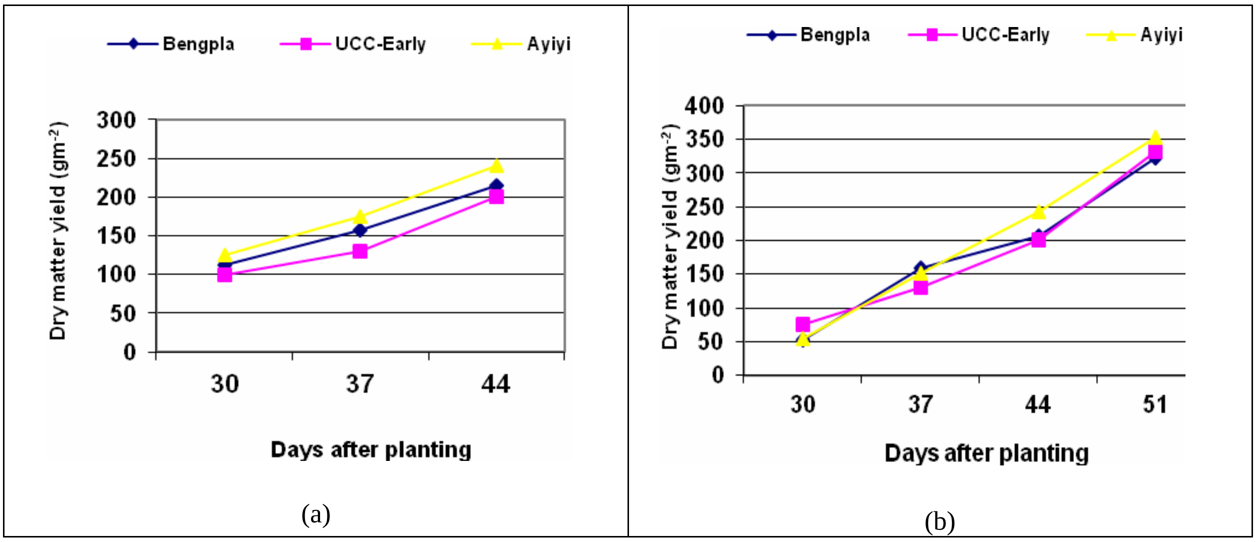

Figure-1. Total dry matter accumulation for three varieties of cowpea at (a) Cape Coast and (b) Twifo Hemang.

Total dry matter production increased linearly with density on all the sampling occasions (Figure-2). At the first sampling stage, total dry matter increased with increasing density for all the varieties (Figures 2a and 2b). At the final sampling stage however total dry matter production at Cape Coast for Ayiyi and UCC-Early increased to a maximum and then remained almost constant as density was increased (asymptotic response). However, Bengpla continued to increase in dry matter production with increasing density (Figure-2c). At the

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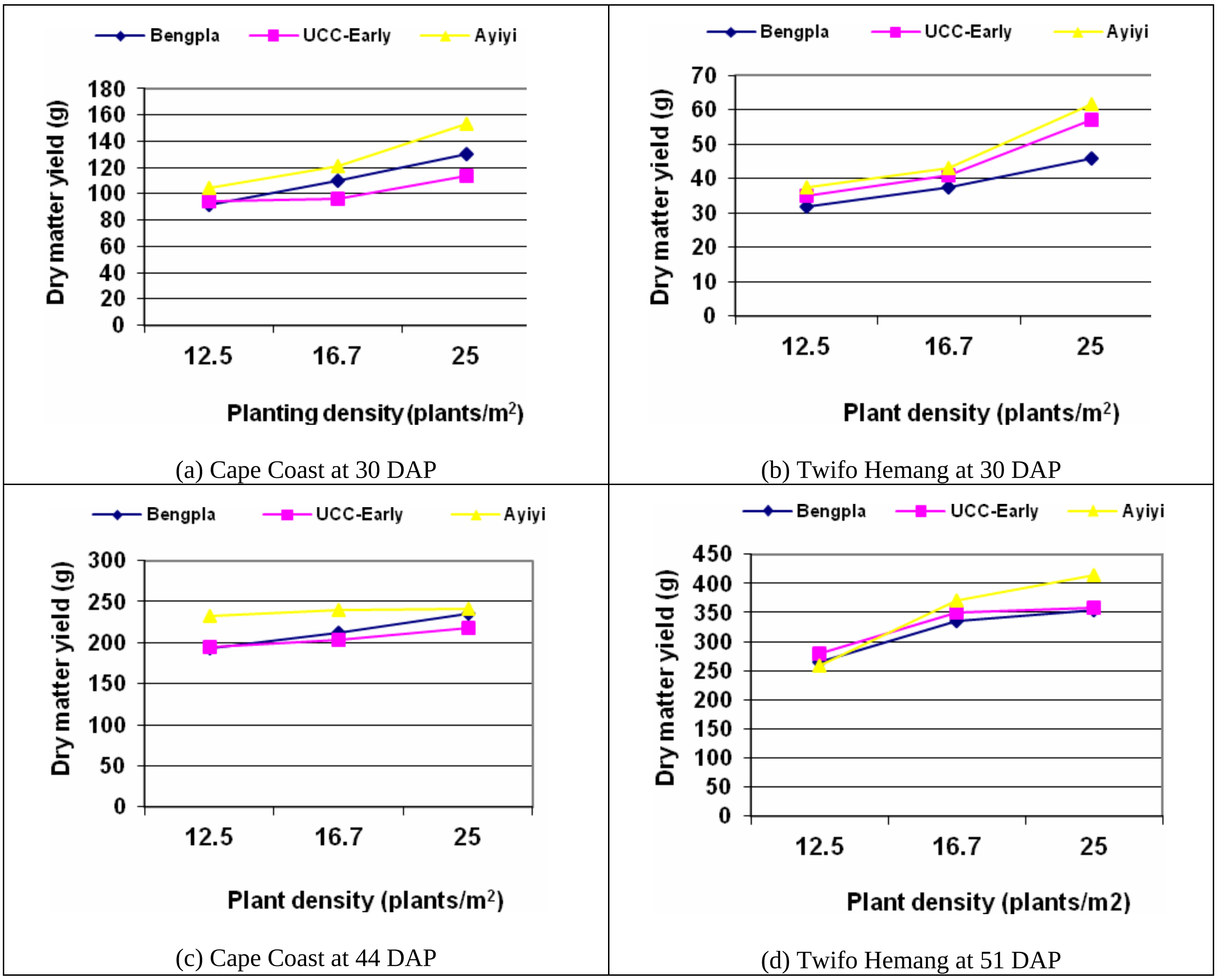
final sampling stage at Twifo Hemang dry matter yield of UCC-Early and Bengpla also increased to a maximum at the medium density and remained almost constant with further increases in plant density. Dry matter production of Ayiyi on the other hand, showed an increase with increasing density (Figure-2d).



(a) Cape Coast at 30 DAP

(b) Twifo Hemang at 30 DAP

(c) Cape Coast at 44 DAP

(d) Twifo Hemang at 51 DAP

Figure-2. Total dry matter production for three varieties and three densities of cowpea at Cape Coast and Twifo Hemang.

Growth analysis

Generally, the growth parameters measured in this study- LAI, NAR, and CGR- were all higher at Twifo Hemang than Cape Coast on all sampling dates. The higher growth parameter values at Twifo Hemang further reflected the higher rainfall and better soil nutrient conditions there. It was interesting to note however, that from plant establishment to maturity the development of these parameters followed similar patterns at both locations.

Mean leaf area index (LAI) significantly differed among the locations at 44 days after planting (Table-4). Highly significant differences were also recorded among the varieties only at the third sampling. Ayiyi recorded the highest mean LAI whereas Bengpla gave the least. Significant differences were established between the densities across location and variety over the three sampling stages. Interactions of location and variety, and location and density significantly affected LAI only at the third sampling stage. Records of other interaction effects were not significant.

The pattern of LAI with time at Twifo Hemang and the effect of density averaged over the two locations are shown in Figures 3 and 4, respectively. For both Bengpla and UCC-Early, LAI increased with time but remained almost the same between 37 and 44 DAP, and then reduced after 44 DAP. The LAI of Ayiyi however increased up to 37 DAP and remained almost the same after that. Mean LAI increased as plant density increased (Figure-4).

LAI, which describes the size of the assimilatory apparatus of the plant stand, is said to be the primary factor that determines the rate of dry matter production in a closed stand. It also reflects differences in productive efficiency between crop varieties (Kvet *et al.*, 1971). All the varieties recorded LAI between 1 and 3 during the period of sampling. In a similar study carried out at IITA (1977), it was reported that, for large yields of cowpea to

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be achieved, LAI between 1 and 2 were required for as long as possible after flowering. This, however, needed to be combined with efficient partitioning of dry matter into fruits. Ayiyi and UCC-Early gave the large LAI which were significantly higher than that of Bengpla. Ayiyi and UCC-Early showed some spreading habits and this perhaps contributed to the large leaf area indices produced. Similarly, Terao *et al*., (1995) found that cowpea varieties with spreading growth habits collected more light than those with erect growth habit and consequently produced more leaves which resulted in larger leaf area index. These observations suggested that different cowpea varieties under the same environmental conditions attained their peak LAI at different times of the growth period due to differences in maturity dates. The pattern of leaf area development in this study was similar to those obtained by Enyi (1975) in *Phaseolus vulgaris* and Osafo (1976), in maize.

The highly significant effect of density on LAI were expected since at higher densities there were more plants per unit area and therefore more leaves available. This finding agrees with those of Carson (1971) and Enyi (1975), who found that high plant densities led to high leaf area indices in wheat and *Phaseolus spp*, respectively. In a density trial ranging from 160.4 to 445.7 x 10^3 bambara bean plants per hectare, Doku and Whyte (1978), also observed LAI to increase with increasing density. They also observed the relationship of total biological and economical yields with density to be linear.

The results of this study showed that although densities higher than 250,000 plants ha^{-1} could be used to achieve higher LAI in all the varieties at both locations, in terms of biological and economic yields such increases beyond the highest density used in this study would not be beneficial for a variety such as UCC-Early. It meant that each cowpea variety has its density threshold within which an optimum biological and economical yield could be achieved. Hence for any released variety it was imperative for such density trials to be carried out to determine the optimum plant density at which optimum grain yield could be achieved.

Mean net assimilation rate at both locations did not show any significant difference between them (Table-5). During the first sampling interval (30-37 DAP), varietal differences in NAR across location and density were highly significant. Bengpla recorded the largest NAR followed by Ayiyi and UCC-Early (Table-5). Plant density effect on NAR was not significant. Various interactions of location, variety and density were also not significant. The trend of NAR at Twifo Hemang showed some fluctuations in all the varieties (Figure-5).

Table-4. Main effects of location, variety and plant density on leaf area index (LAI).

Main effect	**Weekly samplings** (from 30 DAP)		
	30	37	44
Location (L)			
Cape Coast	1.3	1.7	1.6
Twifo Hemang	1.4	2.1	2.2
	ns	ns	**
Variety (V)			
Bengpla	1.1	1.7	1.6
UCC-Early	1.5	2.1	1.9
Ayiyi	1.5	1.9	2.1
	ns	ns	**
Density (D)			
Low	1.2	1.5	1.6
Medium	1.3	1.9	1.9
High	1.6	2.4	2
	*	**	*
Interactions			
L X V	ns	ns	*
L X D	ns	ns	*
V X D	ns	ns	ns
L X D X D	ns	ns	ns
C.V (%)	40.1	35.6	27.2

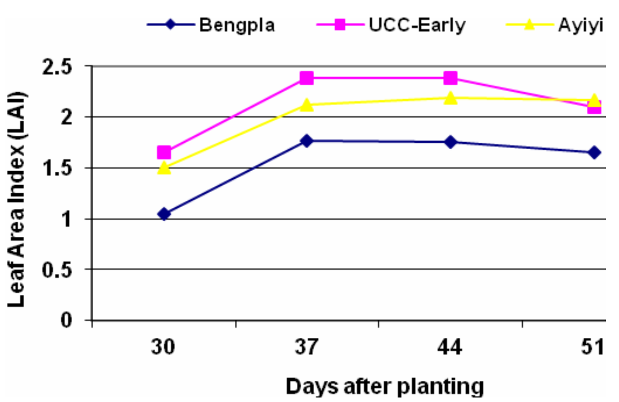

Figure-3. Leaf area index (LAI) curves for three varieties of cowpea at Twifo Hemang.

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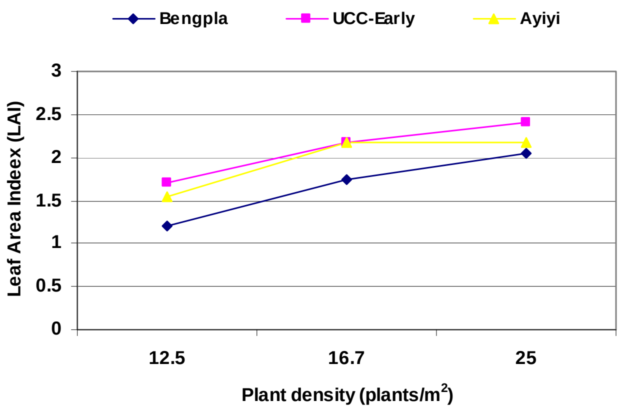

Figure-4. Effect of plant density on leaf area index (LAI) averaged over two locations.

Table-5. Mean effects of location, variety and plant density on net assimilation rate (NAR) ($g/m^2/day$).

Main effect	**Sampling intervals** (DAP)	
	30 - 37	37 - 44
Location (L)		
Cape Coast	5.5	5.5
Twifo Hemang	8.0	5.4
	ns	ns
Variety (V)		
Bengpla	9.1	6.2
UCC-Early	3.7	4.7
Ayiyi	7.5	5.4
	**	ns
Density (D)		
Low	6.7	6.7
Medium	7.0	5.1
High	6.5	4.5
	ns	ns
Interactions		
L X V	ns	ns
L X D	ns	ns
V X D	ns	ns
L X D X D	ns	ns
C.V (%)	34.2	25.7

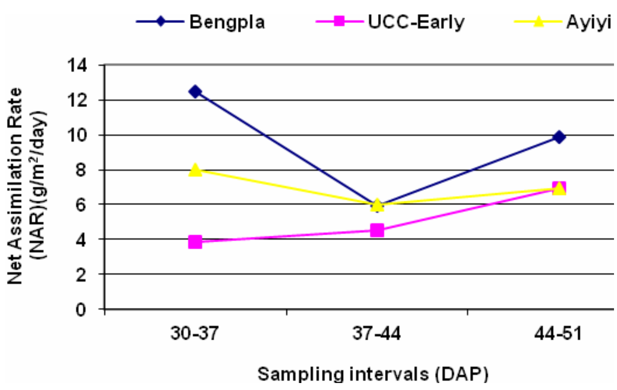

Figure-5. Net assimilation rate (NAR) curves for three varieties of cowpea at Twifo Hemang.

The higher NAR values of Bengpla and Ayiyi suggested that the leaves of the two varieties were more efficient in producing dry matter than UCC-Early. According to Arnon (1972), apart from solar radiation, NAR was also influenced by mineral nutrition and water supply and therefore any limitations to these factors might affect NAR. In the present study the fluctuations in NAR could be probably due to the effect of weed growth on the plants. However, the growth habits of these varieties showed the extent to which weed competition affected their NAR. UCC-Early partially closed its canopy early and therefore was able to smother weeds to some extent, but until its canopy was fully closed, it suffered from weed competition which reflected in its early low value of NAR during the first sampling interval. Both Ayiyi and Bengpla were tall and therefore were able to record high NAR values at the same stage that UCC-Early recorded its lowest NAR (37 DAP). Nevertheless, as weed competition intensified the NAR of Ayiyi and Bengpla declined at the time that UCC-Early was rising (44 DAP).

In a comparative study of the growth of three cowpea varieties, Castro *et al*., (1984), found higher NAR to occur from 30 to 50 days after emergence. Soon after the second weeding, (40 DAP), all the three varieties recorded remarkable increases in NAR up to the final sampling (51 DAP). These increases therefore suggested that the early decline in NAR as recorded by these varieties was due to weed competition, probably for light, soil nutrients and water. Most of the weeds at Twifo Hemang were fast growing and tall, and according to Forbes and Watson (1992), tall growing weeds cast considerable shade, thereby reducing NAR. In the case of Ayiyi and UCC-Early, it appeared that because of their spreading ability and large leaf areas, they were able to withstand weed competition to some extent and therefore the reduction in their NAR values was not as severe as that of Bengpla.

Although in this study NAR declined with increasing plant density, the differences were not large enough to be statistically significant. This was probably because the current densities were not high enough to have their effects felt. Other studies (Blackman and Black, 1959a, b; Wassink, 1961; Huxley, 1967) have shown that

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increasing density resulted in a decline in NAR, probably as a result of very high densities causing mutual shading of leaves which contributed to low photosynthetic efficiency. In maize, Haizel and Ahiekpor (1975), and in *Phaseolus spp*., Enyi (1975) reported that NAR decreased with increasing plant density.

Crop growth rate (CGR) showed a significant difference between Cape Coast and Twifo Hemang at the first sampling interval (Table-6). The trend at Twifo Hemang is represented in Figure-6a. Significant differences in CGR were also recorded among the varieties in the first sampling stage (30 - 37 DAP), but differences in the second sampling interval (37-44 DAP) were not significant. Ayiyi recorded the highest crop growth rate followed by Bengpla and UCC-Early. Crop growth rate increased with increasing plant density (Figure-6b). However, significant differences were established between densities in the first sampling stage only (Table-6). Various interactions of the three factors did not have any significant effect on CGR.

Since CGR measured the accumulation of dry matter per unit time, it was, therefore a reasonable approximation of the canopy photosynthetic rate per unit ground area (Clawson *et. al*., 1986). The significantly higher CGR values of Ayiyi and Bengpla as against UCC-Early, suggested that the strands of these two varieties produced more dry matter per unit ground area than UCC-Early. In spite of its low CGR, it was observed that CGR of UCC-Early increased continuously from the initial sampling (30 DAP) stage to the final sampling stage (51 DAP). In contrast CGR of Ayiyi and Bengpla fluctuated, but the fluctuations were wider in Bengpla than Ayiyi between 37 and 51 DAP.

Table-6. Main effects of location, variety and plant density on crop growth rate (CGR) ($g/m^2/day$).

Main effect	**Sampling intervals** (DAP)	
	30 - 37	37- 44
Location (L)		
Cape Coast	7.1	8.1
Twifo Hemang	11.9	10.6
	*	ns
Variety (V)		
Bengpla	11.1	8.5
UCC-Early	6.3	8.6
Ayiyi	11.1	11.1
	*	ns
Density (D)		
Low	7.2	9.2
Medium	10.1	9.3
High	11.2	9.6
	*	ns
Interactions		
L X V	ns	ns
L X D	ns	ns
V X D	ns	ns
L X D X D	ns	ns
C.V (%)	20.8	26.5

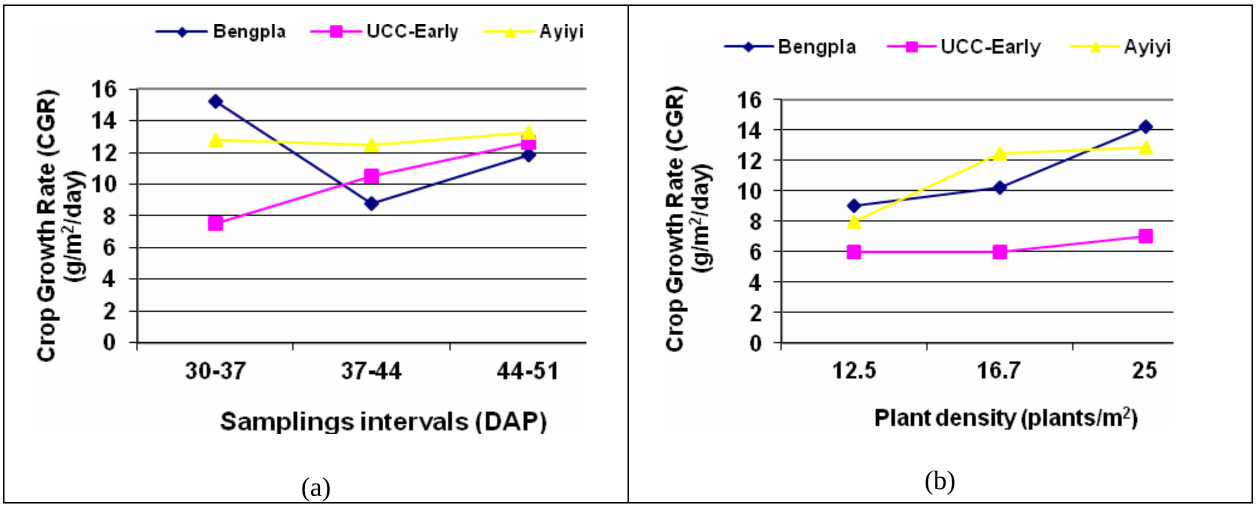

Figure-6. Crop growth rate (CGR) of three varieties of cowpea as affected by (a) time of sampling at Twifo Hemang, and (b) plant density averaged over two locations.

CONCLUSIONS

From the results obtained in this study, it could be concluded that the performance of the three cowpea varieties in terms of dry matter and growth parameters were better at Twifo Hemang than Cape Coast. Ayiyi proved to be the best variety on the basis of the growth parameters measured at both locations. Dry matter production showed a linear increase with increased plant density across locations. It is recommended that further study be carried out on detailed growth analysis of various plant parts of cowpea to ascertain how dry matter is partitioned under different agro-ecological conditions, and also to establish the actual relationship between LAI and CGR.

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