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PERFORMANCE OF THREE COWPEA (*Vigna unguiculata* (L) Walp) VARIETIES IN TWO AGRO-ECOLOGICAL ZONES OF THE CENTRAL REGION OF GHANA II: GRAIN YIELD AND ITS COMPONENTS

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ABSTRACT

Field experiments were conducted in two agro-ecological zones (Twifo Hemang in the transition zone and Cape Coast in the Coastal savanna) of Ghana during the 2008 minor rainy season to study the effects of plant density on grain yield and its components of three cowpea varieties. Three density levels: low, medium and high (125 X 10^3, 1667.7 X 10^3 and 250 X 10^3 plants/ha, respectively) and three 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. Mean pod length and mean number of seeds per pod were almost the same at both locations. This implied that these characters were least affected by the environment. Mean number of pods per plant, 1000 seed weight and grain yield were higher at Twifo Hemang than at Cape Coast, indicating that with adequate control of insects, higher yields of cowpea could be achieved in more humid locations. Ayiyi gave the highest grain yield at both locations followed by UCC-Early and Bengpla. The relationship between grain yield and density across locations was parabolic.

Keywords: cowpea varieties, plant density, grain yield, Ghana.

INTRODUCTION

The increasing population calls for high levels of food production to meet the high demand. However, food production has not kept pace with the rising human population, especially in the developing countries. Much worse is the deteriorating quality of nutrition. Protein requirements are usually met from two main sources, animal and vegetable. Animal sources of protein are usually preferred because of their quality and nutritional balance. But in Ghana, production of animal protein is very limited because of several constraints such as under developed range lands, poor breeding stocks, poor husbandry practices, poor veterinary delivery system and low productivity. Gross national product budget contribution of the animal industry to the national budget is only about 5% (PPMED, 1991) so the only recourse is to satisfy demand from vegetable sources.

Legumes are rich in protein, iron and vitamin B, which make them excellent foods even when eaten in small amounts (FAO, 1988). Although, vegetables (legumes) protein is not as rich as animal protein on account of limiting amount of certain amino acids such as cystine and methionine, it has the advantages of complementing production of cereals in cereal/legume rotations, and mixtures, a relatively shorter life cycle and high yields. Virtually all cereal proteins are deficient in the essential amino acid, lysine. Food legumes are, however, comparatively rich in lysine and therefore a combination of cereal protein and legume protein comes very close to providing an ideal source of proteins for human beings. The comparatively low levels of methionine and cystine in legumes is in large part offset by the higher proportions of these amino acids present in most cereals (Siegel and Fawcett, 1976).

Apart from their nutritive value legumes are also of great importance in agriculture, for they have the ability to produce nodules in more acid soils and soils more deficient in phosphorus, calcium and other nutrients (Purseglove, 1968). In Ghana, a wide array of legumes is produced but cowpea is preferred on account of its short life cycle, fodder use and quality. The dry seeds may be boiled and eaten with “Garri" (a cassava product). It is also boiled together with rice and a coloring agent to give “Waakye”. The boiled seeds could also be served with fried ripe plantain. It is also used in preparation of weaning foods.

In spite of its numerous benefits, the yields of the crop in Ghana are among the lowest in the world, averaging 310kg/ha (IITA, 1993, cited by Ofosu-Budu *et al*., 2007). An important aspect of the management of the crop is plant density and its relationship to yield. The response of individual plants to changes in plant population and the relationships between plant size and plant number per unit area and yield are dependent on the plasticity of the morphological attributes which determine grain yield. Isolation of the morphological attributes which determines the yield response of a cultivar to plant population may lead to the formation of empirical rules and their use to predict economic optimum populations without recourse to field studies (Carson, 1971). Consequently, cultivars may have to be evaluated at their optimum plant population levels and not on a constant plant population basis. Summerfield *et al*., (1985) suggested that detailed comparative growth experiments at sites of contrasting potential productivity should be conducted in order to pin point the environmental conditions leading to large seed yields. This paper reports on the effects of plant density on grain yield and its components of three cowpea varieties grown in two different locations in Ghana.

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 are sandy clay loam, belonging to the Benya series, which is a member of the Edina-Benya-Udu compound association developed over Sekondian material (Asamoa, 1973). They are classified as Typic Haplustult (USDA Soil Taxonomy and Haplic Acrisols (FAO/UNESCO). 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^{o}C to 28^{o}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, 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, but has a potential of about 2.6 tons /ha. 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-eyes cultivar. It matures between 60 to 65 days. It has a mean grain yield of about 1,023 kg/ha and a potential of 1.8 tons/ha. 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 in 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 three 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 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 presented 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

Chemical analysis of soils collected at the two locations is shown in Table-3. Soil samples taken from the experimental plots were air-dried in the laboratory and analyzed for C, N, P, K and pH using the methods described by Allen (1994), Black (1965) and Watanabe and Oslen (1965).

Table-3. Soil nutrient analysis.

Location	% N	% P	% K	% C	C/N Ratio	pH
Cape Coast	0.035	0.002	0.007	0.612	17.49	5.1
Twifo Hemang	0.210	0.002	0.029	2.365	12.55	7.2

Yield parameters measured include the number of pods per plant, pod length, number of seeds per pod, 1000 seed weight, and grain yield. The number of pods per plant was obtained by randomly selecting five plants within the harvested area and counting the pods on them. The average number of pods per plant was then determined. Also, ten pods from each harvest were selected and their lengths measured with a meter rule. For the average number of seeds per pod, twenty pods from each harvested plot were shelled and the seeds counted and the average found. Four lots of 1000 seeds from the shelled pods of each plot were counted and weighed. The average was then taken as the weight of 1000 seeds. After harvesting pods from each plot, they were shelled and the grains weighed to determine the final yield expressed in kilogram per hectare (kg ha^{-1}).

RESULTS AND DISCUSSIONS

Number of pods per plant

The higher number of pods per plant recorded at Twifo Hemang (8.3), as against 6.9 at Cape Coast, although not significantly different, could be attributed to the favourable moisture regime and soil nutrient conditions there. This finding is consistent with those of other workers. For example, Hall and Patel (1985) observed that cowpea plants under high moisture regimes produced more pods per plant than those under deficient moisture. Ndunguru *et al*., (1995) have also shown that limited moisture supply reduced number of pods per plant in groundnut. Location x plant density interaction did not have any significant effect on mean number of pods per plant. The mean of the three varieties however, differed significantly.

Table-4. Main effects of location, variety and plant density on number of pods per plant.

Variety	Plant density	Location		Variety mean
		Cape Coast	Twifo Hemang	
Bengpla	Low	7.8	4.6	
	Medium	5.6	7.6	
	High	5.9	8.3	
	Mean	**6.4**	**6.8**	**6.6**
UCC-Early	Low	6.8	9.2	
	Medium	5.7	9.4	
	High	4.9	6.0	
	Mean	**5.8**	**8.2**	**7.0**
Ayiyi	Low	10.5	9.1	
	Medium	8.4	11.7	
	High	6.5	8.2	
	Mean	**8.5**	**9.7**	**9.1**
Location Mean		6.9	8.3	

Variety LSD (0.01) = 2.1 C.V = 30%

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The significantly higher number of pods per plant recorded by Ayiyi across locations than Bengpla and UCC-Early, indicated that Ayiyi was more efficient in partitioning photo-assimilates into pods. Similarly, Okafor (1986), and Sekyi (1990), recorded significant varietal effect on number of pods per plant. Thus the number of pods per plant could be assumed to be under genetic control and varied among cowpea varieties. Fery (1985) confirmed in his work that variation in number of pods per plant among varieties was due to genetic factors, and estimated that a heritability of 53.1 percent accounted for the observed differences in the varieties he used.

At both locations the number of pods per plant declined as the density was increased from 125,000 to 250,000 plants ha^{-1} although the differences were not significant. Similar results have been recorded by other workers (Holiday, 1960; Donald, 1963; Haizel, 1972; Eskine and Khan, 1976; Anyomi, 1980; Braithwaite, 1982; Dapaah and Ennin, 1989; Sekyi, 1990). For example, Sekyi (1990) found that as plant density was increased from 100,000 plants ha^{-1} to 250,000 plants ha^{-1}, the number of pods per plant declined from 14.7 to 8.4. A possible explanation for this trend is that as plant density increased there were both intense inter-and intra-plant competition, especially during the reproductive stage, resulting in shortage of nutrients for assimilate production. This in turn could have affected assimilate partitioning during the appearance of floral buds. The net effect was the abortion of flowers which reduced number of pods per plant.

Pod length

Mean pod length at both Cape Coast and Twifo Hemang were almost the same, 15.6cm and 15.2cm, respectively (Table-5). The inference is that environmental conditions had little or no effect on pod length in cowpeas. Fery (1985) showed that pod length was highly heritable with average heritability estimate of 75.2 percent.

Table-5. Main effects of location, variety and plant density on pod length (cm).

Variety	Plant density	Location		Variety mean
		Cape Coast	Twifo Hemang	
Bengpla	Low	16.1	14.7	
	Medium	15.8	15.3	
	High	16.1	15.8	
	Mean	**16.0**	**15.3**	**15.6**
UCC-Early	Low	14.8	14.6	
	Medium	15.2	15.3	
	High	14.6	14.4	
	Mean	**14.9**	**14.8**	**14.8**
Ayiyi	Low	15.6	15.6	
	Medium	15.6	15.7	
	High	16.0	15.3	
	Mean	**15.7**	**15.5**	**15.6**
Location Mean		15.6	15.2	

Variety LSD (0.01) = 0.71 C.V. = 6.0%

Pod length across locations clearly showed the differences among the three varieties. Ayiyi and Bengpla recorded the same pod length (15.6cm) which was significantly higher than that of UCC-Early (14.8cm). Since pod length of each variety was almost the same at both locations, this also implied that pod length was variety specific and least influenced by the environment. The non-significant effect of plant density on pod length obtained in this study agrees with the findings of Haizel (1972) who indicated that when density stress was induced in a population, various plant parts would be affected or unaffected by their degree of plasticity at different intensities. The results in this study and other studies suggest that pod length could be under strong genetic control and therefore remains unaffected by density stress.

Number of seeds per pod

Location did not affect the number of seeds per pod (Table-6). This implied that seed number per pod was also genetically controlled and that environmental conditions may have had little or no effect on it. Fery (1985) pointed out that number of seeds per pod was moderately heritable under most environmental conditions with mean heritability estimated at 52.8 percent.

Ayiyi and UCC-Early gave almost the same average number of seeds per pod (11.6 and 11.7, respectively) which was significantly higher than that of Bengpla (10.1 seeds). Since Bengpla and Ayiyi recorded the same pod length, it was expected that they should also give more seeds per pod than UCC-Early. However, contrary to expectations, Ayiyi and UCC-Early recorded more seeds per pod than Bengpla. This discrepancy could imply that although Bengla had longer pod length, the seeds within the pods were widely spaced, compared to that of Ayiyi and UCC-Early. Both seed number and spacing in the pod seem to be genetically controlled. Leleji (1975) reported that small number of seeds per pod was partially dominant over larger number. Aryeetey and Laing (1975) also reported that a single genetic factor conditioned seed number per pod.

Table-6. Main effects of location, variety and plant density on number of seeds per pod.

Variety	Location	Plant Density				
		Low	Medium	High	Mean	
	Cape Coast	10.6	9.9	10.4	10.3	
Bengpla						10.1
	Twifo Hemang	9.8	10.2	10.1	10.0	
	Cape Coast	12.1	11.6	11.6	11.8	
UCC-Early						11.7
	Twifo Hemang	12.4	12.1	10.5	11.7	
	Cape Coast	11.7	10.8	11.8	11.4	
Ayiyi						11.6
	Twifo Hemang	11.7	12	11.5	11.7	
	Cape Coast	11.5	10.8	11.3	11.2	
Location Mean						
	Twifo Hemang	11.3	11.4	10.7	11.1	
Density Mean		11.4	11.1	11.0		

LSD (0.01): Variety = 0.70 LSD (0.05): same location, different density = 0.66
LSD (0.05): different location, same or different density = 1.51
C.V. = 11.0%

Although all the three varieties used in this study showed no variation in number of seeds per pod at both locations, it appeared that in response to the dry and less fertile environment at Cape Coast, Ayiyi and UCC-Early compensated for such conditions by reducing number of pods per plant, while maintaining the same number of seeds per pod. In contrast, these two varieties recorded higher number of pods per plant at Twifo Hemang, yet number of seeds per pod were the same as that obtained in Cape Coast. Such attribute of cowpeas has been reported by Turk *et al*., (1980) and Grantz and Hall (1982). According to Squire (1990), the reproductive sink of such varieties develop gradually, and each unit of the sink is filled soon after it is set. The non-significant effect of plant density on number of seeds per pod has also been reported by other workers (Haizel, 1972; Anyomi, 1980; Sekyi, 1990). Although both location and density showed no significant effect on number of seeds per pod, their interaction was significant. This could be due to complex interactive effect of environment and genotype.

1000 Seed weight

Seed weight, which is a measure of seed size, has been found to be moderately to highly heritable with heritability estimate averaging 67.8 percent (Fery, 1985). Notwithstanding the high heritability estimate, other workers have shown that seed size was affected by climatic and cultural factors (Squire, 1990). The highly significant location effect on 1000-seed weight in this study seemed to support this school of thought (Table-7). At Cape Coast where the environment was relatively dry with low soil nutrient levels (Table-3), seed size was significantly lower (131.6g) than Twifo Hemang (148.0g), where there was enough moisture and higher nutrient levels. Similarly, Kamara (1976) reported that seed weight was significantly reduced when cowpea plants were under deficient moisture.

Table-7. Mean 1000 seed weight (g) as affected by location, variety and plant density.

Variety	Location	Plant Density				
		Low	Medium	High	Mean	
	Cape Coast	144.25	140.25	137.13	140.54	
Bengpla						149.1
	Twifo Hemang	159.88	156.63	156.25	157.59	
	Cape Coast	142.25	134.00	130.75	135.67	
UCC-Early						145.3
	Twifo Hemang	155.75	156.00	153.25	155.00	
	Cape Coast	121.13	119.38	115.63	118.71	
Ayiyi						125.0
	Twifo Hemang	131.63	131.21	131.00	131.34	
	Cape Coast	135.88	131.21	127.84	131.64	
Location Mean						
	Twifo Hemang	149.09	148.00	146.83	148.00	
Density Mean		142.5	139.6	137.3		

LSD (0.01): Location = 12.44, LSD (0.01): Variety = 3.86
LSD (0.01): Density = 5.07, C.V. = 10.77%

The highly significant varietal differences in seed weight across locations obtained in this study agree with the findings of Okafor (1986) and Sekyi (1990). For example, Okafor (1986) found significant differences in 100 seed weight among nine cowpea varieties tested in Nigeria. Sekyi (1990) also observed significant differences among three varieties of cowpea in Ghana. Thus it would appear that seed weight was influenced by both genetic and environmental factors. Bengpla recorded the highest 1000-seed weight, followed by UCC-Early and Ayiyi.

Seed weight decreased significantly as plant density was increased. Similarly, Anyomi (1980) reported a decreasing trend in 100-seed weight as plant population was increased. Sekyi (1990), however, did not obtain any significant difference due to density in 100-seed weight of the varieties they used. These different observations might have resulted from the different varieties of cowpea used and the prevalent environmental conditions during the experimental period. In the present study, a possible biological interpretation of density effect could be that as plant density was increased, available resources became limited. Incident of severe intra- and inter-row competition among plants meant that individual plants had less assimilates at their disposal to fill the growing pods and seeds within.

Grain yield

The significantly lower grain yield obtained at Cape Coast compared to Twifo Hemang (897.9 vs. 1268.1 kg/ha in Table-8) could be due to the poor environmental conditions at Cape Coast which made it impossible for the varieties to realize their potential yield. For example, total rainfall recorded during the experimental period at Cape Coast was only 24.4mm as against 181.0mm at Twifo Hemang. This compares favourably with results obtained by the Crops Research Institute, Kumasi, Ghana from long term multi-locational trials carried out between 1985 and 1993. For example, during the 1985 minor season average grain yield of ten varieties tested at Kwadaso (forest zone) and Pokuase (coastal savanna) were 1258kg ha^{-1} and 858 kg ha^{-1}, respectively. Sangakkara (1995) also observed that planting cowpea in the wet season produced the highest grain yields. All these results suggested that higher yields of cowpea were achievable in high rainfall areas and negated the notion that cowpeas were not suitable for high rainfall or forest areas (GGDP, 1989). Perhaps, what was required to sustain the high yields in these areas was the timely application of appropriate insecticides to control the heavy biotic (insect) pressures.

Table-8. Mean grain yield (kg/ha) as affected by location, variety and plant density.

Variety	Location	Plant Density			
		Low	Medium	High	Mean
	Cape Coast	815.8	829.9	840.2	828.6
Bengpla					
	Twifo Hemang	677.7	688.5	713.9	693.4
	Cape Coast	932.0	940.9	893.8	921.9
UCC-Early					
	Twifo Hemang	1455.9	1857.4	1168.8	1494.1
	Cape Coast	935.6	980.4	1013.3	976.4
Ayiyi					
	Twifo Hemang	1667.1	1596.7	1586.4	1616.7
	Cape Coast	861.1	917.0	915.8	897.9
Location Mean					
	Twifo Hemang	1266.9	1380.9	1156.4	1268.1
Density Mean		1064.0	1148.9	1036.1	

LSD (0.05): Location = 264.77, LSD (0.05): same location, different variety = 301.29
LSD (0.01): Variety = 213.05, LSD (0.05): different location, same or different variety = 510.16
C.V. = 45.76%

The higher grain yield obtained at Twifo Hemang could also be attributed to the better soil nutrients or soil properties of the site compared to Cape Coast. Generally, the performance of a crop could be estimated from the analysis of its growth parameters. Since growth parameters such as leaf area, relative growth rate, net assimilation rate, and crop growth rate of the varieties were all higher at Twifo Hemang than Cape Coast, it implied that the varieties were more vigorous in growth at Twifo Hemang and subsequently led to higher grain yield (Addo-Quaye, Darkwa and Ampiah, 2011).

Ayiyi showed better performance over Bengpla and UCC-Early in grain yield at both locations, with mean grain yield of 976.4 and 1616.7kg/ha for Cape Coast and Twifo Hemang, respectively. These yield values compared favourably with the mean grain yield of 1255 kg/ha for this variety reported by the Crops Research Institute (1987). The superior performance of Ayiyi could have been due to the cumulative effect of its various growth functions most of which also were found to be greater than the other two varieties. For example, Ayiyi recorded the largest leaf area, LAI and CGR (Addo-Quaye, Darkwa and Ampiah, 2011).

UCC-Early followed Ayiyi closely with mean grain yields of 921.9 and 1494.1 kg/ha at Cape Coast and Twifo Hemang, respectively. This was not unexpected since UCC-Early also followed Ayiyi in recording higher LAI and CGR. Furthermore, UCC-Early recorded the highest shelling percentage (results not shown), which implied it was the most efficient in partitioning its pod assimilates into seeds. The results therefore suggest that UCC-Early is a potential good yielder and it requires further attention.

The low yield of Bengpla at Twifo Hemang implied that probably Bengpla was unable to withstand the biotic pressures (insects), even though it recorded the highest NAR. Numerous insects were found on this variety at Twifo Hemang and it was observed that Bengpla had the highest flower abortion. This might have accounted for its lowest number of pods per plant at Twifo Hemang. Similar variation in yield of Bengpla across location had been reported by the Crops Research Institute, Ghana (1988). The highly significant interaction effect between location and variety on grain yield obtained in this study showed how grain yield was affected by both genetic and environmental factors. This has been reported by many workers (Eskine and Khan, 1977; Smithson *et al*., 1980; Summerfield *et al*., 1983).

The overall density - grain yield relationship across location and variety was parabolic i.e., grain yield increased from the lowest to the medium density and then declined at the highest density, which is in agreement with the findings of other workers (Holliday, 1960; Donald, 1963; Wiley and Heath, 1969). Each of the three varieties used in the present study however, responded to density stress differently at the two locations. The density - grain yield relationship of UCC-Early was parabolic at both locations, while at Cape Coast Ayiyi and Bengpla exhibited a linear response. Similarly, at Twifo Hemang the relationship between grain yield and density for Bengpla was linear.

Similar results have been reported by other workers (Duncan, 1954; Lang *et al*., 1956; Hinson and Hanson, 1962; Wiley and Heath, 1969; Aryeetey, 1971; Arnon, 1972; Yayock and Asenime, 1977; Jallow and Ferguson, 1985). For example, of the 18 cultivars of cowpea evaluated by Jallow and Ferguson (1985), eight were found to show a linear response to plant density ranging from 40,000 to 250,000 plants/ha, while the others varied differently.

The results of the present study and those of other workers suggest that the density at which optimum grain yield could be achieved varied from variety to variety within a species. Another implication was that for a variety like Bengpla, where the response was linear, further work was required to establish the optimum density.

CONCLUSIONS

Ayiyi proved to be the best variety in terms of grain yield at both locations. It produced the highest mean grain yields across locations (1296.5 kg ha^{-1}), followed by UCC-Early (1208.0 kg ha^{-1}), with Bengpla recording the least yield of 761.0 kg/ha. Indications were that for drier areas such as Cape Coast, Ayiyi and Bengpla could be planted at density of 250,000 plants ha^{-1} for higher grain yields. For UCC-Early, 166,667 plants ha^{-1} appeared to be the optimum plant density for both the coastal and transition zones. Under higher moisture regimes, plant density of 125,000 plants ha^{-1} could be adopted for Ayiyi to obtain high yields. Bengpla could still be planted at 250,000 plants ha^{-1} under more moist conditions, even though the indication was that grain yields had not peaked yet within the range of plant densities used in the study.

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