Exploitation of Genetic Variability in Cowpea Improvement for High Moisture Tolerance: 3. Response of Genotypes to High Moisture Stress

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Abstract: Cowpea is cultivated in varied agroecological environments in the humid tropics and is beset with different type of stresses such as high moisture – a phenomenon of heavy rainfall characterized by temporary waterlogging and drought at all stages of plant development and eventual low grain yield production. Twenty-seven germplasm of cowpea from diverse genetic origin were grown under rainfall condition in two locations located in rainforest-savanna transition area with sandy-loam soils and in the humid rainforest area with clay and clayey-loam soils during early and late cropping seasons in randomized complete block design with three replicates in 2006. The response of the cowpeas to increasing moisture tolerance was evaluated for different agronomic characters based on mean weekly soil moisture level and susceptibility rating scale. High moisture deficit delayed days to 50% flowering, 50% maturity, reduced pods per plant, seeds per pod, 100-seed weight and grain yield. Early season planting resulted in significant difference in crop yield of 613kg/ha in Ekpoma and 117.4kg/ha in Obayantor. The results indicated that cowpea grown under increasing moisture stress experienced delay in flowering and seed development phases though some genotypes exhibited more tolerance level to increasing moisture stress in the two seasons. Such genotypes can be exploited and improved upon for effective adaptation to waterlogged prone areas. [New York Science Journal 2010;3(5):123-129]. (ISSN 1554 – 0200).

Keywords: Cowpea germplasm, response, high moisture stress, grain yield.

1. Introduction

Vigna unguiculata (L.) Walp. crop plant is known to be well suited to the tropical guinea savanna areas due to its characteristic nature for drought-tolerant with better growth in warm climates. However, to some extent, the crop is grown in the rainforest regions during the period of rains by subsistence peasant farmers. Since cowpea crop is cultivated in varied agroecological environments in the humid tropics in developing countries of Africa in general and Nigeria in particular, it is beset with different type of stresses which consequently result in low grain yields attributable mostly to eratic and early ceasation of rains in arid areas (Ngundo and Taylor, 1974) on one hand, and high soil moisture resulting from high water table, hard pan and/or poor soil drainage among others for cowpea crop production in the south. The exposure to high soil moisture at the vegetative, flowering and podding stages are common phenomena.

The periods of heavy rainfall are characteristic of the rainy season in the humid rainforest tropics and often result in temporary waterlogging (Minchin *et al*., 1978). This is due to the fact that rainfall distribution in Nigeria experiences a bimodal pattern which are typically characterized by alternate periods of drought and heavy rains and can occur during any stage of plant development. Researches have shown that cowpea requires a precipitation of 50mm–127mm each month from sowing through flowering (Ndunguru and Summerfield, 1975; De–Oliveriera and De–Carvalho, 1988). Vidal *et al* (1981) reported that podding is the yield component most responsive to moisture and that pod number, pod weight and seed weight were greatly affected by moisture stress and that pods were unfilled and grain wrinkled (Kamara, 1976) in cowpea while seeds per pod and seed yield were reduced in mung bean (Pandey *et al.*, 1984b). In all grain legumes, number of pods per plant exert a very strong influence on the yield produced by the plant (Kumar and Dubey, 2001; Mera *et al*, 2003; Kumari and Prasad, 2005) which is as a result of water supplied during the reproductive stage (Singh *et al*, 1997).

Both too much and too little soil moisture have been known to be major causes of crop yield losses around the world. In order to achieve improved and stable yields in stress-prone environments, it is desirable to improve tolerance to major abiotic constraints prevalent in target environments (Zaidi et al, 2008) and in this case high soil moisture stress. Thus, the ability of cowpea crop to tolerate high moisture can therefore be an important selection criterion in the development of improved genotypes for high rainfall areas. Consequently, this study is aimed at evaluating some cowpea germplasm agronomic characters response to high moisture stress.

2. Materials and Methods

Two field experiments in each of the two locations were conducted at the Teaching and Research Farm, Ambrose Alli University, Ekpoma located in a rainforest-savanna transition zone with mean yearly precipitation of 1200mm–1550mm, and Benin–Owena River Basin Development Authority, Obayantor situated in a humid rainforest zone with mean yearly precipitation of 2,032mm–2540mm in 2006, respectively. The soil in Ekpoma is sandy–loam while soil in Obayantor consists of clay and clay–loam (Table 1). Twenty–four lines of cowpea obtained from IITA genebank along with three other local cultivars were used as genetic materials. Each test material was sown into plot sizes of 3m x 2m at a spacing of 30cm x 60cm in three replications in two different seasons – early (01st and 06th May, 2006) and late (07th and 12th August, 2006) at Ekpoma and Obaynator, respectively.

Soil samples from the two experimental locations were taken from top soil surface (0–15cm) with soil augur prior to sowing and at weekly intervals in each replicate throughout the period of experimentation. Soil samples collected were oven–dried for 24 hour at 105^{o}c for moisture level determination (Igwilo, 1982) and values obtained in percentage transformed by arcsine (Gomez and Gomez, 1984)(Table 2). Observations of cowpea genotype's response to high moisture stress commenced from the fourth week after sowing (DAS) at weekly intervals. Evaluation was based on visual observation under field condition of the growing cowpea plants. IBPGR (1983) rating scale (1–9) for stress susceptibility level was adopted where 1–3 (tolerance); 4–6 (medium tolerance), and 7–9 (high susceptibility). All agronomic management was followed.

Data were collected on ten plants randomly selected from each plot. The following characteristics were evaluated for plant height, leaf area index (LAI), days to 50% flowering, 50% maturity, pods per plant, pod length, pod weight, seeds per pod and seed weight. Grain yield was obtained from the mid–rows in each plot. Pods were threshed and seeds oven–dried at 65^{o}c for 24 hours and all yield adjusted to 12% moisture content. Data were subjected to appropriate statistical analysis using SAS software model. Mean separation of individual genotype was carried out using student–Newman–Keuls Test at 0.05 alpha.

Table 1 Monthly precipitation for the test locations in 2006 cropping period

Co–ordinates	Ekpoma	Obayantor
(Site locations):	Lat. 6^{o} 08' E, Long. 6^{o} 42' N	Lat. 6^{o} 09' N, Long. 5^{o} 35' 27'' E
Attitude level:	460m	304.8m
Soil classification:	Sandy–loam	Clay and clay–loam
Precipitation (mm)		
March	96.9(6)*	78.7(8)
April	112.0(5)	149.0(9)
May	234.1(13)	290.8(17)
June	292.7(15)	170.4(10)
July	449.9(19)	358.0(20)
August	348.1(15)	279.2(17)
September	554.2(25)	368.2(24)
October	42.2(19)	268.7(15)

*Figures in parenthesis are the numbers of rainy day in each month.

3. Results and Discussion

Agrometeorological conditions differed between the two experiments with abundant precipitation at the test locations (Table 2). Rainfall fostered an environment of high moisture at all stages of crop development in the two sites.

Table 2. Angular transformed mean weekly soil moisture level in the experimental locations.

DAS*	Early Season		Late Season	
	Ekpoma	**Obayantor**	**Ekpoma**	**Obayantor**
07	21.22	24.20	18.21	23.11
14	25.18	18.00	19.28	24.40
21	17.46	18.44	11.39	14.89
28	19.91	21.56	17.16	25.84
35	23.58	22.87	19.09	29.13
42	20.27	24.04	20.79	23.19
49	12.39	20.00	19.19	24.73
56	15.50	18.72	18.24	27.97
63	21.89	22.30	22.38	24.50
70	27.90	27.40	24.12	25.99
77	23.73	24.73	23.34	24.50
84	23.42	27.97	18.53	24.04

*DAS = Days after sowing

Weekly moisture levels in Ekpoma and Obayantor ranged from 12.39–27.90 and 18.00–27.97 during the early season respectively. Late season moisture levels were 11.39–24.12 (Ekpoma) and 14.89–29.13 (Obaynator) locations. There was a substantial moisture as from 35 DAS in both locations when most of the plants commenced their reproductive (flowering) phase in the early season planted cowpeas and this appeared to have influenced the reproductive performance and consequently affected the final yield of the individual genotype in Obayantor due to the clayey nature of the soil in this environment which may have hindered proper soil drainage. However, for the late season planted crops, only Obayantor site experienced a relatively much higher moisture deficit during the flowering phase. Studies have shown that flower opening is very sensitive to moisture stress. Stress at this phase leads to severe drop of flowers and fruits and that pod set and filling phases are adversely affected (Sinha, 1977; Haqqani and Pandey, 1994). Thus, increased soil moisture may have significantly delayed flowering and maturity of all cowpea genotypes in this study. The delay in days to flowering was more apparent in *Gopolonare (–A)*(79.33) and *Gar–bl* (67.67); and *Gopolonare (–A)*(65.67) and *Gar–bl* (64.00) in both locations, respectively. However, some of the genotypes that attained flowering never progressed to maturity phase nor produce any pods. For instance, *ZM/A–5004B, ZM/A–5029A, Ibadan–40, Egyptian(–A), 67–3, Gopolonare(–A), GIN 89–171* and *ILCA–12666* due probably to the effect of increased moisture deficit on them in early sown cowpeas. In Ekpoma site, delayed maturity was observed in *Gar–w*(84.33), *ZM/A–500AD*(83.33) and *ILCA–12648* (78.67); and in *ILCA–12648*(81.67); *Ekp–br.* (80.67), *Gar–w*(78.67) and *Gar–bl*(75.00) in Obayantor site.

There was a significant response to increasing moisture level in the early season grown cowpeas for yield and its components (Table 3a). Pods per plant were the most severely affected yield component due to increasing moisture stress. There was substantial variation among the genotypes in response to high moisture stress. In Ekpoma and Obayantor sites, highest pods per plant was obtained in *ILCA–12666*(15.00) and 325(4.67) for the early season crops when compared to *ZM/A–5004D* (14.13) in Ekpoma and *Egyptian*(–A)(5.33) in Obayantor for the late season crops (Table 3b). Pandey *et al* (1984) and Muchow (1985) had reported that pod number, pod weight and seed weight were greatly affected by moisture stress which is in conformity with the results in this study.

For pod length character, five genotypes– *Ibadan–40*, (21.87cm), *Ekp–br.* (20.10cm), *V.U.1*(18.57cm), *ILCA–12646*(17.67CM) and *325*(16.80cm) exhibited relatively significant longer pods in Ekpoma in the early season sown cowpeas. Only *ILCA–12646* (17.57cm) had longer pod length in Obayantor. Similar trend was observed in the late season crops in *Ekp–br* (18.83cm), *ILCA–12643*(18.70cm), *ILCA–12646*(18.70cm), ILCA–*12647*(18.20cm) and *Gin 89–171*(17.37cm) genotypes in Ekpoma location (Table 3b). However, only two genotypes exhibited similar longer pod length in Obaynator location – *Ekp–br.*(18.29cm) and *ILCA–12646*(18.09cm). Significant variations in seeds per pod and seed weight existed among the genotypes sown during early season in both locations. For seed numbers per pod, *Ekp–br*(16.10), *ILCA–12646*(15.40) were observed while *ILCA–12643*(14.20G), *Ibadan–40*(13.37g), *325*(14.07g) were recorded for seed

Table 3a. Mean values for eight characters in twenty-even genotypes evaluated in Ekpoma and Obayantor early season

	EKPOMA								OBAYANTOR							
Genotype	Moist Tol.	50% Flowering	50% Maturity	Pods/ Plant	Pod Length	Seeds/ Pod	100–Seed wt	Grain Yield	Moist Tol.	50% Flowering	50% Maturity	Pods/ Plant	Pod Length	Seeds/ Pod	100–Seed wt	Grain Yield
2851–C	1.00	40.67	59.33	11.33	10.9	10.6	9.27	485.1	4.85	41	60.00	4.6	9.8	7.97	8.13	31.9
ZM/A–5004B	7.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	7.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Reauster	1.33	42.67	60.67	12	12.07	11.43	10.43	361.7	4.93	50.00	70.67	3.7	10.9	9.43	8.37	30.6
ZM/A–5029A	7.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	7.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Ibadan–40	4.63	52.67	71.00	5.87	21.87	9.70	13.37	49.1	6.67	50.00	0.00	0.00	0.00	0.00	0.00	0.00
Gar–w.*	6.17	60.00	84.33	4.07	16.43	10.43	10.53	24.3	6.43	63.33	78.87	3.77	15.87	12.03	9.17	33.6
Ekp.–br.*	1.67	47.67	68.00	8.20	20.10	16.10	10.43	250.4	2.83	50.00	80.67	2.93	16.44	15.10	8.57	60.4
Egyptian(–A)	4.17	46.00	63.00	10.33	9.60	9.33	10.27	89.2	6.67	46.33	0.00	0.00	0.00	0.00	0.00	0.00
ILCA–12643	3.50	46.33	64.33	7.67	16.17	10.40	14.20	132.1	5.17	49.33	23.67	4.37	4.77	2.77	3.30	10.5
67–3	6.60	44.67	70.33	7.57	14.13	10.30	9.90	9.60	7.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
ILCA–12646	1.80	46.67	6700	3.90	17.67	15.40	9.87	307.2	2.50	46.67	72.00	4.37	17.57	13.33	9.73	117.4
G–126	2.13	44.33	62.33	4.40	11.83	10.73	9.33	240.5	5.37	47.33	67.67	4.40	12.00	8.63	8.80	18.7
53–C–91–2	1.33	50.33	60.67	10.10	11.50	11.13	8.73	184.3	5.53	42.00	64.67	4.30	9.80	9.10	8.53	7.60
ILCA–12647	7.00	67.67	0.00	0.00	0.00	0.00	0.00	0.00	6.93	65.67	0.00	0.00	0.00	0.00	0.00	0.00
325	1.33	45.33	62.00	2.47	16..80	11.27	14.07	239.1	3.50	48.00	63.00	4.67	14.67	8.23	11.60	53.9
Gopolonare(–A)	7.00	79.33	0.00	0.00	0.00	0.00	0.00	0.00	7.00	65.67	0.00	0.00	0.00	0.00	0.00	0.00
Dan–Tamanin	1.00	42.33	60.00	3.13	16.43	15.00	8.53	268.3	3.70	48.00	63.00	1.87	14.97	11.77	7.87	82.3
ZM/A–5004D	5.00	64.33	83.33	8.65	15.03	9.77	13.07	63.70	6.33	20.33	25.33	0.67	5.07	3.33	3.30	3.70
53C	1.00	42.67	61.00	9.83	12.40	10.27	11.33	441.0	4.20	43.33	63.67	5.67	10.30	8.70	9.07	21.50
ILCA–12665	4.17	51.67	70.00	11.33	15.60	14.97	8.53	613.0	1.93	40.67	59.67	9.50	12.07	11.20	9.07	136.2
53–C–82	1.00	37.67	59.00	8.47	12.00	10.87	10.53	580.3	2.03	41.33	59.33	5.67	10.67	10.43	7.57	61.3
Gin 89–171	7.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	7.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
304	1.00	42.67	61.00	8.50	14.00	12.33	9.93	353.2	4.27	48.00	64.00	3.67	14.03	9.07	10.03	12.7
Gar.–bl.*	7.00	67.67	0.00	0.00	0.00	0.00	0.00	0.00	6.77	64.00	75.00	0.00	0.00	0.00	0.00	0.00
V.U.1	1.00	41.33	57.67	7.23	18.57	13.63	10.33	290.5	5.37	42.67	58.00	2.87	16.00	9.37	8.77	59.9
ILCA–12666	1.00	43.00	54.67	15.00	14.33	13.27	6.67	94.8	6.33	53.67	0.00	0.00	0.00	0.00	0.00	0.00
ILCA–12648	2.67	62.00	78.67	6.97	14.10	15.03	8.23	98.5	3.20	62.67	81.67	2.30	14.00	15.40	8.50	116.7
Mean	3.411	43.238	49.226	5.934	11.126	8.999	7.788	188.63	5.019	39.321	43.26	2.583	8.694	6.820	5.577	38.12
SE	1.11	12.13	9.38	8.15	0.57	1.03	3.53	0.03	0.76	48.60	144.05	1.25	5.58	3.75	3.09	0.01

*Local cultivars **Pods without seeds

Table 3b. Mean values for eight characters in twenty-even genotypes evaluated in Ekpoma and Obayantor late season

	EKPOMA								OBAYANTOR							
Genotype	Moist Tol.	50% Flowering	50% Maturity	Pods/ Plant	Pod Length	Seeds/ Pod	100– Seed wt	Grain Yield	Moist Tol.	50% Flowering	50% Maturity	Pods/ Plant	Pod Length	Seeds/ Pod	100– Seed wt	Grain Yield
2851–C	1.67	46.33	68.00	11.03	9.60	8.83	145.6	7.00	7.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
ZM/A–5004B	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Reauster	1.67	48.67	68.00	5.63	12.80	9.97	12.03	143.9	7.00	49.33	0.00	0.00	0.00	0.00	0.00	0.00
ZM/A–5029A	2.53	60.00	83.33	4.23	16.97	12.87	12.27	145.1	4.83	60.00	76.00	5.20	16.73	10.93	14.07	27.6
Ibadan–40	1.33	46.67	74.00	5.77	13.77	11.90	11.47	255.1	3.70	50.00	76.00	1.00	9.67	9.77	10.43	38.5
Gar–w.*	1.00	55.67	72.67	4.87	16.87	15.30	9.33	476.1	2.63	58.67	75.67	2.93	15.47	15.00	10.23	161.8
Ekp.–br.*	1.00	50.67	69.00	4.73	18.83	16.87	9.63	478.9	1.67	50.67	73.00	2.40	15.17	14.17	10.47	191.0
Egyptian(–A)	2.17	46.67	71.00	7.07	11.47	10.60	9.77	195.3	3.97	48.67	72.67	3.83	18.20	9.73	11.17	27.0
ILCA–12643	4.00	51.00	68.00	4.07	18.70	8.80	12.53	53.3	3.00	49.00	74.00	3.90	18.17	10.07	14.03	87.0
67–3	2.93	54.33	74.67	5.63	12.70	8.77	8.17	158.7	4.43	61.33	76.33	3.63	17.83	10.53	8.20	17.5
ILCA–12646	1.00	47.00	65.33	5.33	18.70	16.60	9.33	541.8	1.10	50.67	72.62	5.33	10.53	14.53	10.37	269.5
G–126	1.67	45.00	64.33	3.50	14.07	12.60	9.70	292.7	2.67	49.67	69.67	5.27	17.63	8.20	10.20	131.4
53–C–91–2	3.87	46.67	68.00	6.37	11.93	10.97	8.17	86.3	5.00	48.67	74.00	3.13	12.03	5.23	5.63	0.2
ILCA–12647	3.27	54.00	75.67	5.37	18.20	12.97	10.50	162.6	2.33	60.00	77.67	4.13	18.43	15.83	11.37	233.4
325	1.33	49.33	66.33	2.97	16.50	10.83	13.10	380.7	3.50	40.23	70.00	3.67	13.73	7.37	12.30	50.1
Gopolonare(–A)	1.00	51.67	69.00	3.87	14.10	15.90	8.23	402.7	2.50	50.67	69.33	2.67	10.43	14.9	8.63	190
Dan–Tamanin	1.33	45.00	64.00	3.30	16.87	15.27	8.03	340.8	3.03	46.67	72.33	2.53	18.33	7.97	7.90	103.6
ZM/A–5004D	2.50	52.33	74.00	14.13	15.07	10.97	12.73	238.3	3.50	49.33	76.33	3.07	14.67	8.00	12.33	64.8
53C	2.77	44.33	70.33	7.67	12.97	11.17	9.97	274.9	6.33	43.67	69.67	5.20	14.97	1.63	3.03	18.3
ILCA–12665	2.70	44.67	59.33	6.17	14.50	14.53	8.23	247.3	4.43	59.00	79.00	3.40	12.00	13.27	9.20	244.8
53–C–82	3.70	45.00	67.33	5.17	10.13	8.37	10.03	65.5	6.87	42.00	61.67	4.70	13.20	0.00	0.00	0.00**
Gin 89–171	2.27	54.67	69.33	3.90	17.37	12.63	9.33	173.9	2.93	64.00	77.00	1.40	10.17	12.73	9.13	83.8
304	5.33	46.67	68.00	2.10	5.00	4.10	3.10	67.0	6.83	44.00	60.00	1.97	14.83	0.00	0.00	0.00**
Gar.–bl.*	6.10	0.00	0.00	0.00	0.00	0.00	0.00	0.00	3.23	60.00	72.00	1.00	9.67	14.27	9.07	74.4
V.U.1	4.03	48.67	69.00	0.00	0.00	15.27	10.57	109.2	7.00	42.00	0.00	0.00	0.00	0.00	0.00	0.00
ILCA–12666	1.00	54.33	73.00	5.73	13.63	13.00	8.53	135.2	2.00	42.00	61.33	7.87	13.73	11.87	8.60	16.6
ILCA–12648	1.00	54.67	73.33	6.10	14.87	16.33	9.50	315.4	2.00	61.33	72.67	2.17	15.7	15.63	9.57	196.1
Mean	2.316	44.429	60.571	4.776	13.096	10.935	8.702	210.23	3.694	47.441	57.274	2.795	11.464	8.274	7.355	79.65
SE	2.07	5.14	59.14	3.18	3.33	2.49	1.73	0.01	1.39	11.97	8.97	1.73	0.66	2.70	2.95	0.02

*Local cultivars **Pods without seeds

weight in Ekpoma when compared to *ILCA–12648*(15.40) and *325*(11.60g) for early season crops in Obayantor location. *Ekp–br* and *ILCA–12646* only exhibited higher number of seeds per pod in response to high moisture stress in the late season. Pandey *et al* (1984a) and Muchow (1985) reported reduction in seed weight under increasing water deficit in mung bean. An observation revealed that seed per pod was seriously reduced generally in Obayantor when compared to what was obtained in Ekpoma. Similar investigation was reported in mung bean (Mohanty and Sharma, 1983; Pandey *et al*., 1984b).

In Tables 3a and 3b, grain yield performance in all genotypes evaluated for the character showed significant differences among each other in the two locations and seasons due to high moisture stress. Lower grain yield was recorded in Obayantor in comparison to Ekpoma in both seasons. In Ekpoma location, genotypes *ILCA–12665*(613 kg/ha), *53–C–82*(580.3kg/ha), *2851–C* (485.1kg/ha). *53C*(441kg/ha), *ILCA–12646*(307.2kg/ha) and *V.U.1* (290.5KG/ha) exhibited relatively higher grain yield in contrast to *ILCA–12665* (136.2kg/ha), *ILCA–12648*(116.7kg/ha), *DanTamanin*(82.3kg/ha) and *ILCA–12648*(116.7kg/ha) in Obayantor during the same period. However, appreciable high grain yields were obtained in Obayantor in late season crops though still lower than what was obtained in Ekpoma in the same period. High grain yield has been reported in late season sown cowpea (Remison, 2005). However, despite increased moisture level in the soil, early season crops yielded more than the late season crops. This could be attributed to over-saturation of the soil in the late season grown crops as most crop plants have their threshold under which they can perform effectively.

These results indicated that cowpeas grown under increasing moisture deficit experienced moisture stress at flowering and seed development phases and consequently yield performance. This study further revealed that some genotypes exhibited more tolerance to increasing high moisture stress irrespective of the season. Such genotypes could be selected and further developed for adaptation to high soil moisture in waterlogged-prone areas.

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