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Effects of water stress at different stages on growth, grain yield and seed quality of cowpea genotypes

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ABSTRACT: Effects of water stress applied at three morpho-physiological growth stages, on growth, grain yield and seed quality of contrasting genotypes of cowpea (*Vigna unguiculata* (L) Walp) were investigated in potted experiments during the 1998 and 1999 cropping seasons. Water stress was imposed by withholding watering for three weeks at the vegetative, flowering and pod-filling growth stages and rewatered thereafter. Water stress applied at the vegetative growth stage significantly reduced growth parameters such as leaf production, branching and plant height when compared with the control and other stress treatments. Water stress at this growth stage also significantly reduced number and weight of nodules per plant thereby suggesting a significant decrease in N-fixation. Water stress at any growth stage significantly reduced grain yield with greater effects with stress occurring at flowering and pod-filling stages. While plant nutrients contents (especially N) were significantly decreased by water stress, nutrients composition of the harvested seeds were not appreciably affected thereby indicating that the food quality of grain was not significantly affected. The results of this study have serious implications for delayed planting of short season cowpeas. It was therefore suggested that planting should be done not latter than 3rd week of August for the medium/long duration ($\geq$ 65 days) varieties and 1st week of September for short duration ($\leq$ 60 days) varieties to increase the chances for crop to escape drought conditions during flowering and pod-filling stages. Alternatively, drought-tolerant varieties should be grown. From the result of the present study, 1T89KD-374-57, TVX L25 and IT87D-41-1 are promising as drought tolerant varieties.

Key Words: Cowpea (*Vigna unguiculata*); Cowpea genotypes; Water stress; Drought tolerance.

Introduction

Cowpea is the most important grain legume in the semi-arid areas of sub-Saharan Africa, including Nigeria. It could be grown as a forage or dual purpose crop that provides high protein grain for human consumption and crop residues of high nutritive value for animal feed. The crop is also desirable in that it has little dependence upon chemical fertilizer (which is often unavailable to and or unaffordable for many small scale farmers in the region) for optimum yields if successfully nodulated with appropriate Rhizobium (Zablotowicz et al, 1981).

However, in Nigeria drought is a potential constrain to cowpea production in the savannah ecological zone which is the principal area of cultivation. Although cowpea is a relatively drought tolerant species as compared to other grain legumes (Wein *et al*, 1979), water stress has been shown to reduce grain yield (Summer field et al, 1976; Wien *et al*, 1979; Turk and Hall 1980a; 1980c; Trurk *et al*, 1980), nodulation and hence N-fixation (Doku, 1970; Kamara, 1976; Venkateswarlu *et al*, 1990; Afolabi, 1998; Aderolu, 2000).

Various studies have been reported elsewhere to show the effect of water stress on growth, grain yield and seed quality of cowpea varieties. It is apparent, however, that the sensitivity of cowpea growth to drought during different stages of growth has not been adequately established, especially at the savannah ecological zone which is the main production are in the country. Moreover, the previous studies elsewhere on the sensitivity of cowpea yield to water stress at different growth stage have produced conflicting results. While Hiler *et al*, (1972) reported that cowpea were more sensitive to water stress during the flowering stage, Summer field *et al*, (1976) later showed that cowpea were more sensitive to water at the vegetative stage of growth. Whereas, Wien *et al*, (1979) reported that a two-week drought during the vegetative and flowering stage had no significant effect on seed yield. It was therefore the objective of this study to investigate the effect of water stress at different growth stages on growth, grain yield and quality of different cowpea genotype.

Material and Methods

The study was conducted during dry periods of December 1997 to February 1998, and December 1998 to February 1999 in a screen at the University of Ilorin, Nigeria. Plants were grown in plastic pots (10 litre capacity) filled with sandy soil (Table 1).

The study was designed as 4x8 factorial experiment in split-pot arrangement with three replications. Eight cowpea varieties (Table 2) were subjected to water stress conditions by withholding watering for three weeks during each of the vegetative, flowering and pod-filling growth stages and re watered at the end of each stress period. The water stress treatment constitute the main plot, while the cowpea varieties were sub-plots.

Table 1: Physical and chemical Properties of the soil used for the experiments.

Soil Properties	
% Clay	5.60
% Slit	4.92
% Sand	89.48
pH (in water)	6.8
Organic matter	1.0
Nitrogen (%)	0.56
K+ (Mole/kg)	0.30
Na+ (Mole/kg)	0.10
Ca2+ (Mole/kg)	0.30
mg2+ (Mole/kg)	0.60
Available (mole/kg)	0.016
Total acidity	0.58

Table 2: Description of cowpea varieties used in the experiments

Variety	Description	
	Growth Habit	Seed Colour
Ife Brown	Semi erect	Brown
TVXL25	Semi erect	Muttled
IT84E-124	Semi erect	Brown
IT89KD-374-57	Semi erect	White
IT89D-041-1	Erect	Dark brown
IT90K-102-6	Semi erect	Light brown
IT89KD-256	Spreading	White
Local check (Bewehe)	Spreading	Whites

All necessary agronomic management practices were observed during the study. The soil used for the study was sandy with little available nutrients (Table 1) consequently a starter dose of fertilizers was applied at 30 N, 30 K_20, 80 P_2 0_5 in Kg ha $^{-1}$ using NPK (15-15-15) and single super phosphate at two weeks after (WAP) Weed control was achieved in pots by weekly hand rougueing. As soon as the first set of flowers were observed, all pots were sprayed with an insecticide solution using Karate at 3ml/litre of water in a knapsack sprayer. The spraying operation continued at weekly intervals until the pods were physiologically mature.

Two weeks after planting, two plants in each pot were tagged for proper identifications, and these plants were used for the measurement of number of leaves per plant, number of branches, plant height and flower production. Pods from the two tagged plants in each pot were harvested and dried. Thereafter the following data were recorded: total number of pods per plant, pod weight per plant, number of seeds per pod, seed weight per plant and shelling percentage. All data collected were subjected to analysis of variance using the split-plot mode. Significant means were separated using the Duncan's Multiple Range Test at 5 percent probability level.

Results and Discussion

Many aspects of plant growth are known to be affected by drought stress including leaf expansion which is reduced due to the sensitivity of cell to water stress (Hsiao, 1973). Results of this study show that water stress applied at the vegetative growth stage significantly reduced number of leaves per plant, branching and plant height (Fig. 1) compared to the control and water stress at flowering and pod-filling growth stages. These results are similar for all varieties investigated and hence no significant interactions. Water stress is known to reduce leaf production and promote senescence and abscission (Kamaras, 1980), resulting in decreased total leaf area per plant. While water stress at the flowering and pod-filling growth stages had no appreciable effects on leaf production, there was also no evidence in the present study no suggest that water stress at these growth stages resulted in increased leaf senescence. This was probably due to minimal change in plant water potential during stress (Turk *et al*, 1980; Turk and Hall, 1980a Wien *et al*, 1979b) indicating that cowpeas are excellent drought avoiding plants. This then shows that leaf production is more sensitive to water stress than leaf senescence in cowpea.

Reduction in leaf production and hence leaf area with stress at the vegetative stage might also be a drought avoiding mechanism. Shackel and Hall (1979) have shown that cowpeas avoid drought by reduction in leaf area, decrease in stomatal conductance and changes in leaflet orientation. Reduction in leaf growth in the present study was accompanied by reduced branching and decreased height (Figs 1b

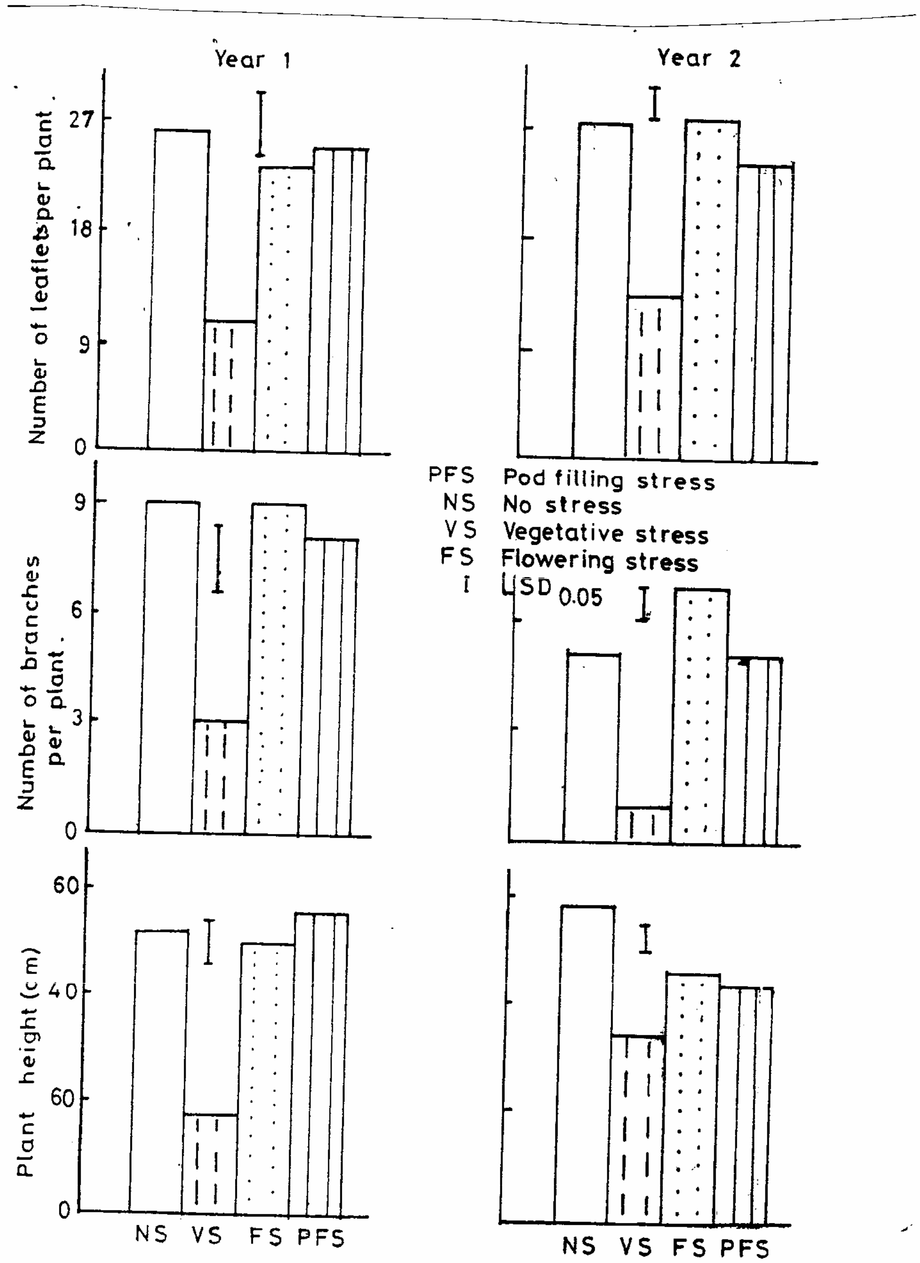

Fig. 1: Effect of water stress at different growth stages on leaf production, branching and plant height in cowpeas. (Data taken at full flowering).

and 1c) and hence reduced biomass production. This was in line with the results of Hiler *et al*, (1972). Afolabi; (1998) and Aderolu (2000), which showed decreases in shoot dry weight, leaf area index, number of leaflets, average leaf area and percent ground cover as a result of moderate to severe stress. Plant height, branching and size have also been shown to be substantially decreased by water stress (Summer field et al, 1976).

Water stress has been shown to cause severe inhibition of nitrogenous activity and nodulation in *Glycine max*; *Lupinus arbsreus; Trifolium repens* and a number of legumes (Engin and Sprent, 1973; Sprent, 1976; Albrecht et al, 1984). Results in Table 3 shows that water stress significantly reduced number and weight of nodules per plant. The reduction in nodulation observed may be due to nodule shedding (Sprent, 1981; Venkateswarlu *et al,* 1989, 1990) and this suggests decreased N-fixation. Even though cowpea is considered a drought tolerant legume, the N-fixation has however been shown to be sensitive to water stress as a result of reduced nodulation (Zablotowicz, et al, 1981). These authors demonstrated that in the drought regime, N-fixation was inhibited by combined interactions of drought on initiation, maintenance and integrity of nodule. The general response of N-fixation to water stress in cowpea groundnut (*Arachis hypogea*, L) had indicated that cowpea is more sensitive than groundnut at a comparable stress level (Venkateswarlu *et el,* 1989; 1990).

Table 3. Effect of water stress at different growth period in nodulation of cowpea in 1998 and 1999.

Water stress	1998		1999	
	No of nodules (no)	Nodule dry weight (mg)	No of nodules (no)	Nodule dry weight (mg)
No stress	14a	59.85 a	20.a	82.5 a
Vegetables stage	6.0 b	25.65 b	18 a	76.9 a
Flowering stage	13 a	55.58 a	18 a	76.9 a
Pod- Filling stage	14 a	58.75 a	19 a	101.9 a
SEED	1.73	10.05	2.6	14.48

Means followed by the same letter(s) in each column are not significantly different at 5 percent probability level by DMRT.

Results of plants tissue analysis showed that N concentration was significantly decreased by water stress, while P was increased and K was not significantly affected (Table 4). The result on N concentration was in line with the reports of other workers who have shown decreases in N concentration in soybean (*Glycine max*, L, *Pigeon pea* and *Cajanus cajan*, L) Derries *et al*, 1989) and maize (*Zea mays* , L) Wolf *et al*, 1988, Frederick *et al*, 1990). However, the result on P was in contrast with the reports of other workers who showed significant decreases in P concentration in stressed plants compared to the unstressed plants (Lawlow *et al*, 1981; Tanguilig *et al*, 1987; Abayomi, 1992).

Effects on Yield and Yield Components

Seed yield cowpea is determined by the product of three components viz-aviz the number of pods per plant that reach maturity, the average number of seed in each pod and mean dry weight of individual seed (Akyeampong, 1985). Of this yield components, the most important is the number of pods that reach maturity (Doku, 1970; Stewart *et al,* 1978).

Result of the present study show that water stress at any growth stage insignificantly decreased the number of pods per plant (Table 5). Nevertheless, linear regression of yield versus pod density at all water stress treatment has a r^2 of 0.91. The number of seed per pod on the other hand was significantly decreased by water stress at flowering and pod-filling stages and not significantly affected by a stress at the vegetative stage. There was also a positive relationship between grain yield and seeds per pod (r^2 =

0.77). These results are similar to those reported by Turk et al, (1980). The yield component most sensitive to water stress in the present study was the number of seeds per pods. It has earlier been observed that reduced number of seeds per pod may contribute to low yield in drought-stressed cowpea (Shouse *et al*, 1981; Kamara, 1976), although Turk *et al,* (1980) have reported that the component is of leser importance than pod density.

Table 4: Effects of water stress and variety on nutrient concentration in cowpea plant

Treatment	N Concentration	P Concentration	K Concentration
Water stress			
Unstressed	4.68a	0.21a	4.3a
Stressed	3.93b	0.24a	4.7a
SEED.	248	0.022	0.47
Variety			
Ife Brown	4.39ab	0.25a	4.58a
TVXL25	4.20ab		
IT84-124E	3.46b	0.14c	3.73a
IT89KD-374-57	4.85a	0.18b	4.92a
IT89D-041-1	4.25ab	0.3b	4.26a
IT90K-102-6	4.65a	0.24ab	5.30a
IT89KD-256	4.48a	0.25a	4.42a
Local check	4.20ab	0.21ab	4.84a
S.E.D.	0.497	0.032	0.946

All figures followed by the same alphabets in each column are not significantly different at 5 percent probability level.

It has been suggested that seed production which is positively correlated with leaf area (Rawson and Turner, 1982) may be reduced by leaf area reductions induced by drought stress. Results of the present study show that water stress at any growth stage significantly reduced grain yield with grater effects when the stress occurred at flowering and pod-filling stages (Table 6), even though only the vegetative stress had significant effects on leaf areas. The result are in consonance with those of Labaanauskas *et al,* (1981); Turk *et al,* (1980) who clearly showed that water stress during flowering and pod-filling stages of cowpea plants had a major effects on grain production. These high reduction in yield may be attributed to lower flower production (Fig 2) which may be due to flower abscission (Turk *et al,* 1980; Shouse *et al,* 1980). However, Summer filed et al (1976) and Wien et al (1979) had presented data disagreeing with this view.

Results of this show that water stress occurring during vegetative, flowering and pod-filling growth stages reduced grain yield by 35, 42 and 46 percent respectively . These result are similar to those reported by Shouse et al (1981) who showed that water stress imposed at flowering and pod-filling growth stages reduced grain yield by 44% and 39% respectively. Similar results have been presented by Kamara (1976) and Turk *et al* (1980). Drought stress at vegetative stage is usually considered not deternental to seed yield provided environmental conditions subsequent to the relief of drought are conductive to recovery (Babalola, 1980; Akyeampong, 1985) .Nevertheless, significant yield loses due to water stress at the vegetative stage had been reported. (Summerfield *et al*, 1976).

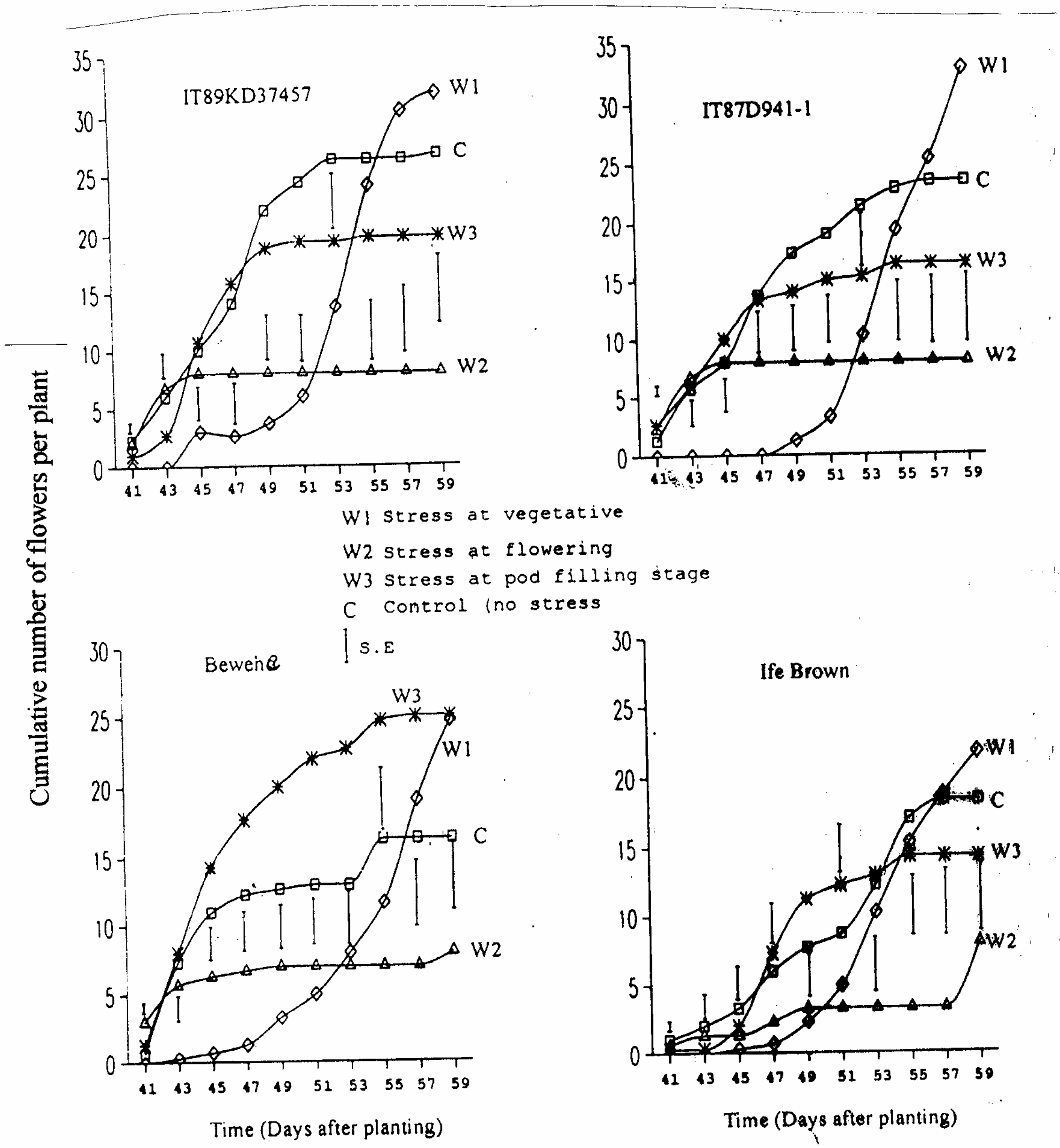

Fig. 2a Effects of water stress at different growth stages on flower production dynamics of cowpea varieties

Table 5. Effect of growth stages at water stress application and variety on yield components and grain yield per plant in 1998 and 1999.

Treatment	1998					1999				
	NP (no)	NSP (no)	TNG (no)	100SWT (g)	SP (%)	NP (no)	NSP (no)	TNG (no)	100SWT (g)	SP (%)
Water stress										
No stress	4.9a	5.4a	26.5a	15.3a	79.4a	6.0a	5.5a	34.0a	16.01a	77.3a
Vegetative Stress	3.8a	5.0ab	19.0b	14.2a	69.0a	5.0ab	5.0a	27.5ab	13.93a	70.6a
Flowering Stress	3.8a	4.2bc	16.0b	14.8a	66.9a	4.0b	4.8a	20.0b	15.28a	73.7a
Pod-filling Stress	3.9a	3.8c	14.8b	14.7a	67.2a	5.0ab	4.7a	25b	15.18a	79.7a
S.E.D.	0.50	0.55	2.80	2.01	5.69	0.65	0.64	3.30	2.112	5.19
Variety										
Ife Brown	4.39ab	5.9a	25.4ab	9.8e	66.7a	6.0ab	6.0a	39.5a	13.19c	78.0
TVXL25	4.0b	6.8a	27.2a	12.1de	78.0a	4.0c	6.9a	22.5bc	13.88b	74.5
IT84-124E	4.6b	4.1b	18.9bc	16.8bc	73.39	3.0c	4.5bc	13.5bc	17.11abc	71.6
IT89KD-374-57	3.3b	4.2b	13.99c	18.6ab	76.5a	4.5bc	4.0bc	19.0bc	17.54ab	74.0
IT90K-041-1	3.8b	4.1b	15.6c	17.3bc	76.7a	3.5c	3.6c	16.0bc	11.64c	62.8
IT90K-102-6	3.9b	4.3b	16.8c	14.5cd	63.3a	6.0ab	6.0a	37.5a	14.61bc	80.6
IT89KD-256	3.4b	3.7b	12.6c	21.6a	70.9a	5.5b	4.8abc	25.5b	20.84a	81.9
Local check	5.6a	3.7b	20.7bc	15.6bcd	63.5a	7.5a	5.3ab	38.5a	12.19c	79.2
S.E.D.	0.70	0.78	3.8	1.86	8.04	0.85	0.72	5.1	1.92	7.99

All figures followed by the same alphabets in each column are not significantly different at 5 percent probability level.
NP = Number of pode per plant, NSP = Number seed per pod, TNG = Total number of grains per plant,
100SWT = 100 seeds weight, SP = Smelling percentage.

Table 6: Effect of water stress at different growth stages on grain yields of contrasting genotypes.

	1998					1999				
	Water stress applied at					Water stress applied at				
	No Stress	Vegetative	Flowering	Pod-filling	x	No Stress	Vegetative	Flowering	Pod-filling	x
Ife Brown	3.48	4.01	1.19	1.22	2.48	7.86	7.11	2.23	6.08	5.81
TVXL25	4.26	3.90	2.25	2.70	3.28	2.96	2.98	3.47	2.35	2.94
IT84E-124	4.72	3.15	1.79	3.01	3.17	3.76	1.91	2.70	1.13	2.35
IT89KD-374-57	3.08	2.85	1.94	2.48	2.59	3.72	2.42	3.70	4.15	3.50
IT89D-041-1	3.68	2.21	2.11	2.79	2.70	4.07	2.29	1.31	3.20	2.72
IT90K-102-6	4.53	1.84	2.10	1.28	2.44	7.62	6.31	5.17	2.32	5.46
IT89KD-256	5.21	1.68	2.03	2.01	2.72	6.92	3.35	5.75	4.32	5.09
Bewehe (Local)	3.45	1.88	5.52	2.04	3.23	5.25	5.29	3.12	4.98	4.63
Mean	4.05	2.69	2.37	2.17	-	5.26	3.96	3.43	3.75	-

LSD(0.05) between

Water stress treatment :	0.7211	1.69
Varieties:	ns	3.407
ws x variety:	2.041	ns

Effects on grain quality

Reduced N-fixation resulting from reduced nodulation and decreased nitrogenous activity due to water stress suggest that water stressed cowpea may produce grains that are poor in protein contents. This then become a matter for serious concern since cowpea are important source of protein for human consumption in the sub-humid African including Nigeria. The results of grain analysis, however, show that most elements and particularly N were not significantly affected by water stress at any growth stage (Table 7). This was in line with the report of Labanauskas *et al* (2981) who showed that nutrients contents in water-stressed cowpeas seeds were not significantly affected due to the mobility of these elements which may be translocated to the seed from the maturing plant. It is therefore gratifying to note that even though drought may results in reduced grain yield, the food quality of seeds may not be affected.

Table 7: Effect of water stress at different growth stages in content of seeds at final harvest in 1999.

Water stress at	kg ha^{-1}					
	N	P	K	Ca	Mg	Na
No stress	131a	2.4a	24b	46a	10b	336
Vegetative stress	130a	2.1a	42ab	45a	16a	133ab
Flowering stress	138a	2.5a	37b	5ab	11b	140a
Pod-filling stress	124a	2.6a	52a	46a	10b	102b
S.E.D.	7.2	0.51	6.1	3.3	1.4	16.9

Means followed by the same letter(s) in a column are not significantly different at 5 percent probability level by DMRT.

In conclusion, it was apparent from the present study that drought stress during flowering and pod-filling stages may substainlly reduce grain yield in cowpea. These results have serious implication for planting late in short season cowpeas in the southern Guinea Savannah zone where farmers plant sometimes as late as mid-September, thereby suggesting that rainfall may cease at the period of flowering and /or pod-filling stages. This may results in yield losses in cases where the water available to the root is not substantial. In this case, it may be possible to maximise yield by choosing showing dates and varieties that decreases the probabilities of drought at flowering and pod-filling stages. It is therefore suggested that in this region, planting of short-season cowpea should be done not latter than 3rd week of August for medium/long duration varieties, ($\geq$ 65 days) and 1st week of September for short duration ($\leq$ 60 days) varieties, which could increase the chances for crop to escape drought condition during flowering and pod-filling stages. From the results of the present study, IT8KD-374-57, TVX L25 and IT87D-941-1 are promising as drought tolerant varieties.

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