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Effect of Post-flowering Water Stress on Dry Matter and Yield of Three Tropical Grain Legumes

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ABSTRACT

This study investigated the effect of imposed single and double water stress on the growth and yield of three grain legumes commonly grown in sub-Saharan Africa. Water stress significantly reduced growth of both cowpea and Bambara groundnut but not groundnut. In cowpea, it also reduced the number of seeds set but not the seed weight. For Bambara, single water stress significantly reduced the number of pods per plant but not the seed weight, although double water stress resulted in many immature pods of very low weight. Groundnut was the most tolerant of post-flowering water stress among the three legumes.

Key Words: Bambara groundnut; Cowpea; Drought tolerance; Groundnut; Harvest index

INTRODUCTION

Legumes are generally tolerant to drought but there are known differences between species and varieties (Lawn, 1982). For example Trung *et al.* (1985) found that both mungbean and adzuki bean maintained relatively high yield even under severe water stress whereas for groundnut and soybean yields were reduced. Kirda *et al.* (1989) found that water stress has detrimental effect on nitrogen fixation. Ofori and Djagbletey (1995) and Ofori (1996) found variation in yield components among cowpea and Bambara groundnut genotypes.

Water stress may be more severe at certain growth stages and if this is known, planting can be timed on the basis of weather forecast. Such knowledge could enhance agricultural decision in terms of what legumes to recommend for production by farmers. This is also important in determining the priority of water supply among legume species during the growing season.

This study compared the effect of post-flowering water stress on the growth and yield of cowpea, groundnut and Bambara groundnut.

MATERIALS AND METHODS

Cowpea (*IT-1627*) groundnut (*Kumawu Red*) and Bambara groundnut (*Jabajaba*) were grown in pots under rain-out shelters at Legon in January to April 2000, during the dry season. Table I shows the average temperature, sunshine hours and relative humidity during the study period. The soil used was taken from the 0-15 cm depth and was loamy sand. The soil belongs to Adenta series, a savanna Acrisol (FAO, 1990). After homogenising and passing through a 2 mm sieve, the average bulk density of the soil when packed was 1.40 Mg m^{-3}. All the varieties used were early maturing and non-spreading.

Four seeds of each legume were planted in 12 pots per replication, in a completely randomised design with three replications. At 12 days after planting (DAP) the seedlings were thinned out to two per pot. All pots were liberally watered until 40 DAP. From 41 DAP, four pots per replication for each species were allocated to each of three water treatments. The first was liberal watering until maturity; the second was with a seven-day dry cycle from 41 to 47 DAP; the third was with two dry cycles: from 41 to 47 DAP followed by resumed liberal watering and another dry cycle from 54 to 59 DAP. All pots were mulched with dry grass straw to reduce surface evaporation. The legumes were harvested at maturity and partitioned into vegetative matter, pods and seeds, which were dried for three days at 65°C. Significant differences specified were all at $p < 0.05$.

Table I. Climatic conditions at Legon during study period (January-April 2000)

Month	Temperature (°C)		Sunshine hours	Relative humidity (%)
	Minimum	Maximum		
January	22.4	28.7	7.6	53
February	22.5	30.0	8.4	48
March	23.0	30.7	8.5	49
April	22.8	31.0	8.3	51

RESULTS AND DISCUSSION

The experimental period was quite dry with no rainfall; average temperature was 26°C and relative humidity about 50% (Table I). Post-flowering water stress reduced the total dry matter accumulation in cowpea and Bambara groundnut (Table II) but the difference for cowpea under single and double water stress was not significant. For

Bambara groundnut, dry matter decreased by 30% with single water stress and by a further 20% with double water stress. For groundnut, there was no significant difference between the treatments. The total dry weight in cowpea and Bambara groundnut indicates that it continued to accumulate even after flowering.

The number of pods per pot for cowpea was not significantly affected by water treatments, presumably because pods were set before water stress (Table III). The number of seeds per pot showed a large variation, but apparently double stress had less effect than single. The average seed weight was not affected by water stress. The yield per pot was significantly reduced but more for single than double stress. As the average seed weight was not significantly different, it appears that water stress reduced the number of seeds per pod most probably through a reduction in pod filling. For Bambara groundnut, the number of pods per pot was significantly reduced by water stress, with no difference between single and double stress. Since most pods of Bambara groundnut contained one seed the number of seeds per pot followed the same trend. For the average seed weight, single stress had no significant effect, but double stress gave many immature seeds of very low weight. The decline in seed yield per pot with single stress can be attributed to fewer seeds per pot, but with double stress the drastic reduction in yield was due to poor development of seeds.

The reduction in seed number per pot in cowpea and Bambara groundnut was similar to that reported for soybean (Sepaskhah, 1977). He found that drought stress reduced pollen fertility, increased pod abortion and also reduced pod filling in soybean. Elia and Mwandemele (1986) also found that drought stress reduced flower formation and pollen fertility of Bambara groundnut. In their study, plants watered daily produced 19 pods per plant as opposed to 3 by plants watered at 12 day intervals.

In groundnut, water stress led to more pods and seeds and lower seed weight, but there was no significant difference between single and double stress. Nagesnera *et al.* (1988) reported that groundnut plants could compensate for an earlier pre-flowering drought period by initiating a flush of reproductive growth after the relief of the stress. When groundnut plants were subjected to transient soil moisture stress during vegetative phase followed by removal of stress, Nautiyah *et al.* (1999) also found an increase in pod yield.

The harvest index was unaffected by water treatment in cowpea but was slightly reduced in groundnut. For Bambara groundnut, harvest index was drastically reduced from 0.49 to 0.08 with double stress (Table II). Bambara groundnut appears to allocate a greater fraction of its total dry matter to roots irrespective of soil water status (Collison

Table II. Effect of water stress on the total dry matter and harvest index

Treatment	Cowpea	Bambara groundnut	Groundnut
		Total dry weight (g pot^{-1})	
No stress	15.9 ± 0.6	21.5 ± 1.1	20.7 ± 1.9
Single stress	10.8 ± 1.9	14.9 ± 0.9	24.8 ± 3.3
Double stress	11.3 ± 1.1	11.8 ± 1.2	20.9 ± 2.8
Lsd (5%)	3.2	5.6	NS
		Harvest index (%)	
No stress	0.54 ± 0.03	0.49 ± 0.06	0.46 ± 0.03
Single stress	0.57 ± 0.07	0.39 ± 0.08	0.41 ± 0.09
Double stress	0.51 ± 0.04	0.08 ± 0.03	0.31 ± 0.06
Lsd (5%)	0.04	0.24	0.08

NS: Not significant

Table III. Effect of water stress on pod and seed yield

Treatment	Pods pot^{-1}	Seeds pot^{-1}	Single seed weight (g)	Seed yield pot^{-1} (g)
		Cowpea		
No stress	6.7 ± 0.8	77.7 ± 8.9	0.12 ±0.02	8.7 ± 0.6
Single stress	6.1 ± 1.2	66.7 ± 8.7	0.10 ±0.01	6.4 ± 0.6
Double stress	7.3 ± 1.7	71.8 ± 9.3	0.10 ±0.02	6.7 ± 0.5
Lsd (5%)	NS	15.2	NS	1.8
		Bambara groundnut		
No stress	46.7 ± 1.3	47.3 ± 1.6	0.22 ±0.03	10.2 ± 0.4
Single stress	26.7 ± 2.4	27.7 ± 2.7	0.21 ±0.05	5.9 ± 1.0
Double stress	30.0 ± 2.3	30.0 ± 3.0	0.09 ±0.05	2.6 ± 0.6
Lsd (5%)	12.4	12.0	0.12	5.2
		Groundnut		
No stress	17.0 ± 1.7	34.0 ± 3.4	0.28 ±0.01	9.6 ±0.6
Single stress	22.0 ± 1.2	44.0 ± 2.3	0.21 ±0.02	9.1 ± 0.8
Double stress	21.0 ± 2.3	42.0 ± 4.2	0.19 ±0.04	7.9 ± 0.4
Lsd (5%)	3.1	6.1	0.05	NS

NS: Not significant.

et al., 1996). This may account for the low harvest index under double water stress.

Bambara groundnut performed better than cowpea and groundnut under poor fertility conditions (Haq, 1983) and produced some seeds after 100 days of drought compared to no seeds from groundnut (Babiker, 1989), but our findings indicate that groundnut was the most tolerant of post-flowering water stress. Thus, groundnut should recover from multiple drought conditions and still produce seeds as experienced in its large-scale cultivation in many semi-arid regions.

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