

Effects of Water Stress on Yield Components and Yield of Soyabean Genotypes

Mustapha, Yunusa.

Department of Agricultural Education,
Federal College of Education (Technical),
Gombe, Nigeria

Email: myunusan64@gmail.com

Salem, Abdullahi

Federal College of Horticulture,
Dadin Kowa, Gombe, Nigeria

Hayatuddeen, A. M.

Department of Agricultural Education,
Federal College of Education (Technical),
Gombe, Nigeria

Abstract – Pot experiment was conducted at the Department of Agronomy Crop Pavilion of the University of Ilorin, Ilorin (8° 29' N, 4° 35' E) to evaluate the effects of water stress on yield components and yield of soybean genotypes. Six soybean genotypes (TGX 536-02D, TGX 1830-2DE, TGX 1019-2EN, TGX 1740-2F, TGX 1485-1D and TGX 1817-12E) were subjected to water stress at three growth stages (vegetative, flowering, post-flowering, and stages) with a well-watered control. The experiment was designed as a factorial trial and laid out in split-plot arrangements. Morphological growth characters such as number of leaves, leaf area, branch and dry matter production were measured during growth while yield components and grain yield were measured at harvest. Results show that yield components such as number of flowers, total number of pods, percentage aborted flowers, harvest index, biomass and grain yields were significantly reduced by water stress occurring at both vegetative and flowering stages, while post-flowering stress has no appreciable effects thereby suggesting that water stress occurring at post-flowering stage is not critical to grain yield in soybean. Amongst the investigated genotypes TGX 1817-12E was the most tolerant while 1485-1D was the least tolerant genotype.

Keywords – Water Stress, Yield Components, Yield, Soybean, Genotype.

I. INTRODUCTION

Soybean (*Glycine max* (L) Merr) is the most important edible grain legume in the world due to its high nutritional value and high seed protein content of about (38-42%) [1].

The oil, which is 20% of the seed, is high in essential fatty acids and devoid of cholesterol and constitutes more than 50% of the world's edible vegetative oil in trade [2]. Increasing demand for edible oil and proteins in developing countries has led to the recent expansion of soybean cultivation in Nigeria. However, evidence available indicated that yield obtained on farmers' fields were very low [3]. Insufficient water, especially during emergence, flowering and pod-filling stages limits the yields of soybean [4], [5].

Drought is a serious problem in the semi-arid regions of West Africa and can occur at any time during a cropping season, vegetative, flowering and pod-filling stages. Of all the factors controlling crop productivity, limitation of moisture and nitrogen are by far the most serious and may lead to total crop failure [6]. It is well known that moisture stress reduces soybean yield [4], [7], [8] and that the effects of moisture stress on yield and yield components are influenced by the timing and severity of the stress [4], [5], [8], [9]. The timing, duration and severity of the

moisture stress determine the extent of yield loss on soybean varieties. The objective of this study is therefore to evaluate the effects of water stress on the yield components and yield of cowpea genotypes.

II. MATERIALS AND METHODS

The experiment was conducted at the Department of Agronomy Crop Pavilion of the University of Ilorin (8° 29'N, 4° 35' E) in the Southern Guinea Savanna ecological zone of Nigeria. Six soybean genotypes (TGX 536-02D, TGX 1830-2DE, TGX 1019-2EN, TGX 1740-2F, TGX 1485-ID and TGX 1817-12E) were subjected to water stress at three growth stages (vegetative, flowering and post-flowering stages) with a well watered control. The experiment was designed as a 4 x 6 factorial experiment laid out in split-plot arrangements with the genotypes constituting the main plots and water stress treatments as sub-plots. All treatments combinations were replicated four times.

Ten seeds of each of the soybean genotypes were planted in each pot later thinned to five seedlings per pot, two weeks after sowing. All the pots were watered every other day from planting until the commencement of the stress treatments two weeks after planting, when watering was stopped in treatment WSI (vegetative). Similarly, water stress WS2 and WS3 were applied at flowering and pod-filling stages respectively for two weeks after which watering was resumed.

Between 3 and 8 WAP, a labelled plant from each pot was used for the determination of non-destructive measurements such as number of leaves, branches, etc. As soon as the first sets of flowers were observed, flowering data consisting of counting of number of flowers that opened per day, and this continued until no new flowers were observed.

When all the pods were fully dried, the remaining two plants in each pot were uprooted and oven-dried, after which post-harvest data like weight of total biomass measured in (g), total number of pods were weighed and shelled to determine the shelling percentage. The percentage flowers and pods were also determined.

All data collected were subjected to analysis of variance (ANOVA) using the split-plot model. The analyses were done using GENSTATS. Duncan multiple range tests were used to separate significant means at 0.05 probability level. Simple linear correlation was done for post harvest data to determine and quantify the contributions of physiological and morphological growth characters to yield variations in soybean genotypes.

III. RESULTS

Effects of water stress on yield components and grain yield

Table 1: Anova table showing mean squares for harvest index (HI), shelling percentage (SP), percentage aborted flowers (PAF) and number of flowers (NF)

Source of variation	df	HI	SP (%)	PAP (%)	PAF (%)	NF
Genotype (G)	5	0.019256**	80.00ns	431.66ns	55.91ns	23885ns
Error (a)	15	0.003939	49.89	152.17	27.05	9887
Water stress (WS)	3	0.005827ns	189.38ns	95.76ns	234.47***	26143ns
G x WS	15	0.002314ns	55.52ns	105.71ns	100.72***	16280ns
Error (b)	54	0.002969	78.71	89.75	24.87	9966

** and *** denote effects significant at 1 and 0.1% probability level respectively
 ns denotes effect not significant.

Table 1 shows the mean squares from the analysis of variance for harvest index (HI), shelling percentage (SP), percentage aborted pods (PAP), percentage aborted flowers (PAF) and number of flowers (NF) per plant. The

results show that only HI was significantly affected by the genotype, while only PAF was affected by both stress and genotype x water stress.

Table 2: Main effects of genotype and water stress on yield parameters

Genotype	HI	SP %	PAP %	PAF %	NF
TGX 536-02D	0.09bcd	27.4ab	38.1a	38.8b	228.0a
TGX 1830-2DE	0.15a	28.4ab	23.7c	39.9b	138.0c
TGX 1019-2EN	0.11abc	25.2ab	30.8ab	41.1a	208.0abc
TGX 1740-2F	0.06d	25.7ab	34.9ab	42.6a	217.0a
TGX 1485-1D	0.14ab	29.7a	27.3b	38.3b	155.0bc
TGX 1817-12E	0.07cd	23.6b	32.8a	38.4b	155.0bc
S.E.D	0.02219	2.497	4.361	1.839	35.2
Water stress					
No stress	0.11a	27.9a	33.6a	43.1a	218.0a
Vegetative	0.11a	26.5ab	29.0a	38.2bc	148.0b
Flowering	0.08a	22.9b	32.0a	35.9c	165.08b
Post-flowering	0.11a	29.4a	30.4a	40.8ab	205.0ab
S.E.D	0.01573	2.561	2.735	1.440	28.8

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

Harvest index (HI) was significantly highest with TGX 1830-2DE and lowest with TGX 1740-2F. Water stress at any growth stage had no effect on HI (Table 2). The table also shows that shelling percentage was significantly higher in TGX 1485-1D than in TGX 1817-12E, while both of them were not significantly better nor worse than in the other genotypes respectively. Shelling percentage was highest with post-flowering stress and least with flowering stress, the flowering stress, the two values being significantly different but similar to values from the other stress treatment. Percentage aborted pod was significantly higher in TGX 536-02D than in TGX 1830-2DE and TGX 1485-1D, both of which showed significantly different values. Water stress at any growth stage had no significant effects on pod abortion. Percentage flower abortion was significantly higher in TGX 1019-2EN and TGX 1740-2F than in the other genotypes which had similar values. Flower abortion percentage was significantly reduced by the vegetative and pre-flowering water stress treatments.

Table 2 also shows that number of flowers per plant was highest with TGX 536-02D but was not significantly higher than in TGX 1019-2EN and TGX 1740-2F. TGX 1830-2DE showed the lowest number of flowers, which was, however not significantly lower than in TGX 1485-1D and TGX 1817-12E. Water stress at any period reduced the number of flowers per plant with significant differences with vegetative and flowering stresses.

Table 3 shows the mean squares from the analysis of variance for biomass yield, total number of pods per plant, number of filled and unfilled pods and grain yield. The results showed significant effects of genotype on biomass yield, total number of pods and unfilled pods and insignificant effects on filled pods, pods weight (filled) and grain yield. However, all these parameters including grain yield were significantly affected by water stress, while the genotype x water stress effects were not significant for any of the component and grain yield.

Table 3: Anova table showing mean squares for yield components and grain yield

Source of variance	df	Biomass yield	Total pod no.	Unfilled pods	Filled pods	Wt of filled pods	Grain yield (g/plant)
Genotype	5	633.5*	25214**	22316**	968.0ns	89.58ns	56.61ns
Error (a)	15	216.4	5722	4324	1869.0	76.23	32.88
Water stress							
(WS)	3	1029.6**	32414**	12837**	4848.0*	388.36**	124.14**
G x WS	15	244.0ns	9558ns	4396ns	1541ns	97.23ns	37.70ns
Error (b)	54	229.2	5908	2932	1275	70.81	25.19

* and ** denote effects significant at 5 and 1% probability level respectively, ns denotes effect not significant.

Table 4: Main effects of genotype and water stress of grain yield and yield components

Treatments	Biomass yield	Total no. of pods	Unfilled pods no.	Filled pods number	Wt of filled pods (g)	Grain yield g/plant
Genotype						
TGX 536-02D	36.5abc	181.6a	130.2a	51.4a	13.91ab	7.32ab
TGX 1830-2DE	28.1c	101.6b	47.2c	54.4a	14.9ab	8.6a
TGX 1019-2EN	41.0ab	173.8a	114.2ab	59.6a	16.3a	8.6a
TGX 1740-2F	44.9a	187.3a	133.4a	53.9a	12.5ab	5.4ab
TGX 1485-1D	32.3bc	109.1b	57.3c	51.7a	14.0ab	8.5a
TGX 1817-12E	31.7bc	117.6b	81.0bc	36.6a	9.4b	4.2b
S.E.D	5.20	26.74	23.25	15.29	3.087	2.027
Water stress						
No stress	43.4a	183.0a	117.2a	65.8a	18.0a	9.2a
Vegetative	30.4b	111.8b	69.3c	42.5bc	11.63bc	6.4ab
Flowering	30.2b	115.5b	79.4bc	36.1c	8.9c	4.2b
Post-flowering	38.9ab	170.3a	109.6ab	60.7ab	15.5ab	8.6a
S.E.D	4.37	22.19	15.63	10.31	2.429	1.449

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

Biomass yield was highest with TGX 1740-2F and the value was significantly better than in TGX 1830-2DE, TGX 1485-1D and TGX 1817-12E (Table 4). Biomass yield was lowest with TGX 1830-2DE, although the value was not significantly poorer than in all other genotypes except TGX 1019-2EN and TGX 1740-2F. Water stress at any period reduced biomass yield with significant differences at vegetative and flowering growth stages.

Table 4 also show that the total number of pods was highest with TGX 1740-2F, even though the value was similar with those of TGX 536-02D and TGX 1019-2EN, while TGX 1830-2DE showed the least number of pods which was not significantly lower than in TGX 1485-1D and TGX 1817-12E. Water stress at vegetative and pre-

flowering growth stages significantly reduced number of pods produced. The number of unfilled pods was highest with TGX 1740-2F, however, the value was not significantly higher than in TGX 536-02D and TGX 1019-2EN. The least number of unfilled pods was shown by TGX 1830-2DE and the value was similar to those of those of TGX 1485-1D and TGX 1817-12E. Water stress at any growth stage reduced number of unfilled pods with significant differences at vegetative and pre-flowering and stages. All genotypes produced similar number of filled pods, even though the value was highest and least with TGX 1019-2EN and TGX 1817-12E respectively. Water stress at both vegetative and pre-flowering stages significantly reduced number of filled pods.

Table 5: Interactive effects of genotype and water stress on grain yield

Genotype	No stress	Veg. stress	Flow. Stress	Post-flow. Stress	Genotype mean
TGX 536-02D	11.9abcd	6.2cdef (52.1)	3.6f (30.3)	7.7abc (64.7)	7.4pq
TGX 1830-2DE	11.5abc	4.3e (37.4)	7.1bcdef (62.6)	11.5abcd (100)	8.6p
TGX 1019-2EN	14.3ab	4.6ef (32.2)	3.5f (24.5)	12.2ab (85.3)	8.7p
TGX 1740-2F	7.8abc def	5.1cdef (65.4)	2.4f (30.8)	6.2cdef (79.5)	5.4pq
TGX 1485-1D	5.6cdef	14.6a (38.4)	5.2cdef (35.6)	8.5abcdef (58.2)	8.5p
TGX 1817-12E	4.1f	3.8f (92.7)	3.4f (82.9)	5.6cdef (136.6)	4.2q
Water stress	10.7x	4.93y (46.1)	4.2y (39.3)	8.6x (80.4)	

S.E.D- G x WS = 3.682

Figures followed by the same letter (s) in each column are not significantly different at 5 % probability by DMRT

Result on table 5 shows that water stress at the vegetative growth stage significantly reduced grain yield in TGX 1485-1D, TGX 1830-2DE and TGX 1019-2EN. Both vegetative and pre-flowering stresses significantly decreased grain yield in TGX 1019-2EN, while water stress at any growth stage had no appreciable effects on TGX 1740-2F and TGX 1817-12E.

Relationship between grain yield and yield components

Table 6: Simple linear correlation coefficient of yield components and grain yield

Vs	r
Biomass yield	0.520**
Total number of pods	0.600**
Number of unfilled pods	0.335**
Number of filled pods	0.818**
Weight of filled pods	0.947**
Number of flowers	0.582**
Harvest index	0.665**
Shelling percentage	0.209*
Percentage of aborted pods	-0.285**
Percentage of aborted flowers	0.114ns

*, ** denote r significant at 5 and 1% probability respectively. ns denotes r not significant.

Results of the simple linear correlation of grain yield with yield components showed that all yield components were significantly positively related with grain yield with the exception of percentage aborted pods, which showed a significant negative relationship with yield as shown in Table 6. Percentage aborted flowers also showed positive but insignificant relationship with grain yield.

DISCUSSION

Percentage aborted flower was increased by moisture stress while total number of pods and biomass yield were decreased by water stress occurring at vegetative and pre-flowering growth stages. All these resulted in soybean yield loss. This agreed with the finding of [10] who found that water stress cause large reduction in vegetative plant weight (20-50%) and yield (21-46%).

Contrary to the findings of [11] and [12] who found that stress during reproductive development leads to pods shedding and reduced seed size, it was stress at vegetative and reproductive growth stages that reduced number of pods produced in this study.

In general, water stress reduced grain yield in all genotypes especially when it occurred at vegetative and pre-flowering stages. It has been observed that in a stress soybean, the flower primordial will not develop properly nor will anthesis or fertilization be fully effective, seed yield is thus depleted by reduced seed number [13]. Also shortage of water at any stage throughout the vegetative and flowering phases can lead to reduction in final yield [14].

In conclusion therefore, vegetative and flowering growth stages are the critical stages of moisture requirement of soybean. Furthermore, water stress at any growth stage decreased plant growth parameters, yield

components and grain yield. The reductions in grains were most significant with both vegetative (53.9%) and pre-flowering (60.7%) stresses and less appreciable with post-flowering stress (19.6%), significant genotype X water stress interactions revealed differential genotypic responses to water stress showing that TGX 1817-2E and TGX 1485-1D were the most and least tolerant genotypes respectively.

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AUTHOR'S PROFILE



Yunusa Mustapha

was born in Tsaragi, Kwara State, Nigeria on the 15th December, 1966. He is presently a lecturer at Federal College of Education (Technical), Gombe. He has taught in Federal Government Colleges for more than a decade, part-time Lecturer at University of Ado-Ekiti, Nigeria. He is a researcher, supervising students at N.C.E and undergraduate levels. He has some publications to his credit among which are 1. Agricultural Science Practical Notes for Schools and Colleges: Oyo, Oyo State, AYOMS Nig. Enterprises, 2010 revised. 2. Effect of Climate Change on Agricultural Education in Nigeria: *Vunoklang Multi-Disciplinary Journal of Science and Technology Education*, 2011, pp: 22-26, ModibboAdama University, Yola, Nigeria 3. Improving Root and Tuber Crops Production to Enhance Food Security in Nigeria. Proceedings of the 26th Annual Conference of the Farm Management Association of Nigeria (FAMAN), Umudike, October, 2012. He is currently working on breaking of dormancy in date palm and locust bean, agronomical parameters in groundnut genotypes, fertilization in cowpea and soybean and organic farming.

Educational Background:

Institutions Attended From To	Cert. /degree	Obtained and Year
L. S. M. B. Tsaragi, Kwara state, Nigeria	1973-1978	Primary School Certificate-1978
Govt. Sec. School, Bacita, Kwara State, Nigeria.	1978-1983	G. C. E. /S.C (WAEC)-1983
Kwara State College of Technology, Ilorin, Kwara State, Nigeria	1983-1985	IJMB - 1985
Ahmadu Bello University, Zaria, Kaduna State, Nigeria	1986-1990	B. Agric. (Crop Science) – 1990
University of Nigeria, Nsukka, Nigeria	2000-2001	PGDTE- 2002
University of Ilorin, Ilorin, Kwara 2003, State, Nigeria.	2005	M.Sc. (Agronomy)- 2006
F.C.E.(T), GOFCECON-Computer Training, Gombe, Nigeria	2011	General Cert. Comp. June, 2011
Adv. Cert. in Microsoft-Excel-2012		

Mr. Mustapha is a member of the following professional associations:

- i. Teachers Registration Council of Nigeria (TRCN),
- ii. Soil Science Society of Nigeria (SSSN).
- lii .Farm Management Association of Nigeria (FAMAN),
- iv. International Union of Soil Science (IUSS),
- v. .Science Teachers Association of Nigeria (STAN).

Committee Membership:

- Member: Seminar/Journal Committee, F.C.E.(T.), Gombe; - Student Seminal Coordinator, F.C.E.(T.), Gombe
- Member: Student Project Committee, F.C.E.(T.), Gombe; -Editorial Secretary: Journal of Research in Vocational Education, F.C.E.(T.), Gombe;
- Member, Farm/Practical Committee, F.C.E.(T.), Gombe.

Email: myunusan64@gmail.com