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EFFECTS OF WATER STRESS ON THE PHYSIOLOGICAL GROWTH INDICES ON PERFORMANCE OF SOYBEAN GENOTYPES

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ABSTRACT

Pot experiment was conducted at the Department of Agronomy Crop Pavilion of the University of Ilorin, Ilorinto assess the effects of water stress at different growth stages on the physiological parameters 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 and post-flowering 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, branching and dry matter production were measured during growth which were used to determine physiological growth indices.Results show that crop growth rate (CGR), relative leaf growth rate (RLGR), net assimilation rate (NAR) and leaf area ratio measured at vegetative growth were significantly reduced by water stress occurring at the vegetative stage.Amongst the investigated genotypes TGX 536-02D was the most tolerant while 1485-1D was the least tolerant genotypes.

Key words: water stress; physiological indices; growth; soybean; genotypes.

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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].

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 [5]. Many aspects of plant are affected by drought stress [6] including leaf expansion which is reduced due to sensitivity of cell growth to water stress. Reduction in leaf area reduces crop growth and biomass production. Seed production, which is positively correlated with leaf area [7] may also be reduced by leaf area reduction induced by drought stress. Similarly, [8] had reported that the number of active leaves per plant, crop growth rate, relative growth rate and net assimilation rate increased in maize with adequate moisture and nitrogen fertilization. It is therefore the objective of this study to evaluate the effects of water stress on the physiological growth parameters of soybean genotypes.

MATERIALS AND METHODS

The experiment was conducted at the Department of Agronomy Crop Pavilion of the University of Ilorin (8^0 29'N,$4^0$35' E) in the Southern Guinea Savanna ecological zone of Nigeria during 2011 dry season. 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 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.

At 2, 4 and 6 weeks after planting (WAP) a plant was uprooted from each pot and for the measurement of leaf area and dry weight required for estimating physiological growth indices such as relative growth rate (RGR), crop growth rate (CGR), relative leaf growth rate (RLGR) and leaf area ratio (LAR). Between 3 and 8 WAP, a labeled plant from each pot was used for the determination of non-destructive measurements such as number of leaves, branches, etc.

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.

RESULTS

Effects on physiological growth indices

At Vegetative Growth Stage:

Table 1: Anova table showing mean squares from the analysis of variance for physiological growth indices at vegetative growth stage

Source of variation	df	RGR	CGR	RLGR	NAR	LAR
Genotype (G)	5	0.8435ns	0.0007625ns	0.0031685*	54.30ns	1394.5ns
Error (a)	15	0.8414	0.0009427	0.0007804	29.34	627.3
Water Stress (WS)	3	0..9660ns	0.0163980***	0.0022685**	491.52***	6379.2***
G x WS	15	0.8183ns	0.0015582***	0.0017365***	88.57***	1730.6***
Error (b)	54	0.8490	0.0004969	0.0004232	24.71	467.8

*, ** and *** denote effects significant at 5, 1 and 0.1% probability level respectively. ns denotes effect not significant.

Result of the analysis of variance for the physiological growth indices at vegetative growth stage are shown on Table 1. All growth indices were not significantly affected by the genotype with the exception of RLGR. Nevertheless, the effects of water stress and those of genotype X water stress were significant for most indices, except RGR.

Table 2: Interactive effects of genotype and water stress on vegetative growth indices

Genotype	Water stress	RGR	CGR	RLGR	NAR	LAR
TGX 536-02D	No stress	0.06a	0.0590cdefg	0.1163a	6.12fgh	71.9c
	Veg. stress	0.06a	0.0358efghij	0.0405efg	7.32efgh	100.3b
	Flowering	0.08a	0.0443efghij	0.0623c	7.45efgh	111.4a
	Post-flow.	0.08a	0.0310fghij	0.0380efgh	6.07fgh	131.0a
TGX 1830-2DE	No stress	0.11a	0.1005a	0.0135j	18.17bc	54.8d
	Veg. stress	0.04a	0.0130j	0.0225ij	2.50h	140.5a
	Flowering	0.06a	0.0195hij	0.0338fghi	3.97gh	145.6a
	Post-flow.	0.12a	0.0865abc	0.0635c	15.75bcd	80.7bc
TGX 1019-2EN	No stress	0.13a	0.0980ab	0.0315fghi	26.05a	52.2d
	Vegetative	0.05a	0.0103j	0.0310ghi	4.65gh	109.3a
	Flowering	0.06a	0.0260ghij	0.0325fghi	8.25efgh	77.3c
	Post-flow.	0.32a	0.0385efghij	0.0583cd	7.33efgh	101.0b
TGX 1740-2F	No stress	0.1a	0.0618cdef	0.0625c	11.97cdef	80.4b
	Vegetative	0.07a	0.0280fghij	0.0595cd	7.57efgh	87.7b
	Flowering	0.09a	0.0505defghi	0.0493de	9.80defgh	86.6b
	Post-flow.	0.08a	0.0650bcde	0.0477de	10.40defgh	80.6b
TGX 1485-1D	No stress	0.08a	0.0523cdefgh	0.0275hi	9.90defg	96.3b
	Vegetative	0.05a	0.0255ghij	0.0278hi	5.95fgh	90.3b
	Flowering	0.04a	0.0315efghij	0.0333fghi	5.07fgh	89.0b
	Post-flow.	0.1a	0.0818abcd	0.0490de	13.73bcde	81.1b
TGX 1817-12E	No stress	0.12a	0.1010a	0.0693c	19.27ab	63.2cd
	Vegetative	0.04a	0.0165ij	0.0433ef	3.87gh	108.2ab
	Flowering	0.06a	0.0413efghij	0.0408efg	6.85efgh	105.2ab
	Post-flow.	0.13a	0.0822abcd	0.0933b	16.25bcd	86.4b
S.E.D		0.6508	0.01744	0.01601	3.596	15.93
Same genotype		0.6515	0.01576	0.01455	3.515	15.29

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

Across the water treatments, the values of RGR and CGR were similar for all genotypes (Table 2).However, RGR was significantly lowest with TGX 1830-2DE and TGX 1485-1D, while net assimilation ration (NAR) was significantly lower in TGX 536-02D than in TGX 1817-12E; LAR was significantly higher in TGX 536-02D and TGX 1830-2DE than in TGX 1019-2EN and TGX 1740-2F. The values of RGR were similar for all water stress treatments while CGR values was significantly highest with no stress (control) and least with the vegetative water stress. RLGR were significantly reduced by water stress at both the vegetative and pre-flowering growth stages, while LAR was significantly highest with the vegetative and flowering water stress treatments, and least with no stress (control).

The significant genotype x water stress interaction effects for CGR show that water stress at any period had no effects on CGR in TGX 536-02D, while both vegetative and flowering stresses significantly decreased CGR in TGX 1830-2DE and TGX 1817-12E. Water stress at any period significantly decreased CGR in TGX 1019-2EN, while only stress at the vegetative growth stage significantly decreased CGR in TGX 1740-2F. A similar interactive effects on RLGR show that water stress at any period significantly reduced RLGR in TGX 536-02D, while both the flowering and post-flowering stress significantly increased RLGR in TGX 1830-2DE. Both the vegetative and pre-flowering stress had no effects on RLGR, while post-flowering stress significantly increased RLGR in TGX 1019-2EN and TGX 1485-2D whereas both the pre- and post-flowering stresses significantly decreased RLGR in TGX 1740-2F. However, in TGX 1817-12E, both vegetative and flowering stresses significantly decreased RLGR while post-flowering stress significantly increased the parameters. Water stress at any period had no significant effects on net assimilation rate (NAR) in TGX 536-02D and TGX 1740-2F while both vegetative and pre-flowering stresses significantly decreased NAR in TGX 1830-2DE and TGX 1817-12E. However, water stress at any period significantly decreased NAR in TGX 1019-2EN, while post- flowering stress significantly increased NAR in TGX 1485-1D.

Table 2 also shows that water stress at any growth significantly increased leaf area ratio (LAR) in TGX 536-02D, while only vegetative and flowering stresses significantly increased LAR in TGX 1830-2DE and TGX 1817-12E. All water stress treatments increased LAR in TGX 1019-2EN with significant differences at vegetative and post-flowering growth stages. However, water stress at any growth stage had no appreciable effects on LAR in TGX 1740-2F and TGX 1485-1D.

At The Reproductive Growth Stage

Table 3: Anova table showing mean squares from the analysis of variance for physiological growth indices at the reproductive growth stage

Source of variance	df	RGR	CGR	NAR	RLGR	LAR
Genotype	5	0.0009601ns	0.004552ns	6.04ns	0.00076061ns	1390.5**
Error (a)	15	0.0006195	0.002578	14.98	0.0003506	262.0
Water stress (WS)	3	0.0144209***	0.0165879***	423.28***	0.0284961***	4194.3***
G x WS	15	0.0010156ns	0.000548ns	11.69ns	0.0015215***	749.8***
Error (b)	54	0.0005747	0.001960	10.53	0.0004847	243.7

*, ** and *** denote effects significant at 5, 1 and 0.1 % probability level respectively. ns denotes effect not significant.

Results of the analysis of variance for the physiological growth indices of reproductive stage (Table 3) show that all growth indices were not significantly affected by the genotype except LAR. Similarly, interaction effects were not significant for most indices with the exception of RLGR and LAR. Nevertheless all indices were significantly affected by water stress.

Table 4: Mean effects of genotype and water stress on reproductive growth indices.

Treatments	Reproductive Growth Indices				
Genotypes	**RGR**	**CGR**	**RLGR**	**NAR**	**LAR**
TGX 536-02D	0.007a	0.12a	0.06b	7.48a	89.5a
TGX 1830-2DE	0.06ab	0.1ab	0.08a	7.09a	96.5a
TGX 1019-2EN	0.05b	0.08b	0.06b	6.73a	78.5a
TGX 1740-2F	0.06ab	0.11ab	0.06b	7.91a	72.7c
TGX 1485-1D	0.06ab	0.11ab	0.06b	8.19a	74.5c
TGX 1817-12E	0.06ab	0.12a	0.06b	8.24a	78.2bc
S.E.D	0.00880	0.01795	0.00662	1.348	5.72
Water stress					
No stress	0.07a	0.17a	0.1a	10.94a	67.0c
Vegetative	0.04b	0.03b	0.04c	4.08b	96.9a
Flowering	0.03b	0.04b	0.03c	3.97b	87.6b
Post-flowering	0.08a	0.18a	0.09b	11.53a	75.1c
S.E.D	0.00692	0.01278	0.00636	0.937	4.51

Figures followed by the same letter (s) in a column are not significantly different at 5 per cent probability by DMRT.

Relative growth rate (RGR) was significantly higher in TGX 530-2D than in TGX 1019-2EN, while other genotypes showed similar RGR values (Table 4). Both vegetative and flowering stresses insignificantly increased RGR. CGR was significantly higher in TGX 536-02D, TGX 1817-2E than in TGX 1019-2EN while both vegetative and flowering stress treatments significantly reduced CGR. RLGR was significantly higher in TGX 1830-2DE than in all other genotypes, while water stress at any growth stage significantly reduced RLGR. NAR values were similar for all genotypes, while both vegetative and flowering water stress treatments reduced NAR with significant differences. LAR was significantly highest in TGX 1830-2DE and lowest in TGX 1740-2F and TGX 1485-1D. Water stress at any growth stage increased LAR and with significant differences at vegetative and flowering stages.

DISCUSSION AND CONCLUSION

Results of this study show physiological growth indices such as crop growth rate (CGR), relative leaf growth rate (RLGR), net assimilation rate (NAR) and leaf area ratio (LAR) measured at the vegetative growth were significantly reduced by water stress occurring at the vegetative stage. Since moisture stress reduced leaf area definitely CGR will also be reduced [9]. It also follows that since CGR was reduced by moisture stress, soybean yield will be reduced [10]. Watson (1952) has attributed variations in CGR to variation in LA and/or NAR resulting from water deficit conditions. This is in agreement with the findings ofAbayomi and Adedoyin (2004) and Cooper (1979) who reported significant correlation between number of grains at harvest and CGR.

Conclusively, water stress affects all physiological indices at both vegetative and reproductive growth stages in soybeans especially CGR, RGR, NAR and LAR. Amongst the investigated genotypes TGX 536-02D was the most tolerant while 1485-1D was the least tolerant genotypes.

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