Agricultural and Biological Sciences Journal
Vol. 7, No. 3, 2021, pp. 78-82
http://www.aiscience.org/journal/absj
ISSN: 2381-7178 (Print); ISSN: 2381-7186 (Online)

Effects of Soil Water Deficit on Growth and Yield of Some Soybean Genotypes (*Glycine max* (L) Merrill) in Makurdi, Nigeria

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Abstract

A screen house experiment was conducted at the Teaching and Research Farm of the Federal University of Agriculture, Makurdi, Benue state during the 2019 cropping season to investigate the effects of soil water deficit on the growth and yield of soybean genotypes in Makurdi. The experiment was made up of three soybean genotypes (TGX-1448-2E, TGX-1835-10E and TGX-1951-3F) which were subjected to water deficit at three different growth stages which included early vegetative, 50% flowering and early pod filling with a well-watered treatment to serve as control. The experiment was conducted in a Completely Randomized Design (CRD) with three replications. Vegetative attributes evaluated were number of leaves per plant, number of branches per plant, plant height, and dry matter production at 3, 5 and 7 weeks after sowing (WAS). Yield parameters evaluated were number of pods per plant, number of aborted pods per plant, number of seeds per pod, number of seeds per plant and 100-seed weight. Analysis of variance (ANOVA) revealed significant ($p \leq 0.05$) effect of water deficit on all vegetative and yield attributes. Water deficit at early vegetative ontogeny significantly ($p \leq 0.05$) reduced number of leaves per plant, number of branches per plant, plant height and plant dry matter at 3, 5 and 6 WAS. TGX-1835-10E produced significantly highest number of leaves per plant, number of branches per plant and plant dry matter compared to the other two genotypes. TGX-1448-2E however produced significantly tallest plants among the three genotypes. Water deficit at early pod filling stage significantly reduced the number of pods per plant, number of aborted pods per plant, number of seeds per pod, number of seeds per plant and 100-seed weight. TGX-1835-10E tolerated water deficit more than TGX-1448-2E and TGX-1951-3F in all yield attributes except in 100-seed weight in which TGX-1448-2E was superior.

Keywords

Deficit, Genotype, Ontogeny, Stress, Yield

Received: June 24, 2021 / Accepted: August 3, 2021 / Published online: August 30, 2021

1. Introduction

Soybean (*Glycine max* (L) Merrill) is a herbaceous annual legume of the pea family that grows in tropical, subtropical and temperate climates. It belongs to the large botanical family *Fabaceae* and sub-family *Papilionideae* [17]. It is native to the eastern half of North China where it has been traced to be first domesticated [10]. It is one of the most important leguminous crops in the world known by different names in different countries of the world, such as Chinese pea, Chariabean, Cinderalla crop, soybean or soyabean). Soybean in global rating is among the top ten of the most widely grown crops with a total grain production of over 348,712,311 metric tonnes [9]. Brazil is the largest producer, accounting for 36% of world production [9]. The total area of soybean cultivation in Africa is about 1.3 million hectares with the three major soybean producers as South Africa with 1.6 million tons followed by Nigeria, Zambia, Zimbabwe, Uganda and Egypt

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[18]. Soybean is one of the most important leguminous crops grown in the cropping systems of most tropical countries. The crop thrives well in most of the agro-ecological zones of Nigeria and is gaining fast acceptability among famers because of its nutritive value as weaning food for infants and cheap source of protein for the privileged and the less privileged people.

Atli [4] reported that soybean seeds contain 36-56% protein by weight, 32% carbohydrates, 18% fats, 5% minerals, 3% fiber and other trace substances. The beans also contains significant amounts of phytic acid, alpha-linolenic acid and isoflavones, It also serves as a raw material for industries for the production of edible 'vegetable oil' which is used in a wide variety of processed foods. The remaining soybean meal is used mainly as a constituent of animal feed.

Despite the enormous economic and nutritional importance of soybean, most soybean farmers in Nigeria are dependent on rain fed cropping system as such its productivity is repressed by environmental (abiotic) stress factors. Water deficit (drought) stands out as one of the major abiotic stresses which adversely affect soybean growth and yield [14]. This phenomenon can occur at any stage in the life cycle of the crop. It is therefore imperative to find out the stage(s) in the ontogeny of the crop in which the occurrence of water deficit mostly affect growth and yield in the three genotypes.

2. Materials and Methods

Three soybean genotypes consisting of TGX-1448-2E, TGX-1835-10E and TGX-1951-3F were obtained from the seed Center of the Federal University of Agriculture Makurdi during the 2019 cropping season. These genotypes were selected based on their promising agronomic attributes and prevalent cultivation in the soybean producing areas of the Guinea Savanna region. Each genotype was subjected to water deficit at early vegetative stage (T_1) 2WAS, 50% flowering stage (T_2), early pod filling stage (T_3) and the control (T_o) treatment which consisted of a well-watered pot of each genotype. The experiment was carried out in the screen house at the Teaching and Research Farm of the Federal University of Agriculture Makurdi located at Latitude 07°41'N, Longitude 08°37'E in the Southern Guinea Savanna agro-ecological zone of Nigeria. The treatments were arranged in a Completely Randomized Design (CRD) replicated three times.

The plant growth medium consisted of 12 Kg of top sterilized soil each of which was weighed into the 36 perforated plastic pots of 15 liters capacity. Ten seeds each of the soybean genotypes were planted in each pot. N-P-K fertilizer was incorporated in the soil in each pot before planting at the rate equivalent to 20-40-20 kg/ha [8].

All the pots were adequately watered to field capacity consistently in the evening until commencement of water stress treatment two weeks after sowing when watering was stopped except for the control. Thinning to reduce the seedling population to six plants per pot was done at two weeks after sowing (WAS). At 3, 5 and 7 WAS, a plant was uprooted from each pot for the measurement of dry matter production. Between 3 and 7 WAS, a labeled plant from each pot was used for the determination of non-destructive measurements of number of leaves, number of branches and plant height. The number of leaves and branches were determined by physically counting the number of leaves and branches on the labeled plant for each pot while the plant height was measured using a tape rule from the base to the tip of the plant. Number of pods per plant, number of aborted pods per plant, number of seeds per pod, number of seeds per plant and 100 seed weight were also determined. All data collected were subjected to Analysis of Variance (ANOVA) using Genstat 10.3DE. Fischer's Least Significant Difference (FLSD) was used to separate significant means at 5% probability level.

3. Results and Discussion

3.1. Effects of Water Stress on Vegetative Parameters

Result from Analysis of Variance for vegetative attributes is presented in Table 1. The result showed that, number of leaves was highest in the well-watered control and lowest when water stress was subjected at early vegetative growth stage. At 5 WAS, water stress at pod filling stage recorded the highest number of leaves (25.15) followed by the control (24.78) with water stress at early vegetative stage recording significantly ($p \leq 0.05$) the least number of leaves (19.24). The highest number of leaves at 7 WAS was recorded in the control (58.35) followed by early pod filling stage (57.33) and the lowest in early vegetative stage (43.88). The lowest number of branches per plant at 3, 5 and 7 WAS were recorded in early vegetative stage and the highest in early pod filling stage and control. The tallest plants at 3 WAS were found when water stress was imposed at early pod filling stage (24.78) and the shortest plants were recorded when water stress was applied at the early vegetative stage (19.51). A similar trend was observed for plant height at 5 and 7 WAS. Dry matter production at 3, 5 and 7 WAS on the other hand was highest in the control and lowest in the early vegetative stage. The highly significant effect of water stress on vegetative growth parameters of soybean especially at early vegetative stage is an indication that water is very essential during the crop vegetative ontogeny. This is evident in the reduced plant height, number of leaves, number of branches per plant and dry matter production. This observation is in line with the report from

[15], who reported shortening of the internode leading to reduced plant height, number of leaves and number of branches when water stress was imposed during the vegetative growth stage. This finding is also in agreement with that of [13] who reported that, plant height and other vegetative growth attributes in cowpea were substantially reduced by water stress during early vegetative growth stage. Similarly, reduction in plant height in response to soil water deficit has been reported for wheat [6, 1], barley [7] grain sorghum [5] and cowpea [2].

Table 1. Mean Effect of Water Stress at Different Growth Stages on Vegetative Traits of Soybean in Makurdi, 2019.

Water Stress	L./PLT 3 WAS	L./PLT 5 WAS	L./PLT 7 WAS	NOB/PLT 5 WAS	NOB/PLT 7 WAS	PLT HT 3 WAS	PLT HT 5 WAS	PLT HT 7 WAS	DMP 3 WAS	DMP 5 WAS	DMP 7WAS
Control (T_0)	12.98	24.78	58.35	2.02	6.31	24.65	52.60	115.51	0.47	2.29	6.37
Vegetative stage (T_1)	9.33	19.24	43.88	0.58	4.22	19.51	38.95	90.02	0.34	1.30	4.06
50 % flowering Stage (T_2)	12.72	24.66	48.88	2.08	5.61	24.62	53.23	109.31	0.47	2.18	4.52
Pod filling stage (T_3)	12.93	25.15	57.33	2.04	6.36	24.78	53.33	107.89	0.46	2.19	5.80
LSD (0.05)	0.94	1.96	3.76	0.38	0.49	0.94	1.96	3.76	0.02	0.17	0.47

KEY
WAS = weeks after sowing T_0= well-watered control
L/PLT = leaves per plant T_1= water stress at early vegetative stage
NOB/PLT = number of branches per plant T_2 = water stress at 50% flowering stage
PLT HT = plant height T_3= water stress at early pod filling stage
DMP = dry matter production

Water stress and genotype interaction effect on number of leaves per plant at 7 WAS was significantly highest in TGX-1835-10E followed by TGX-1951-3F and least in TGX-1448-2E. At 5 WAS. TGX-1835-10E recorded the highest number of branches per plant across the water stress treatments which were significantly different from those of TGX-1448-2E and TGX I951-3F (Table 2).

Table 2. Mean effect of Genotype on Vegetative Traits of Soybean in Makurdi, 2019.

Genotype	L/PLT 3WAS	L/PLT 5WAS	L/PLT 7WAS	NOB/PLT 5WAS	NOB/PLT 7WAS	PLT HT 3WAS (cm)	PLT HT 5WAS (cm)	PLT HT 7WAS (cm)	DMP 3WAS (g)	DMP 5WAS (g)	DMP 7WAS (g)
TGX 1448-2E	11.97	20.33	46.59	1.37	5.46	24.87	53.74	106.48	0.44	2.05	4.81
TGX 1835-10E	12.40	25.64	55.09	2.64	6.04	23.86	43.31	97.45	0.43	2.07	5.83
TGX 1951-3F	12.70	24.61	54.64	1.43	5.79	21.25	47.70	96.57	0.44	1.85	4.04
LSD (0.05)	NS	1.24	2.57	0.33	0.21	0.82	1.70	3.26	NS	0.15	0.41

KEY:
L/PLT =Leaves per plant
WAS = Weeks after sowing
NOB/PLT = Number of branches per plant
PLT HT = Plant height
DMP = Dry matter production

3.2. Effect of Water Stress on Yield Parameters

Table 3 indicated that number of pods per plant was significantly ($p \leq 0.05$) highest in the control (37.00) and lowest in 50% flowering stage (21.78). The least number of pods per plant recorded when water stress occurred at 50 % flowering stage was as a result of the massive floral abortion as a result of soil water deficit resulting to the production of fewer number of pods per plant. This is similar to what was reported by [12] that water stress during the bloom stage in soybean resulted in floral abortion leading to the production of less number of pods.

The control treatment recorded significantly ($p \leq 0.05$) lowest number of pod abortions (2.83) and the highest values in pod filling (15.94). Number of seeds per pod and number of seeds per plant were highest in the control (2.51) and (66.67) followed by the vegetative stage (2.43) and (57.56) respectively and lowest in early pod filling stage (1.83) and (22.67) respectively. 100 seed weight was highest in early vegetative growth stage (38.28) followed by control (38.08) and the least, early pod filling stage (24.05).

This result clearly indicated that, water stress at early pod filling stage significantly ($p \leq 0.05$) reduced seed yield. This is as a result of the high water demands by soybean plants during reproductive development especially at seed filling stages. This agrees with previous reports by [3] and [11] that pod number and seed yield were significantly reduced when soil water deficit occurred at pod filling stages compared to other stages of growth and development.

Table 3. Mean Effect of Water stress at Different Growth Stages on Yield Traits of Soybean in Makurdi, 2019.

Water Stress	NO OF PODS/PLT	NO OF ABORTED PODS/PLT	NO OF SEEDS/POD	NO OF SEEDS/PLT	100 SEED WGHT (g)
Control (T_0)	37.00	2.83	2.51	66.67	38.08
Vegetative stage (T_1)	28.00	9.61	2.43	57.56	38.28
50 % Flowering stage (t_2)	21.78	8.75	2.39	46.78	37.34
Pod filling stage (T_3)	35.41	15.94	1.83	22.67	24.05
LSD (0.05)	1.98	4.90	0.12	4.05	2.88

KEY
NO OF PODS/PLT = Number of pods per plant
NO OF ABORTED PODS/PLT = Number of aborted pods per plant
NO OF SEEDS/PLT = Number of seeds per plant
100 SEED WGHT = One hundred seed weight
T_o= well-watered control
T_1 = water stress at vegetative stage
T_2 = water stress at 50% flowering stage
T_3= water stress at early pod filling stage

Water stress and genotype interaction effect on TGX-1835-10E was significantly lowest for number of aborted pods per plant and number of seeds per plant compared to TGX-1448-2E and TGX-1951-3F. TGX-1448-2E produced significantly highest 100 seed weight in all the water stress treatments compared to TGX-1835-10E and TGX-1951-3F (Table 4). The differences among genotypes observed for vegetative and yield attributes of soybean subjected to water stress at different growth stages is an indication that, the studied genotypes were genetically different for most of the traits studied. This agrees with the findings of [16] who reported that, when plants are grown in a given ecology, growth and yield differences are observed due to differences in their genotypes.

Table 4. Effect of Genotype x Water Stress Interaction on Yield Traits of Soybean in Makurdi, 2019.

Gen	X	Ws	No of Pods/plt	No of Aborted Pods/plt	No of Seeds/pod	No of Seeds /plt	100 seed wght (g)
		T_o	36.33	4.33	2.40	65.00	40.19
TGX	1448-2E	T_1	27.87	7.83	2.44	53.67	41.30
		T_2	21.80	9.00	2.49	49.67	40.16
		T_3	30.50	15.67	1.83	21.17	21.60
		T_0	39.10	2.00	2.51	70.67	35.54
TGX	1835-10E	T_1	30.13	4.17	2.35	59.00	30.56
		T_2	24.07	6.33	2.40	56.67	28.30
		T_3	30.67	10.67	1.19	27.33	17.78
		T_o	36.67	4.47	2.44	58.67	31.52
TGX	1951-3F	T_1	28.90	8.83	2.40	53.00	25.89
		T_2	23.67	13.00	2.28	43.00	25.56
		T_3	31.17	19.50	1.80	21.00	12.77
LSD	(0.05)		NS	8.49	NS	2.49	4.98

KEY; GEN=Genotype WS = Water stress T_0 = Well-watered Control T_1 = Water Stress at vegetative stage T_2= Water Stress at 50% flowering stage T_3 = Water Stress at early pod filling stage NS = Not-significant ($p< 0.05$)

4. Conclusion

This study has revealed that water stress had significant effects on growth and yield of soybean. It has showed that water stress at early vegetative growth stage significantly reduced vegetative growth indices such as number of leaves, number of branches, plant height and dry matter production. Results also showed that water stress at early pod filling stage significantly reduced soybean seed yield. TGX-1835-10E exhibited superior performance to TGX-1448-2E and TGX-1951-3F in all the vegetative and yield indices evaluated except in plant height and 100 seed weight in which TGX-1448-2E was the best.

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