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INVESTIGATING THE REPERCUSSIONS OF MOISTURE STRESS ON DROUGHT TESTING CHANGES IN SUMMER SOYBEAN (*GLYCINE MAX* L. MERRILL) GENOTYPES

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ABSTRACT

Drought stress, which is connected to climate change, is one of the key determinants pertaining to crop yield. The study was to seek investigating the repercussions of moisture stress on drought testing changes in *summer* soybean [*Glycine max* (l.) Merrill] genotypes in during of *summer* 2022. Three irrigation conditions were the primary determinants in a field experiment conducted using a split plot design: irrigation at sowing and seedling stage (I_0), irrigation at sowing, seedling stage and 50% flowering stage (I_1) and irrigation at sowing, seedling stage, 50% flowering stage and 50% pod development stage (I_2), as well as 20 soybean genotypes as secondary determinants. At 50% flowering stage, drought test such as relative leaf water content (RLWC) and canopy temperature were documented, as well as percent reduction on the basis of yield. The outcomes revealed significant differences between genotypes under various irrigation regimes. Relative leaf water content (RLWC) levels decline and Relative leaf water content (RLWC) level rise considerably during irrigation at the sowing and seedling stages (I_0), indicating moisture stress while increase the percent reduction on the basis of yield. With greater relative leaf water content (RLWC), minimumcanopy temperature and percent reduction, the genotype KDS-992 was shown to be tolerant of moisture stress, while genotype KDS-1271 was found to be susceptible to it.

Key words : Soybean, Relative leaf water content, Moisture stress, Canopy temperature, Drought, Genotypes.

Introduction

A significant leguminous crop, soybeans are used to produce biofuel, animal feed and human food due to their high protein and oil levels. Despite having a 10% share of the global soybean crop, India only contributes 4% of the world's total production, suggesting that its productivity is comparatively poor when compared to the global average (Bhatia *et al*., 2014).

Because of its great nutritional content soybean (*Glycine max*. L.) are one of the most significant oilseed crops in the world. It has roughly 36–40% protein, 18–20% oil, 30% carbohydrate, 7.3% sugar and 9.3% dietary fibre. It additionally contains minerals like calcium and P, as well as vitamins A, B, C and D (FAO, 2013).

Drought is defined as stress caused by a lack of available water. Drought is a climate term that refers to a period of less rainfall. Drought stress in plants occurs when soil water levels fall, causing continual evaporated water through transpiration. Plants require water to survive and carry nutrients. Water scarcity causes drought stress, reducing plant viability (Ashkavand *et al.*, 2018).

Worldwide, the frequency of droughts is increasing owing to reduced precipitation and modified patterns of rainfall (Lobell *et al.*, 2011). Severe droughts negatively impact plant physiology, development and reproduction, which lower crop yields significantly (Barnabas *et al.*, 2008). The amount of all of greenhouse gases is rising, which is one of the primary causes of global warming. Over the last 250 years, CO_2 and methane concentrations have increased by 30 to 150 percent (Friedlingstein and Prentice, 2010). Plant development and productivity are restricted by these pressures more than by any other environmental factor.

Materials and Methods

The study conducted fieldwork on the Agriculture Botany farm at the Post Graduate Institute, Mahatma Phule Krushi Vidyapeeth, Rahuri, Ahmednagar, during the year 2021–2022. Two replicates and a split plot design were used to set up the research undertaking. Three irrigation conditions –1) at sowing and seedling stage (I_0); 2) at sowing, seedling stage and 50% flowering stage (I_1) and 3) at sowing, seedling stage, 50% flowering stage and 50% pod development stage (I_2)– were used as the study's main factors. Twenty genotypes were used as sub factors. The genotypes are: G_1: KDS-1175, G_2: KDS-1201, G_3: JS-335, G_4: KDS-1173, G_5: KDS-1188, G_6: KDS-1200, G_7: KDS-1132, G_8: KDS-1194, G_9: KDS-1286, G_{10}: KDS-1193, G_{11}: KDS-1172, G_{12}: KDS-1187, G_{13}: KDS-1271, G_{14}: KDS-1216, G_{15}: JS-9305, G_{16}: KDS-992, G_{17}: KDS-726, G_{18}: KDS-344, G_{19}: KDS-753, G_{20}: DS-228. The source of the twenty genotypes of soybeans employed in this study was Soybean Breeder, ARS Kasbe Digraj, Dist. Sangali (MH). Plot dimensions were 3.0 × 1.2 m^2. For soybean crops, a fertilizer dosage of 50:75:45 NPK kg ha^{-1} is recommended. The dibbling method was applied to seed soybean variety genotypes on flat beds on February 3rd, 2022. Plants were spaced 10 cm apart from one another and rows 30 cm apart. Immediately after sowing, the soil was irrigated to encourage optimal germination.

Drought test at 50 % flowering

Estimation of relative leaf water content (RLWC) (%)

Relative leaf water content (%) was estimated by using relative turgidity technique (Barrs and Weatherley, 1962). RLWC was estimated at 50 % flowering (45 DAS). Three leaves from each genotype and replication for experiment were used. The leaf which was physiologically functional *i.e.*, flag leaf was selected for estimation. Twenty five discs of 1 cm diameter were cut and their fresh weight was recorded immediately. Discs were cut midway between the base and tip of the leaf blade included the midrib. Then these discs were kept floated on water in closed Petri-dish for at least 6 hr under laboratory conditions. Then extra water from the discs was removed by blotting with fine filter paper before weighing to determine their turgid weight. Dry weight was determined after drying the leaf discs in hot air oven at 70ºC till constant weight. It was calculated by the formula given as below

$$\text{RLWC (\%)} = \frac{\text{Fresh weight (g)} - \text{Dry weight (g)}}{\text{Turgid weight (g)} - \text{Dry weight (g)}} \times 100$$

Estimation of canopy temperature

Canopy temperature was made using a hand held infrared thermometer (Model OS 530 HR, Omega Engineering Inc. Stamford CT USA). Two measurements were recorded per plot (genotype and replication wise) from an approximate distance of 0.5 m from the edge of the plot and approximately at 45º from the horizontal plane of crop. The measurements were recorded at top, middle and basal level between 11.00 am to 12.00 pm hours on cloudless and bright days. Two readings in each plot were taken at 50% flowering.

Drought tolerance indices on the basis of yield

Estimation of percent reduction in yield

$$\text{Percent Reduction} = \frac{Yp - Ys}{Yp} \times 100$$

Where,

Ys = Yield in water stress condition

Yp = Yield in irrigated condition

Statistical analysis

The data on various variables were statistically analyzed using the standard methods for split plot design proposed by Gomez and Gomez (1984).

Results and Discussion

Relative leaf water content (RLWC)

The most significant measure of a plant's ability to withstand dehydration is its relative leaf water content, which is a plant water status indicator that represents metabolic activity in tissues. When a leaf is first forming, its RWC is higher; as the leaf ages and dry matter builds up, it becomes less. RWC is linked to both water loss through transpiration and water uptake by the roots. When leaves undergo exposure to drought, they exhibit notable decreases in RWC and water potential, according to Nayyar and Gupta (2006). Siddique *et al*. (2000) found that plants under drought stress saw a considerable decrease in their leaf water potential, RLWC and transpiration rate, along with an increase in their leaf temperature.

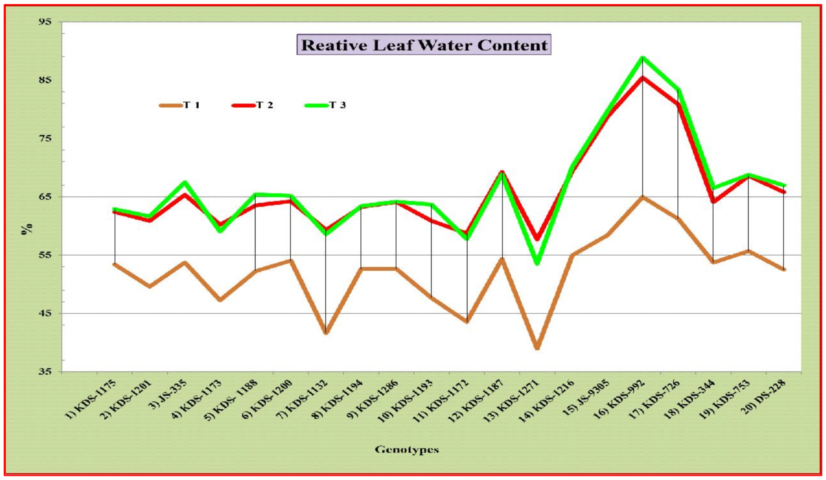

Fig. 1 : Relative leaf water content influenced by different irrigation conditions under moisture stress in *summer* soybean genotypes.

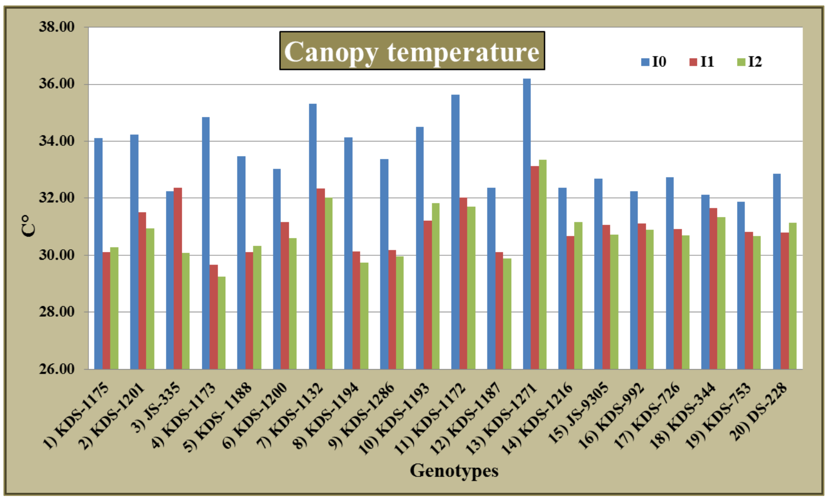

Fig. 2 : Canopy temperature influenced by different irrigation conditions under moisture stress in *summer* soybean genotypes.

Table 1 and Fig. 1 shows the data for RLWC at 50% flowering stage as influenced by genotype, moisture stress, and their interaction. At 50% of the flowering stage, significant variations in RLWC were observed due to varying irrigation conditions as well as genotype. The percentage of irrigation at the sowing, seedling, 50% blooming and 50% pod development stages (I_2) was 66.79% and it dropped to 52.16% at the sowing and seedling stage (I_0).

After receiving irrigation during the sowing and seedling stages (I_0), the genotypes KDS-992 and KDS-1271 reported statistically different levels of RLWC at 50% flowering: 64.97% for the former and 38.98% for the latter.

After irrigation during the sowing, seedling, and 50% flowering stages (I_1), genotypes KDS-992 and KDS-1271 exhibited significantly different levels of RLWC (85.42%) and 56.73%, respectively at 50% flowering.

Irrigation at the sowing, seedling, 50% flowering, and 50% pod development stages (I_2). At 50% flowering, genotype KDS-992 recorded a substantially greater RLWC (88.84%) than genotype KDS-1271, which documented a substantially reduced RLWC (53.55%).

Relative water content (RWC) adversely affected by stresses, particularly drought stress, is thought to be a stronger indicator of water status than water potential achieved by plants during drought stress mitigation (Payam, 2011). According to several studies, RWC is lowered by water scarcity (Sanchez *et al.*, 2004; Rai *et al.*, 2015).

According to Chaimala *et al.* (2023), relative water content (RWC) is an important functional metric and signal for predicting how plants will respond to environmental change. RWC discovered a significant decrease in genotypes under situations of moisture stress relative to control conditions. The results of the current study were supported by other recent research, which showed that a genotype that was drought-tolerant had a higher RWC than a genotype that was susceptible (Khar *et al.*, 2022).

Canopy temperature (°C)

One important parameter for assessing the drought status of the plant is canopy temperature. The leaf temperature must be closer to the air temperature in order to maximize productivity. Canopy temperature is significantly influenced by plant water conditions. Through a variety of plant adaptation properties, canopy temperature in drought- and heat-stressed crop plants indicates a significantly greater capacity for absorbing soil moisture and maintaining a relatively better plant water status. Canopy temperature depression (CTD) is the term used to describe the temperature differential between the air and the canopy.

Table 2 and Fig. 2 displays findings on how genotypes, irrigation conditions, and their interactions affect canopy temperature at 50% flowering. Regarding canopy temperature at 50% flowering, the variations across genotypes, irrigation conditions and interactions are statistically significant. Irrigation at 30.83 (°C) during the sowing, seedling, 50% flowering and 50% pod development stage (I_2) and up to 33.52 (°C) during the

Table 1 : Relative leaf water content (%) and membrane stability index influenced by different irrigation conditions under moisture stress in summer soybean genotypes.

Genotypes	Relative leaf water content (%)			Mean (G)
	I_0	I_1	I_2	
1) KDS-1175	53.41	62.43	62.88	**59.58**
2) KDS-1201	49.59	60.89	61.62	**57.37**
3) JS-335	53.72	65.37	67.45	**62.18**
4) KDS-1173	47.25	60.20	59.03	**55.49**
5) KDS- 1188	52.27	63.54	65.39	**60.40**
6) KDS-1200	54.07	64.25	65.13	**61.15**
7) KDS-1132	41.64	59.33	58.59	**53.19**
8) KDS-1194	52.63	63.28	63.37	**59.76**
9) KDS-1286	52.65	64.10	64.19	**60.31**
10) KDS-1193	47.67	60.90	63.67	**57.41**
11) KDS-1172	43.57	58.76	57.73	**53.35**
12) KDS-1187	54.35	69.25	68.87	**64.16**
13) KDS-1271	38.98	57.73	53.55	**50.09**
14) KDS-1216	55.00	69.39	70.16	**64.85**
15) JS-9305	58.40	78.76	79.68	**72.28**
16) KDS-992	64.97	85.42	88.84	**79.74**
17) KDS-726	61.20	80.83	83.36	**75.13**
18) KDS-344	53.74	64.14	66.52	**61.47**
19) KDS-753	55.68	68.61	68.76	**64.35**
20) DS-228	52.50	65.80	66.94	**61.75**
Mean	**52.16**	**66.15**	**66.79**	**61.70**
	Genotypes (G)		**Irrigat-ions (I)**	**G x I**
SE (±)	1.121		0.075	1.941
CD @ 5%	3.174		0.455	NS

Note: I: Irrigations, S: Significant, NS: Non-significant, G: Genotypes, I_0: Irrigation at sowing and seedling stage, I_1: Irrigation at sowing, seedling stage and 50% flowering stage, I_2: Irrigation at sowing, seedling stage, 50% flowering stage and 50% pod development stage.

sowing and seedling stage (I_0).

Under irrigation during the sowing and seedling stage (I_0), the genotypes KDS-1271, KDS-1172, KDS-1132, and KDS-1173 reported significantly higher maximum canopy temperatures (36.19 and 34.64) at 50% flowering, respectively, while the genotype KDS-753 reported significantly lower canopy temperatures (31.87) at 50% flowering.

Table 2 : Canopy temperature influenced by different irrigation conditions under moisture stress in summer soybean genotypes.

Genotypes	Canopy temperature (^{0}C)			Mean (G)
	I_0	I_1	I_2	
1) KDS-1175	34.12	30.11	30.28	**31.50**
2) KDS-1201	34.23	31.50	30.94	**32.22**
3) JS-335	32.25	32.36	30.08	**31.57**
4) KDS-1173	34.85	29.67	29.25	**31.26**
5) KDS- 1188	33.47	30.11	30.33	**31.30**
6) KDS-1200	33.04	31.17	30.61	**31.61**
7) KDS-1132	35.31	32.35	32.02	**33.22**
8) KDS-1194	34.15	30.14	29.75	**31.34**
9) KDS-1286	33.37	30.19	29.97	**31.18**
10) KDS-1193	34.50	31.22	31.83	**32.52**
11) KDS-1172	35.64	32.03	31.69	**33.12**
12) KDS-1187	32.36	30.11	29.89	**30.79**
13) KDS-1271	36.19	33.14	33.36	**34.23**
14) KDS-1216	32.36	30.67	31.17	**31.40**
15) JS-9305	32.69	31.06	30.72	**31.49**
16) KDS-992	32.24	31.11	30.89	**31.41**
17) KDS-726	32.74	30.91	30.69	**31.45**
18) KDS-344	32.12	31.67	31.33	**31.71**
19) KDS-753	31.87	30.83	30.67	**31.12**
20) DS-228	32.86	30.81	31.14	**31.60**
Mean	**33.52**	**31.06**	**30.83**	**31.80**
	Genotypes (G)		**Irrigat-ions (I)**	**G x I**
SE(±)	0.477		0.551	0.826
CD @ 5%	1.350		NS	NS

Note: I: Irrigations, S: Significant, NS: Non-significant, G: Genotypes, I_0 : Irrigation at sowing and seedling stage, I_1: Irrigation at sowing, seedling stage and 50% flowering stage, I_2: Irrigation at sowing, seedling stage, 50% flowering stage and 50% pod development stage.

Irrigation during seeding, seedling stage, and 50% flowering stage (I_1): KDS-1271 and KDS-1173 genotypes showed significantly higher largest canopy temperatures (33.14) and the smallest canopy temperatures (29.64) at 50% flowering, respectively, followed by JS-335 (32.36), KDS-1132 (32.35) and KDS-1172 (32.03).

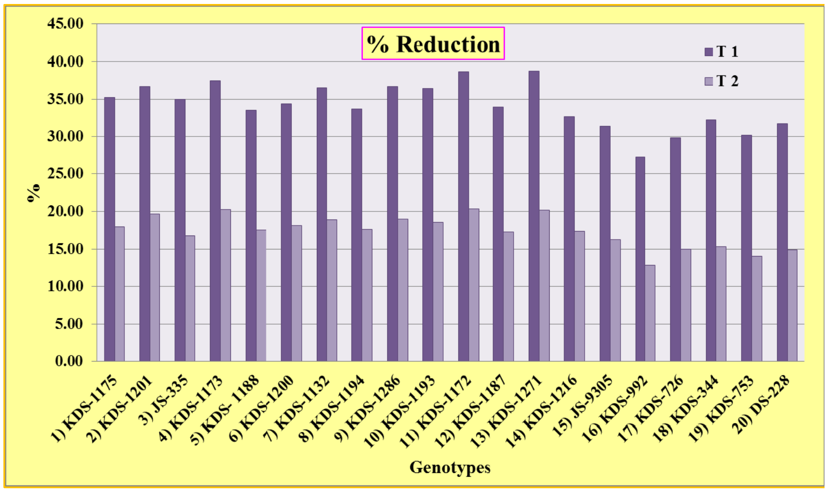

Fig. 3 : Percent reduction on the basis of yield influenced by different irrigation conditions under moisture stress in *summer* soybean genotypes.

Table 3 : Percent reduction (%) influenced by different irrigation conditions under moisture stress in summer soybean genotypes.

Genotypes	Percent reduction (%)	
	I_0	I_1
1) KDS-1175	35.20	17.97
2) KDS-1201	36.69	19.69
3) JS-335	35.00	16.75
4) KDS-1173	37.47	20.25
5) KDS- 1188	33.52	17.51
6) KDS-1200	34.38	18.12
7) KDS-1132	36.53	18.94
8) KDS-1194	33.69	17.63
9) KDS-1286	36.68	18.99
10) KDS-1193	36.45	18.61
11) KDS-1172	38.68	20.34
12) KDS-1187	33.98	17.24
13) KDS-1271	38.71	20.22
14) KDS-1216	32.68	17.34
15) JS-9305	31.38	16.24
16) KDS-992	27.23	12.84
17) KDS-726	29.83	14.98
18) KDS-344	32.19	15.30
19) KDS-753	30.18	14.06
20) DS-228	31.73	14.86
Mean	**34.11**	**17.39**

Note: I: Irrigations, S: Significant, NS:Non-significant, G: Génotypes, I_0: Irrigation at sowing and seedling stage, I_1: Irrigation at sowing, seedling stage and 50% flowering stage, I_2:Irrigation at sowing, seedling stage, 50% flowering stage and 50% pod development stage

Irrigation during seeding, seedling, 50% flowering, and 50% pod development (I_2) genotypes KDS-1271 and KDS-1132 observed considerably higher maximum canopy temperatures (33.36) and 32.02, respectively, at 50% flowering, while genotype KDS-1173 recorded significantly lower canopy temperatures (29.25) at 50% flowering.

Plants under drought stress exhibited higher canopy temperatures than plants receiving regular watering, as reported by Siddique *et al.* (2000). This might be the result of stomata closing due to drought stress, which increased respiration and decreased transpiration. In a similar vein, McMaster *et al.* (2008) showed that stomatal closure brought on by a shortage of water raises canopy temperature. The temperature of the canopy rises above the surrounding air when stomata close from a shortage of water. In fact, genotypes that are resistant to drought showed lower canopy temperatures. This indicates that they will utilize more of the easily accessible water in the soil, reducing the negative effects of water stress on grain yield. The results mentioned above are corroborated by Gupta and Sastry (1986), who demonstrated that the minimum canopy temperatures of well-watered wheat genotypes were below average air temperatures as well as that the difference between canopy temperature and ambient temperature was typically negative.

Percent reduction in yield (%)

Table 3 and Fig. 3 displays the percentage reduction based on yield for summer soybean genotypes under different irrigation regimes. Under moisture stress conditions, irrigation at the sowing, seedling and 50% flowering stage (I_0) was reported by genotypes KDS-1271, KDS-1172 and KDS-992, in order of maximum and minimum percent reduction, respectively, at 38.71 and 38.68, respectively. Under mild moisture stress conditions, irrigation during the sowing, seedling, and 50% blooming stage (I_1) resulted in the largest percent reduction (20.22) for genotype KDS-1271, subsequent to KDS-1172 (20.34) and the least percent reduction (12.84) for genotype KDS-992.

Conclusion

In the current investigation, we discovered genotype KDS-1271 that accumulated less RLWC during stress and others genotypes KDS-992 and KDS-1271 that accumulated more RLWC under stress with minimum percent reduction while canopy temperature of genotype KDS-1271 maximum than other genotypes. These genotypes KDS-992 can be employed in future research to identify the genetic mechanisms that help soybean plants become more resistant to drought stress.

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