The Pharma Innovation Journal 2023; 12(12): 1013-1017

www.ThePharmaJournal.com

The Pharma Innovation

ISSN (E): 2277-7695
ISSN (P): 2349-8242
NAAS Rating: 5.23
TPI 2023; 12(12): 1013-1017

www.thepharmajournal.com
Received: 18-09-2023
Accepted: 30-10-2023

Deciphering the moisture stress resilience of *summer* soybean [*Glycine max* (L.) Merrill] genotypes: An analysis of morphological parameter

Puja R Mate, Rajendra S Wagh, Ramchandra J Navatre, Kantilal B Chande and Tukaram R Sadgar

Puja R Mate
Ph.D. Scholars, Department of Agriculture Botany, Post Graduate Institute, Mahatma Phule Krushi Vidhyapeeth, Rahuri, Ahmednagar, Maharashtra, India

Rajendra S Wagh
Associate Professor, Department of Agriculture Botany, Post Graduate Institute, Mahatma Phule Krushi Vidhyapeeth, Rahuri, Ahmednagar, Maharashtra, India

Ramchandra J Navatre
Ph.D. Scholars, Department of Agriculture Botany, Post Graduate Institute, Mahatma Phule Krushi Vidhyapeeth, Rahuri, Ahmednagar, Maharashtra, India

Kantilal B Chande
Ph.D. Scholar, Department of Agriculture Botany, Post Graduate Institute, Dr. Panjabrao Deshmukh Krushi Vidhyapeeth Akola, Maharashtra, India

Tukaram R Sadgar
Ph.D. Scholars, Department of Agriculture Botany, Post Graduate Institute, Mahatma Phule Krushi Vidhyapeeth, Rahuri, Ahmednagar, Maharashtra, India

Corresponding Author:
Puja R Mate
Ph.D. Scholars, Department of Agriculture Botany, Post Graduate Institute, Mahatma Phule Krushi Vidhyapeeth, Rahuri, Ahmednagar, Maharashtra, India

Abstract

Background: Drought is the most significant abiotic variable constraining word wide soybean production; thus, evaluation and development of moisture stress resistance soybean genotypes is crucial for accomplishing sustainable agriculture.
Method: A research study was set up in split plot design including three irrigation conditions as a main factor namely 1) Irrigation at sowing and seedling stage (I_0), 2) Irrigation condition at sowing, seedling stage and 50% flowering stage (I_1), 3) Irrigation at sowing seedling stage, 50% flowering stage and 50% pod development stage (I_2) and 20 soybean genotypes as a sub factor. At harvest morphological parameters such as plant height and number of branches plant^{-1} were documented in addition to the drought tolerance efficiency on basis of yield.
Result: The results revealed significant variations between genotypes under Irrigation at sowing and seedling stage (I_0) and Irrigation at sowing seedling stage, 50% flowering stage and 50% pod development stage (I_2). Plant height and number of branches plant^{-1} showed a significant drop in irrigation at sowing and seedling stage (I_0) i.e. moisture stress condition. The genotype KDS-992 was found moisture stress tolerance genotype with higher plant height and number of branches plant^{-1}. Whereas KDS-1271 was identified as a moisture stress susceptible genotype.

Keywords: Soybean, moisture stress, genotypes, morphological parameters, drought etc.

Introduction

Soybean [*Glycine max* (L.) Merrill] has risen to prominence in the world's oilseed cultivation landscape due to its high productivity, profitability, and vital role in soil fertility maintenance. In addition to oil and cheap and high-quality protein, it has a significant value in feed, food and nutrition, pharmaceuticals, and a variety of other industries. Soybean is a valuable leguminous crop with high protein and oil content that is widely used in human consumption, animal feed, and biofuel production. Despite India's 10% share of global soybean acreage, it contributes only 4% of total global production, demonstrating comparatively low productivity in comparison to the global average (Bhatia *et al.*, 2014) [3]. In Madhya Pradesh, the golden bean is mostly farmed by marginal farmers under rainfed conditions.

Although it is a rainfed crop, its productivity is primarily restricted by the unpredictable monsoon, climatic variations, and a variety of eco-edaphic conditions. It has been noted in the past that every year, one or more crop stages and one or more locations experience unexpected drought stress (Manavalan *et al.*, 2009) [11].

During the vegetative stage, drought stress affects leaf development, which starts to curl or drop, resulting in lower plant growth and a significant reduction in output. When soybeans are in their reproductive stages, they are particularly vulnerable to drought damage. Early-stage reproductive stress from drought has led to an increase in flower and pod abortion in later reproductive stages. Small pods with fewer, smaller, and shriveled seeds than usual are the result of protracted dryness (Boyer, 1982) [5].

Climate change is visible and poses a challenge to soybean production. We must develop cultivars that can endure climate variability such as delayed monsoon, drought, water logging, and high temperatures (Director's annual report 2018-19). As a result, it’s critical to investigate prospective genotypes for improved yield and drought tolerance efficiency under both normal and drought stress. Consequently, the research concern is to screen soybean genotypes for drought resistance.

Materials and Methods

The field experiment was conducted during *summer* season of year 2021-2022 at farm of Agriculture Botany, Post Graduate Institute, Mahatma Phule Krushi Vidyapeeth Rahuri, Ahmednagar. The experiment was laid out in split plot design with 2 replications. There were three irrigation conditions as a main factor *viz*., 1) Irrigation at sowing and seedling stage (I_0), 2) Irrigation condition at sowing, seedling stage and 50% flowering stage (I_1), 3) Irrigation at sowing seedling stage, 50% flowering stage and 50% pod development stage (I_2) and 20 genotypes as a sub factor. 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. These twenty genotypes of soybean used for the present investigation were obtained from the Soybean Breeder, ARS Kasbe Digras Dist. Sangali (MS). The plot size was 3.0 x 1.2 m^2. Fertilizer dose applied to soybean crop as per recommended dose 50:75:45 NPK kg ha^{-1}. The seed of soybean varieties genotypes was sown on 3rd February 2022, in the flat beds by dibbling method. The sowing was done at the distance of 30 cm between row and 10 cm between the plants. To ensure good germination the field was irrigated immediately after sowing.

Estimation of plant height

The plant height was measured in centimeters from the base (ground level) to the tip of the plant at harvest. Height of 5 plant randomly selected from each irrigation treatment was measured by using meter scale and the mean value was subsequently computed.

Estimation of number of branches plant^{-1}

The number of branches plant^{-1}, including the main stem, was tallied at harvest from five randomly chosen plants and the mean value was computed**.** The productivity of the crop is significantly influenced by the number of main branches and sub- braches since these areas are where leaves, flowers and pod develop.

Results and Discussion

Plant height

Plant height is a vital and obvious indicator of plant growth. Intermodal elongation and leaf emergence determine plant height. Because leaves are born on the stem, leaf area development and biomass production are closely related to plant height. Table no. 1 shows the results on mean plant height (cm) impacted by genotypes, moisture stress treatment and their interaction effects that were statistically significant at harvest.

It was revealed that when moisture stress increased, plant height decreased. Irrigation at sowing, seedling stage, 50% flowering stage and 50% pod development stage (I_2) 52.0 cm and irrigation at sowing and seedling stage (I_0) 66.1 cm.

The genotype KDS-1216 (67.7 cm) showed the considerably highest plant height at harvest under irrigation at the sowing and seedling stage (I_0), while the genotype KDS-1271 (28.4 cm) showed the significantly lowest plant height. With irrigation applied during the sowing, seedling stage and 50% flowering stage (I1), the genotypes KDS-344 (77.7 cm) and KDS-1216 (73.2 cm) recorded the highest and lowest plant heights respectively. While genotype KDS-1271 (31.0 cm) recorded the lowest plant heights. The genotypes KDS-344 (86.0 cm) and KDS-1216 (83.3 cm) recorded the significantly highest and lowest plant heights at harvest respectively, under irrigation during the sowing, seedling, 50% flowering and 50% pod development stages (I_2). At the same time, genotype KDS-1271 (34.2 cm) recorded the significantly lowest plant height at harvest.

The results of this study also demonstrated that all genotypes plant heights decreased under stressful conditions. These results corroborate those of Khan *et al*. (2001) [8], who discovered that when water stress rose, the height of maize plants considerably decreased. The decline in plant height could be linked to a reduction in cell enlargement and an increase in leaf aging. The decrease in shoot growth might be an adaptive reaction to water scarcity, potentially due to a decline in plant cell turgor, which hinders cell division and expansion. These observations align with the discoveries made by Zhang and Shi (2018) [19] in alfalfa, indicating that heightened water stress resulted in reduced plant height. Water stress led to a decrease in the stem cell water potential, reaching the minimum level needed for cell elongation, thereby resulting in shorter internodes and reduced plant height due to stress. In drought conditions, the loss of water through plant tissues impedes overall growth, as described by Borell *et al*. (2001) [4].

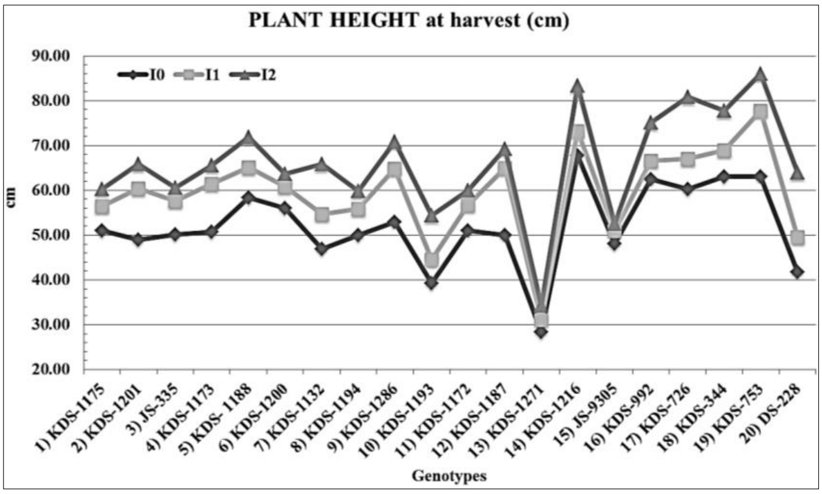

Fig 1: Plant height

Number of branches plant^{-1}

The number of branches plant^{-1} at harvest varied significantly in relation to genotype and moisture stress conditions. There were more primary branches under control conditions (irrigation at sowing, seedling stage, 50% flowering stage and 50% pod development stage) than under moisture stress conditions (irrigation at sowing and seedling stage). Irrigation at sowing, seedling stage, 50% flowering stage and 50% pod development stage (I_2) 3.30 and its dropped as far as 1.92 in irrigation at sowing and seedling stage (I_0).

Irrigation at the sowing and seedling stages (I_0), genotype KDS-992 (2.90) had the maximum number of branches per plant at harvest, followed by genotype KDS-726 (2.70), and KDS-1271 (1.10) had the lowest number of branches per plant. Irrigation during the sowing, seedling and 50% flowering stages (I_1) resulted in a considerably higher number of branches per plant at harvest for genotype KDS-992 (3.30), KDS-726 (3.20) and JS-9305 (3.00), while genotype KDS-1271 (1.70) resulted in a significantly lower number of branches per plant. Irrigation at sowing, seedling stage, 50% flowering stage and 50% pod development stage (I_2) resulted in a significantly higher number of branches per plant at harvest for genotype KDS-992 (5.50), followed by KDS-726 (5.00), while KDS-1271 (2.30) resulted in a significantly lower number of branches per plant at harvest. The negative effects of water stress on new leaf and branch formation was also reported by Mabulwana (2013) [10] and Jaleel *et al*. (2009) [7].

Similar results were seen by Thalooth *et al.* (2006) [18], who noted that skipping one irrigation of at different growth stages significantly decreased the number of branches in comparison to control plants. Similar results were seen in rapeseed by Shirani Rad and Zandi (2012) [17], pigeonpea by Bake *et al.* (2016) [2], sesame by Khatiby *et al.* (2016) [9] and soybean by Purwantoro *et al*. (2017) [12] canola by Rehman and Khalil (2018) [15]. In the current study, there was a positive link between seed output and the number of primary branches per plant. These results support the conclusions obtained by Rasaily *et al*. (1986) [13] and Amarnatha *et al*. (1990) [1].

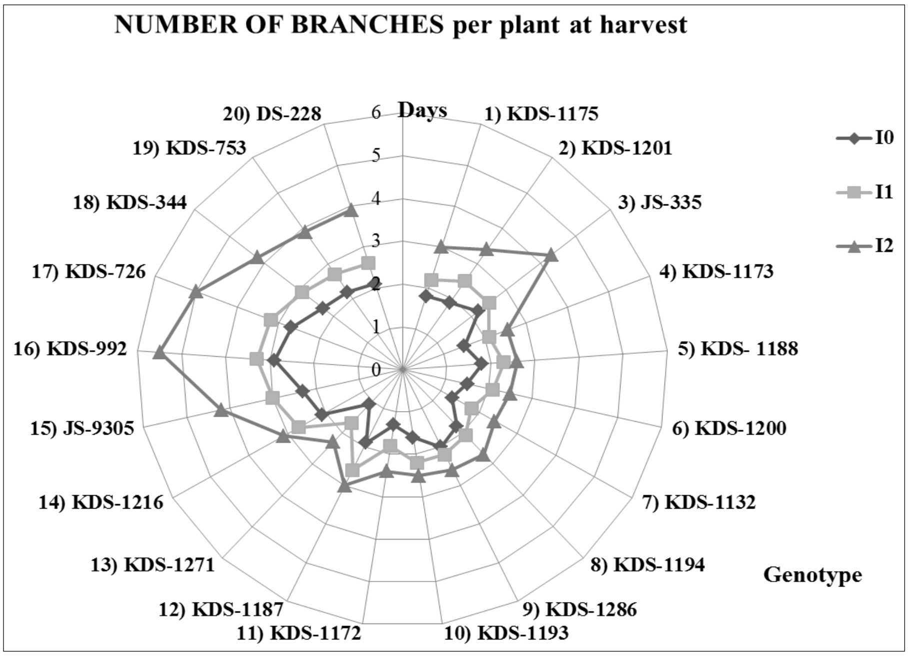

Fig 2: Number of branches plant^{-1}

Table 1: Plant height and number of branches at harvest influenced by different irrigation conditions under moisture stress in *summer* soybean genotypes

Genotypes	Plant height at harvest			Mean (G)	Number of branches at harvest			Mean (G)
	I_0	I_1	I_2		I_0	I_1	I_2	
1) KDS-1175	51.0	56.4	60.3	55.9	1.80	2.20	3.00	2.33
2) KDS-1201	49.0	60.4	65.8	58.4	1.90	2.50	3.40	2.60
3) JS-335	50.1	57.6	60.6	56.1	2.20	2.50	4.30	3.00
4) KDS-1173	50.7	61.4	65.5	59.2	1.50	2.10	2.55	2.05
5) KDS- 1188	58.3	65.1	71.9	65.1	1.80	2.30	2.60	2.23
6) KDS-1200	56.0	60.8	63.6	60.1	1.50	2.10	2.50	2.03
7) KDS-1132	46.9	54.7	65.9	55.8	1.30	1.80	2.40	1.83
8) KDS-1194	50.0	55.9	59.9	55.3	1.80	2.10	2.70	2.20
9) KDS-1286	52.9	64.9	70.9	62.9	2.00	2.20	2.60	2.27
10) KDS-1193	39.2	44.5	54.4	46.0	1.60	2.20	2.50	2.10
11) KDS-1172	51.0	56.7	60.0	55.9	1.30	1.80	2.40	1.83
12) KDS-1187	50.0	65.0	69.2	61.4	1.90	2.60	3.00	2.50
13) KDS-1271	28.4	31.0	34.2	31.2	1.10	1.70	2.30	1.70
14) KDS-1216	67.7	73.2	83.3	74.7	2.10	2.70	3.10	2.63
15) JS-9305	48.1	50.8	52.5	50.5	2.30	3.00	4.20	3.17

16) KDS-992	62.5	66.6	75.1	68.1	2.90	3.30	5.50	3.90
17) KDS-726	60.3	67.0	80.9	69.4	2.70	3.20	5.00	3.63
18) KDS-344	63.1	69.0	77.8	70.0	2.30	2.90	4.20	3.13
19) KDS-753	63.1	77.7	86.0	75.6	2.20	2.70	3.90	2.93
20) DS-228	41.8	49.6	64.0	51.8	2.10	2.60	3.90	2.87
Mean	52.0	59.4	66.1	59.2	1.92	2.43	3.30	2.55
	Genotypes (G)		Irrigations (I)	G x I	Genotypes (G)		Irrigations (I)	G x I
SE(±)	1.560		0.824	2.702	0.96		0.034	0.167
CD @ 5%	4.418		5.015	NS	0.273		0.204	0.472

Note: I: Irrigations, S: Significant, NS: Non-significant, G: Génotypes, I0: Irrigation at sowing and seedling stage, I1: Irrigation at sowing, seedling stage and 50% flowering stage, I2: Irrigation at sowing, seedling stage, 50% flowering stage and 50% pod development stage

Conclusion

The current pursuit towards enhancing our understanding of the effects of moisture stress tolerance and the crucial parameters linked to drought stress is imperative in today's context. This necessitates well-designed experimental programs geared towards augmenting tolerance against diverse combinations of abiotic stresses, especially concerning drought. As we advance our comprehension and quantify the repercussions of mild, moderate and severe water-deficit impacts on various aspects of morphological traits to growth and development. Our ability to apply these factors in studying drought stress will significantly improve. This knowledge is vital and should be earnestly considered. The research findings highlight the diverse reactions of different soybean genotypes to water stress. Water stress adversely affects the overall yield in these genotypes. Moisture stress condition i.e., Irrigation at sowing and seedling stage (I_0) showed minimum plant height and number of branches per plant as compared to normal irrigation condition. Specifically, genotype KDS-992 demonstrated higher tolerance to water deficit stress, while KDS-1271 appeared to be more susceptible in terms of plant height and number of branches per plant. These distinct responses emphasize the necessity for further exploration into genotype-specific adaptations to water stress, aiming to enhance drought resilience and tolerance in soybean genotype.

Improving the efficiency of water utilization within agricultural systems stands as a paramount priority, particularly in arable lands across many regions worldwide. The escalating threat of diminishing water resources underscores the importance of identifying genotypes possessing enhanced drought tolerance. This emphasis on research and development is critical in confronting the challenges posed by water scarcity and ensuring sustainable agricultural practices in the face of increasingly variable and unpredictable environmental conditions.

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