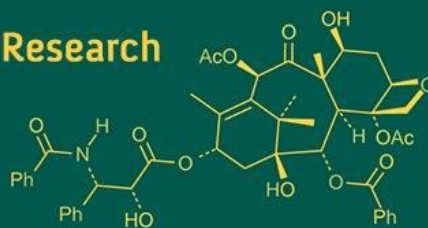
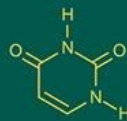
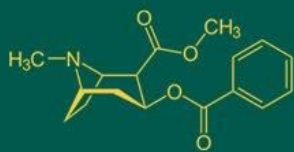


International Journal of Advanced Biochemistry Research



ISSN Print: 2617-4693
ISSN Online: 2617-4707
NAAS Rating (2025): 5.29
IJABR 2025; SP-9(12): 104-108
www.biochemjournal.com
Received: 04-09-2025
Accepted: 08-10-2025

V Bhanuchandra
Ph.D. Research Scholar,
Department of Crop
Physiology, S.V. Agricultural
College, Tirupati, Andhra
Pradesh, India

P Sandhya Rani
Principal Scientist & Head,
Department of Crop
Physiology, Agricultural
Research Station, Darsi,
Andhra Pradesh, India

G Rama Rao
Professor & Head,
Department of Crop
Physiology, Agricultural
College, Pulivendula, Andhra
Pradesh, India

AV Nagavani
Professor, Department of
Agronomy, S.V. Agricultural
College, Tirupati, Andhra
Pradesh, India

L Madhavi Latha
Principal Scientist (Plant
Breeding RARS), Agricultural
Research Station, Kadiri,
Andhra Pradesh, India

Corresponding Author:
V Bhanuchandra
Ph.D. Research Scholar,
Department of Crop
Physiology, S.V. Agricultural
College, Tirupati, Andhra
Pradesh, India

Laboratory screening of sorghum genotypes for drought tolerance using polyethylene glycol (PEG-6000)

V Bhanuchandra, P Sandhya Rani, G Rama Rao, AV Nagavani and L Madhavi Latha

DOI: <https://www.doi.org/10.33545/26174693.2025.v9.i12Sb.6462>

Abstract

A laboratory study was conducted to screen thirty sorghum genotypes for moisture stress tolerance using the Polyethylene Glycol (PEG-6000) method. The experiment utilized a completely randomized design with three treatments, a control (0%), 5% PEG, and 10% PEG representing increasing levels of induced moisture stress. The parameters observed included germination percentage (GP), seedling vigour index (SVI), shoot length (SL), and root length (RL). The results showed a significant negative correlation, with performance declining as PEG concentration increased. Shoot Length and Seedling Vigour Index were the most severely inhibited parameters, with the mean SL dropping from (Control) to (10% treatment). Root Length and Germination Percentage showed comparatively better retention. Genotypes NJ-2791 as the most tolerant under the highest stress (10%), both maintaining 100% germination, with NJ-2791 also showing the highest SVI. NJ-2818 was the most resilient for Root Length, and NJ-2725 for Shoot Length. NJ-2794 was the most susceptible genotype. This study successfully identified resilient genotypes suitable for breeding programs aimed at improving sorghum's drought tolerance.

Keywords: Polyethylene glycol, sorghum, seedling vigour index, germination percentage

Introduction

Sorghum (*Sorghum bicolor* L. Moench) is a vital cereal crop that holds a significant place in global and Indian agriculture. As one of the most resilient crops, it thrives under harsh environmental conditions, particularly in semi-arid and arid regions. Sorghum's adaptability to low water availability, high temperatures, and poor soil fertility makes it indispensable for ensuring food security in drought-prone regions. With its origins tracing back to Africa, sorghum has become a staple for over 500 million people worldwide and is a cornerstone of subsistence farming in regions facing erratic rainfall and rising temperatures. It is ranked as the fifth most cultivated cereal crop, following maize, rice, wheat, and barley. Its cultivation spans across the United States, Africa, and Asia. India, being one of the largest producers of sorghum, contributes significantly to its global production. As of 2024, India cultivated sorghum on approximately 4.7 million hectares, primarily in states like Maharashtra, Karnataka, Telangana, and Rajasthan. Despite its vast acreage, the national average productivity of sorghum remains at 950 kg/ha, which is below the global average. This highlights the need for focused research and innovations to improve yields, particularly under abiotic stresses like drought. In the country it occupied production of 4.78 million tonnes and productivity of 3428 kg ha⁻¹. In A.P. it is cultivated in 1.20 lakh hectares with 4.10 lakh tonnes of production and productivity of 3164 kg ha⁻¹ (Directorate of Economics and Statistics, 2024-25). Sorghum is often referred to as a "climate-smart crop" due to its remarkable ability to grow under extreme environmental conditions, including prolonged droughts and high temperatures.

Drought is defined as a prolonged shortage of water available to plant, primarily due to insufficient rainfall or precipitation. It can also occur due to exceptionally high temperatures and low humidity driving the evapotranspiration in plants. Drought is one of the significant environmental factors affecting crop growth and productivity worldwide. As it can withstand drought conditions so sorghum is popularly known as "Camel crop".

Several sorghum producing regions in Africa are vulnerable to drought stress, Prasad *et al.* (2021) ^[15]. Drought stress is one of the most significant abiotic factors affecting sorghum production worldwide. It disrupts key physiological processes and reduces crop yield, particularly in rainfed agricultural systems. In sorghum, drought stress impacts growth, development, and reproduction at various stages of the crop cycle. The extent of damage depends on the timing, duration, and intensity of the drought stress. It is considered a drought-tolerant crop and can be productive under low-input conditions, drought stress due to water deficiency affects its soil-nutrient uptake capability and nutrient mobilization and transport (Sarshad *et al.* 2021) ^[16].

PEG inhibits the seed germination by creating stress in plants. Several physiological characteristics have been reported as being reliable indicators for the selection of germplasm possessing drought tolerance. These characteristics include seed germination and seedling growth in nutrient solutions with low osmotic potential (Zahoor Ahmad *et al.*, 2015) ^[18]. PEG technique would be suitable for screening drought tolerance in large populations prior to yield testing trials, which could significantly reduce the overall cost and man power. Using this method maximum germplasm can be tested for drought tolerance under limited space and resources (Aradhna Kumari *et al.*, 2014) ^[3].

Materials and Methods

The experiment was conducted at the P.G Laboratory, Department of Crop physiology, at S.V agricultural College, Tirupati, using the standardized PEG protocol. Thirty sorghum genotypes obtained from the Millet Breeder, Agricultural Research Station, Perumallapalle, Chittoor, Andhra Pradesh, were screened to identify resistance and susceptible genotypes.

Sorghum seeds were subjected to different moisture stress condition using PEG-6000 at different Percentages (0, 5, 10) in petriplate method. Observations on germination percentage, root length, shoot length and seedling vigor index (SVI) for all the 30 genotypes were recorded. Aqueous solutions of 0.5%, 10% were obtained by dissolving 0.5g and 10g of Poly ethylene glycol in 100 ml of distilled water respectively by using the formula as suggested by Michel and Kaufmann, 1972. Uniform seeds of different genotypes were collected and these seeds were placed on moistened filter paper in glass petridishes. Filter papers were moistened in the beginning and at regular intervals with the above mentioned solutions. Every day number of seeds germinated were recorded. On the seventh day, the shoot and root lengths were recorded in centimeters

Design and Layout

The experiment was conducted in a completely randomized design (CRD) with 30 Sorghum genotypes. There were Three treatments (0.5%, 10%) with Three replications.

Table 1: List of Sorghum genotypes procured

Genotypes	
1. NJ -2668	19. NJ -2687
2. NJ -2699	20. NJ -2689
3. NJ -2703	21. NJ -2694
4. NJ -2704	22. NJ -2697
5. NJ -2711	23. NJ -2706
6. NJ -2837	24. NJ -2708
7. NJ -2841	25. NTJ 5
8. NJ -2790	26. NJ -2725
9. NJ -2794	27. NJ -2726
10. NJ -2791	28. NJ -2730
11. NJ -2805	29. NJ -2740
12. NJ -2808	30. NJ -2741
13. NJ -2812	
14. NJ -2818	
15. NJ -2820	
16. NJ -2667	
17. NJ -2685	

Observations Recorded

Germination percentage

Seed germination was recorded at every day after placing the seeds in petridishes upto seven days and it was expressed in percentage. A seed was considered as germinated, when the radicle was protruded out the seed coat. Germination percentage of seed was worked out by the following formula (ISTA, 1995).

$$\text{Germination\%} = \frac{\text{Number of seeds germinated}}{\text{Total number of seeds kept for germination}} \times 10$$

Seedling vigour index (SVI)

Shoot length and root length of seedlings were recorded in petriplates on seventh day from the date seeds were kept for germination. Seedling vigour index was calculated by the following formula suggested by Abdul Baki and Anderson (1973) ^[1] and averaged.

$$\text{SVI} = \frac{(\text{Shoot length} + \text{Root length})}{\text{Germination percentage}} \times$$

Shoot length(cm)

Shoot length was measured at seventh day from the date seeds were kept for germination and expressed in cm.

Root length(cm)

Root length was measured at seventh day from the date seeds were kept for germination and expressed in cm.

Results and Discussion

The data on effect of induced moisture stress on germination percentage, seedling vigor index, shoot length and root length using petriplate method was presented here.

Germination percentage & seedling vigor index

Table 2: Screening of Sorghum genotypes for germination percentage and seedling vigor index through induced moisture stress with poly ethylene glycol (Control, 5% and 10%) using petriplate method

S. No.	Genotypes	Germination percentage			Seedling vigour index		
		Control	5%	10%	Control	5%	10%
1	NJ -2668	73.33	73.33	66.67	1463.55	624.07	145.47
2	NJ -2699	100.00	86.67	80.00	1741.50	1267.07	295.60
3	NJ -2703	100.00	100.00	80.00	2507.00	1284.50	386.20
4	NJ -2704	100.00	80.00	80.00	2135.00	795.47	356.60
5	NJ -2711	66.67	60.00	46.67	1578.93	202.17	184.87
6	NJ -2837	100.00	86.67	86.67	2315.00	996.87	324.10
7	NJ -2841	80.00	53.33	46.67	857.80	313.07	213.57
8	NJ -2790	100.00	60.00	40.00	1555.00	350.67	159.08
9	NJ -2794	100.00	66.67	33.33	879.00	505.80	73.50
10	NJ -2791	100.00	100.00	100.00	1880.00	1064.00	609.00
11	NJ -2805	80.00	86.67	66.67	962.00	859.60	202.47
12	NJ -2808	100.00	100.00	46.67	1568.00	850.50	255.07
13	NJ -2812	100.00	80.00	73.33	2133.00	410.60	219.70
14	NJ -2818	80.00	60.00	46.67	1677.07	667.60	412.67
15	NJ -2820	100.00	86.67	66.67	1809.00	616.80	145.20
16	NJ -2667	80.00	80.00	60.00	1681.40	585.00	205.47
17	NJ -2685	100.00	100.00	86.67	1264.00	1352.50	502.60
18	NJ -2686	100.00	80.00	80.00	1988.00	1023.60	197.00
19	NJ -2687	100.00	86.67	80.00	1893.00	996.00	364.80
20	NJ -2689	100.00	86.67	86.67	1542.00	419.30	316.93
21	NJ -2694	86.67	80.00	80.00	2050.40	1136.80	507.33
22	NJ -2697	100.00	86.67	86.67	2108.00	919.00	428.67
23	NJ -2706	93.33	80.00	66.67	1454.83	833.27	194.10
24	NJ -2708	86.67	80.00	66.67	2241.20	708.40	335.20
25	NTJ 5	100.00	100.00	100.00	2751.00	1180.00	434.00
26	NJ -2725	86.67	80.00	73.33	1405.00	642.93	524.67
27	NJ -2726	86.67	73.33	60.00	2802.80	678.53	268.80
28	NJ -2730	86.67	86.67	80.00	1932.13	851.33	245.07
29	NJ -2740	100.00	100.00	80.00	1940.00	808.00	284.80
30	N-15	80.00	46.67	33.33	1104.80	417.60	106.00
	Mean	92.22	80.89	69.33	1774.01	778.70	296.62
	SEM±	4.04	7.69	8.94	161.20	125.09	60.98
	CD(P=0.05)	11.45	21.83	25.36	457.16	354.76	172.95

1. Germination percentage

Sorghum genotypes screened for moisture stress tolerance using Petri plate method at three different concentrations of PEG-6000 viz., control, 5% and 10% differed significantly for germination percentage.

The mean GP significantly declined from 92.22% (Control) to 69.33% (10% treatment), indicating a direct inhibitory effect of the treatment on seed viability.

Control Conclusion (Optimal Conditions)

Performance: High, with a mean of 92.22%. Highest Performers: The majority of genotypes achieved a perfect 100.00% germination. Lowest Performer: NJ-2711 had the lowest initial viability at 66.67%.

5% Treatment Conclusion (Moderate Stress)

Performance: Moderate decline, with a mean of 80.89%. Highest Performers: Genotypes including NJ-2791 and NTJ 5 maintained a perfect 100.00% rate. Lowest Performer: NJ-2841 showed the highest sensitivity, with a low of 53.33%.

10% Treatment Conclusion (High Stress): Performance: Significant decline, with a mean of 69.33%. Highest Performers (Most Tolerant): NJ-2791 and NTJ 5 were the

only genotypes to maintain 100.00% germination at the highest stress level, Lowest Performers (Most Sensitive): NJ-2794 and N-15 were the most susceptible, with the lowest rate of 33.33%.

Majid Khayatnezhad *et al.* (2010) [12] reported significant genotypic differences among the four corn cultivars at different levels of drought treatment (distilled water (0), -2, -4 and -8 bars). They also observed a significant decrease in percentage of germination and germination rate. Batool *et al.* (2014) [4] also stated that osmotically induced water stress adversely affect the germination and seedling growth of maize varieties.

Khodarahmpour (2011) [8] observed that there was a decrease in germination% among maize hybrids due to drought stress increment and maximum germination percent was delayed. Zahoor Ahmad *et al.* (2015) [18] also reported that different levels of PEG-6000 such as control, -0.2MPa, -0.4MPa, -0.6 MPa and -0.8 MPa showed significant effect on the germination of maize hybrids.

Decrease in seed germination under water stress condition could be due to metabolic disorders such as slow hydrolysis of substrate compounds in endosperm or cotyledons and slower transportation of hydrolyzed material to developing embryo axis (Habtamu Ashagre *et al.*, 2014) [10].

2. Seedling Vigour Index

Seedling vigour index of Sorghum genotypes differed significantly at control, 5% and 10% PEG concentrations

Seedling vigour index is a good indicator to evaluate the ability of any seed to germinate and produce normal seedlings (Perez *et al.* 2006) [14].

The SVI experienced a severe drop, with the mean plummeting from 1774.01 (Control) to 296.62 (10% treatment), showing a major impact on overall seedling health and growth potential.

Control Conclusion (Optimal Conditions)

Performance: High, with a mean of 1774.01, Highest Performer: NJ-2726 displayed the maximum vigour (2802.80)., Lowest Performer: NJ-2841 had the lowest vigour (857.80).

5% Treatment Conclusion (Moderate Stress)

Performance: Moderate decline, with a mean of 778.70., Highest Performer: NJ-2685 exhibited the highest vigour (1352.50), Lowest Performer: NJ-2711 was the most affected by this stress level, recording the minimum SVI (202.17).

10% Treatment Conclusion (High Stress)

Performance: Severe decline, with a mean of 296.62., Highest Performer (Most Tolerant): NJ-2791 proved the most resilient, registering the highest SVI (609.00), which is double the population mean., Lowest Performer (Most Sensitive): NJ-2794 was the most compromised genotype, showing the minimum SVI of only 73.50.

Similarly significant differences among corn hybrids for seed vigour in all drought levels (0, -3, -6, -9 and 12Bar PEG6000) were observed by Khodarahmpour (2011) [8].

Das and Kalika (2010) [6] studied locally grown rice cultivars of Assam under different moisture regimes like 0 bar, -2 bars and -6 bar. They observed that moisture deficit resulted in lowering of seedling vigour and speed of germination in all cultivars although the cultivars varied

significantly in their response to moisture stress. Reduction in SVI was due to reduction in both seed germination and seedling length.

Table 3: Screening of Sorghum genotypes for shoot length, root length through induced moisture stress with polyethylene glycol (Control, 5% and 10% PEG) using petriplate method

S. No.	Genotypes	Shoot length(cm)			Root length(cm)		
		Control	5%	10%	Control	5%	10%
1	NJ -2668	8.12	1.10	0.04	11.84	6.91	2.01
2	NJ -2699	5.99	2.13	0.00	11.43	12.54	3.70
3	NJ -2703	9.50	2.51	0.35	15.57	10.34	4.20
4	NJ -2704	9.85	2.23	0.09	11.50	7.33	4.37
5	NJ -2711	9.81	0.53	0.02	14.46	3.55	3.31
6	NJ -2837	10.95	2.89	0.00	12.20	8.43	3.73
7	NJ -2841	4.64	1.84	0.10	6.09	4.03	3.92
8	NJ -2790	4.86	0.80	0.00	10.69	4.54	2.96
9	NJ -2794	2.54	0.91	0.00	6.25	6.60	3.06
10	NJ -2791	10.40	1.44	0.00	11.20	9.20	6.09
11	NJ -2805	4.12	1.73	0.00	7.72	8.19	2.73
12	NJ -2808	4.83	0.56	0.00	10.85	7.95	4.77
13	NJ -2812	6.90	0.73	0.10	14.43	4.75	3.25
14	NJ -2818	8.25	2.16	0.00	11.82	7.50	7.50
15	NJ -2820	7.60	0.90	0.00	10.49	6.19	2.74
16	NJ -2667	6.92	1.36	0.00	14.10	5.26	2.76
17	NJ -2685	3.85	2.01	0.00	8.79	11.52	5.43
18	NJ -2686	5.85	1.60	0.00	14.03	11.20	2.46
19	NJ -2687	5.80	2.06	0.55	13.13	9.44	4.01
20	NJ -2689	6.23	0.63	0.05	9.19	4.11	3.62
21	NJ -2694	9.16	1.95	0.00	14.82	12.27	5.94
22	NJ -2697	8.83	1.45	0.00	12.25	9.13	4.52
23	NJ -2706	5.86	1.21	0.00	9.59	9.14	3.24
24	NJ -2708	10.50	1.83	0.10	15.36	7.03	4.47
25	NTJ 5	9.80	1.75	0.25	17.71	10.05	4.09
26	NJ -2725	7.41	1.43	0.88	8.93	6.76	6.09
27	NJ -2726	13.86	1.22	0.00	18.50	8.01	4.06
28	NJ -2730	9.66	1.57	0.25	12.69	8.29	3.45
29	NJ -2740	7.59	1.25	0.00	11.81	6.84	3.20
30	N-15	5.25	2.25	0.50	8.56	7.28	2.90
	Mean	7.50	1.53	0.11	11.87	7.81	3.95
	SE m±	8.78	0.36	0.12	1.03	0.94	0.53
	CD(P=0.05)	2.20	1.02	0.33	2.93	2.67	1.49

3. Shoot Length(cm)

Significant difference was observed among different Sorghum genotypes for shoot length at three PEG concentrations viz., control, 5% and 10%.

Shoot growth was the most severely inhibited parameter, with the mean falling from 7.50 cm (Control) to an average of 0.11 cm (10% treatment), indicating near-total suppression of aerial growth at high concentration.

Control Conclusion (Optimal Conditions)

Performance: High, with a mean of 7.50 cm., Highest Performer: NJ-2726 produced the longest shoots (13.86 cm), confirming high genetic potential for aerial growth. Lowest Performer: NJ-2794 developed the shortest shoots (2.54 cm).

5% Treatment Conclusion (Moderate Stress)

Performance: Severe restriction, with a mean of 1.53 cm., Highest Performer: NJ-2837 maintained the longest shoot length at 2.89 cm., Lowest Performer: NJ-2711 was the poorest performer, with the shortest shoot length of 0.53 cm.

10% Treatment Conclusion (High Stress): Performance: Near-complete inhibition, with a low mean of 0.11 cm., Highest Performer (Most Resilient): NJ-2725 showed the best resilience, maintaining the longest shoot length (0.88 cm.), Lowest Performers (Complete Inhibition): A large number of genotypes, including NJ-2791, NJ-2740, and NJ-2699, registered 0.00 cm, indicating complete cessation of shoot elongation.

The mean shoot length was decreased with increase in PEG stress in wheat (Aradhna Kumari *et al.*, 2014) [3] and in maize hybrids (Khodarahmpour, 2011) [8]. The extent of reduction in shoot length varies with crop species, for instance it was decreased by 89.8% at -12 bars PEG concentration in maize hybrids (Khodarahmpour, 2011) [8]. Where as in sorghum it was only 25.5% at -0.7 MPa PEG concentration (Fadoul *et al.*, 2016). In the present study also the reduction was 79.6% and 98.5% respectively at -5 and -10 bars osmotic potential. These results suggests that, in general corn genotypes are sensitive to drought.

4. Root Length(cm)

Root length of sorghum genotypes differed significantly at control, -5 bar and -10 bar osmotic potential.

Root length, while significantly reduced, showed better retention than shoot length at the 10% concentration, with the mean dropping from 11.87 cm (Control) to 3.95 cm (10% treatment).

Control Conclusion (Optimal Conditions)

Performance: High, with a mean of 11.87 cm., Highest Performer: NJ-2726 produced the longest roots (18.50 cm.), Lowest Performer: NJ-2841 had the shortest root length (6.09 cm).

5% Treatment Conclusion (Moderate Stress)

Performance: Moderate decline, with a mean of 7.81 cm., Highest Performer: NJ-2699 demonstrated the least inhibition of root growth, achieving the maximum length of 12.54 cm, Lowest Performer: NJ-2711 recorded the shortest root length (3.55 cm).

10% Treatment Conclusion (High Stress)

Performance: Significant restriction, with a mean of 3.95 cm., Highest Performer (Most Tolerant): NJ-2818 was the clear leader, maintaining the maximum length of 7.50 cm, Lowest Performer (Most Inhibited): NJ-2668 showed the lowest root length (2.01 cm).

Similarly, the root length decreased with increasing osmotic potential in all the wheat genotypes (Aradhna Kumari *et al.*, 2014) [3] and maize cultivars (Habtamu Ashagre *et al.*, 2014) [10]. When compared to the shoot, the root length is less affected due to PEG stress and it was 42.3% and 66.7% reduction at 5% and 10% respectively.

Summary

Hence, the present investigation was aimed at evaluating the relative performance of sorghum genotypes for moisture stress tolerance using PEG method through laboratory study. They were initially subjected to physical and physiological screening by inducing moisture stress with polyethyleneglycol. The screening was conducted in petriplate method at three different concentrations (0, 5% and 10%). A significant variation was observed among the

genotypes for germination percentage, seedling vigour index, root length and shoot length.

The overall conclusions from the data show a strong negative correlation between the concentration of the treatment and the measured performance of all genotypes across all four parameters (Germination Percentage, Seedling Vigour Index, Shoot Length, and Root Length).

Severe Inhibition: Shoot Length (SL) and Seedling Vigour Index (SVI) were the most severely affected parameters, with SL showing near-complete inhibition (mean 0.11 cm) and SVI dropping drastically at the 10% concentration.

Differential Impact: Root Length (RL) and Germination Percentage (GP) showed comparatively better tolerance, indicating that the treatment's primary stress mechanism targets growth (shoot, vigour) more aggressively than seed viability and root elongation.

Most Resilient (Tolerant) Genotypes: The best performers under the highest stress (10% treatment) are: NJ-2791: The most tolerant overall, achieving 100% Germination Percentage and the highest Seedling Vigour Index. NTJ 5: Joint best for Germination Percentage at 100%

NJ-2818: Most tolerant for Root Length retention. NJ-2725: Most tolerant for Shoot Length retention.

Most Sensitive Genotypes: NJ-2794: Consistently the most susceptible genotype, ranking among the lowest in Germination Percentage, SVI, SL, and RL across all stress levels. NJ-2711: Highly sensitive to the 5% treatment, ranking lowest in SVI, SL, and RL at that concentration. Optimal Performance (Control). NJ-2726 is the highest-performing genotype under optimal (Control) conditions, achieving the maximum SVI, SL, and RL, representing the maximum genetic potential for growth without stress.

References

1. Abdul-Baki A, Anderson JD. Vigor determination in soybean seed by multiple criteria. *Crop Sci.* 1973;13:630-633.
2. Aradhna Kumari, Sairam RK. Moisture stress-induced increases in the activity of enzymes of osmolyte biosynthesis are associated with stress tolerance in wheat genotypes. *Indian J Plant Physiol.* 2013;18(3):223-230.
3. Aradhna Kumari, Sairam RK, Singh SK, Krishna GK. Early growth response: an indicator of subsequent growth and yield of wheat genotypes grown under simulated water stress conditions. *Indian J Plant Physiol.* 2014;19(2):94-100.
4. Batool N, Ilyas N, Noors T, Saeed M, Mazhar R, Bibi F, Shahzad A. Evaluation of drought stress effects on germination and seedling growth of *Zea mays* L. *Int J Biosci.* 2014;5(4):203-209.
5. Directorate of Economics and Statistics, Ministry of Agriculture and Farmers Welfare. *Indian Agriculture in Brief.* 2024.
6. Das R, Kalika P. Characterization of some upland rice cultivars under moisture stress conditions. *Indian J Plant Physiol.* 2010;15(1):54-60.
7. International Seed Testing Association (ISTA). *Handbook of vigour test methods.* 1995. 117 p.
8. Khodarahmpour Z. Effect of drought stress induced by polyethylene glycol on germination indices in corn (*Zea mays* L.) hybrids. *Afr J Biotechnol.* 2011;10(79):18222-18227.
9. Kotowski F. Temperature relations to germination of vegetable seed. *Proc Am Soc Hortic Sci.* 1926;23:176-184.
10. Habtamu Ashagre, Melkamu Zeleke, Mesfin Mulugeta, Ermias Estifanos. Evaluation of highland maize (*Zea mays* L.) cultivars for polyethylene glycol-induced moisture stress tolerance at germination and seedling growth stages. *J Plant Breed Crop Sci.* 2014;6(7):77-83.
11. Khayatnezhad M, Gholamin R. The effect of drought stress on leaf chlorophyll content and stress resistance in maize cultivars (*Zea mays*). *Afr J Microbiol Res.* 2011;6(12):2844-2848.
12. Khayatnezhad M, Gholamin R, Jamaati-e-Somarin S, Zabihi-e-Mahmoodabad R. Effects of PEG stress on corn cultivars (*Zea mays* L.) at germination stage. *World Appl Sci J.* 2010;11(5):504-506.
13. Michel BE, Kaufmann MR. The osmotic potential of polyethylene glycol 6000. *Plant Physiol.* 1972;51(5):914-916.
14. Perez de Vida FB, Laca EA, Mackill DJ, Fernandez G, Fischer AJ. Relating rice traits to weed competitiveness and yield: a path analysis. *Weed Sci.* 2006;54:1122-1131.
15. Prasad VBR, Govindaraj M, Djanaguiraman M, Djalovic I, Shailani A, Rawat N, Singla-Pareek SL, Pareek A, Prasad PVV. Drought and high-temperature stress in sorghum: physiological, genetic, and molecular insights and breeding approaches. *Int J Mol Sci.* 2021;22(19):82-86.
16. Sarshad A, Talei D, Torabi M, Rafei F, Nejatkhah P. Morphological and biochemical responses of *Sorghum bicolor* (L.) Moench under drought stress. *Surf Sci Technol.* 2021;9(2):210-218.
17. Shahriari AAB, Ghizan P, Saleh B, Rahim ABA. Germination at low osmotic potential as a selection criterion for drought stress tolerance in sweet corn. *Afr J Biotechnol.* 2014;13(2):294-300.
18. Zahoor Ahmad, Ejaz Ahmad W, Rashid Ahmad, Muhammad Aamir I, Masood Iqbal A. Studies on screening of maize (*Zea mays* L.) hybrids under drought stress conditions. *J Adv Bot Zool.* 2015;2(4):1-5.