www.ThePharmaJournal.com

The Pharma Innovation

ISSN (E): 2277-7695
ISSN (P): 2349-8242
TPI 2024; 13(4): xxx-xxx

www.thepharmajournal.com
Received: xx-01-2024
Accepted: xx-02-2024

Ukey BN
Ph.D. Scholar's, Seed Science & Technology, Department of Agricultural Botany, Mahatma Phule Krushi Vidyapeeth, Rahuri, Dist.-Ahmednagar, Maharashtra, India

Dr. VR Shelar
Seed Research Officer, Seed Science & Technology, Department of Agricultural Botany, Mahatma Phule Krushi Vidyapeeth, Rahuri, Dist.-Ahmednagar, Maharashtra, India

Dr. MP Deshmukh
Soybean Breeder, Agricultural Research Station, Kajbe Digral Dist.-Sangli, Maharashtra, India

Dr. MT Bhingarde
Associate Professor, Seed Science & Technology, Department of Agricultural Botany, Mahatma Phule Krushi Vidyapeeth, Rahuri, Dist.-Ahmednagar, Maharashtra, India

Corresponding Author:
Ukey BN
Ph.D. Scholar's, Seed Science & Technology, Department of Agricultural Botany, Mahatma Phule Krushi Vidyapeeth, Rahuri, Dist.-Ahmednagar, Maharashtra, India

Effects of moisture stress on seed quality and seed morphometry characteristics of soybean [*Glycine max* (L.) cultivars

Ukey BN, Dr. VR Shelar, Dr. MP Deshmukh and Dr. MT Bhingarde

Abstract
Soybean, scientifically known as *Glycine max* (L.). Merr., is recognized as a drought sensitive crop. It responds to varying soil moisture stress through morphological, anatomical, physiological, and biochemical adaptations. The extent of damage to the plant depends on the specific cultivar, the stress duration and intensity, and the growth stage when the moisture stress occurs. This stress can lead to significant negative impacts on plant development, productivity, and seed quality. The field experiment was laid out Rainout shelter PGI. Farm Mahatma Phule Krushi Vidyapeeth, Rahuri, District Ahmednagar to evaluate the effects of moisture stress on the seed quality and seed morphometry parameters of soybean cultivars. Eleven soybean cultivars KDS-753, KDS-980, NRC-130, NRC-131, JS-335, DS-228, KDS-726, JS-9305, KDS-344, NRC- 132 and NRC-129 were subjected to water stress by withholding for three different moisture regimes *viz.,* controlled moisture (5 irrigation), terminal moisture (3 irrigation) and severe moisture stress (3 irrigation). The experiment was designed as a Factorial Randomized Block Design (FRBD) and laboratory data were analyzed Factorial Completely Randomized Block Design (FCRD). All treatment combinations were replicated three times. Seed quality characters such as seed germination (%), seedling length, seedling dry weight, seed vigour index-I, seed vigour index-II, electrical conductivity, seed moisture (%) and seed morphometry *viz.,* seed length, seed width, seed area, seed diameter, seed perimeter, and seed roundness were measured. The study revealed that certain cultivars, such as KDS-726, KDS-753, and JS-9305, maintained superior seed quality and morphometry parameters even under water stress conditions. Conversely, NRC-132 and NRC-131 exhibited the least desirable performance for these traits under the same circumstances.

Keywords: Soybean cultivars, moisture stress, moisture regimes, seed quality, seed morphometry

Introduction

Soybean [*Glycine max* (L.) Merill] is an important legume crop belongs to the family *Leguminaceae*, sub-family *papilionaceae* and genus *Glycine*. Soybean, often referred to as the 'Golden bean,' has emerged as a remarkable crop in the 20th century, offering multiple benefits as a nutritious food source, valuable animal feed, and versatile industrial raw material. It stands out among pulses due to its high-quality protein (43.2%) and oil content (19.5%), making it a vital component in our food and agriculture systems. (Chowdhury *et al.*, 2015). Soybean holds the third place in India's edible oil market, offering essential nutrients like amino acids, vitamins A, B, and D. The sprouted seeds provide additional vitamin C, phosphorus, and sulphur. Madhya Pradesh, known as the Soybean State, leads in production, with significant contributions from Maharashtra, Rajasthan, and Karnataka.

In arid and semiarid regions globally, the lack of irrigation water significantly impacts the growth potential of primary agricultural crops. This water scarcity poses a considerable challenge for farmers, hindering their ability to produce sufficient food to meet the growing global demand (Nezhadahmadi *et al.*, 2013) [12]. To combat the challenges of low yield caused by water stress in warm regions, researchers and breeders should focus on developing and characterizing drought-tolerant soybean germplasm. By incorporating these advancements into breeding programs, it is possible to improve crop performance in water-limited environments, benefiting both economically and food security-wise, especially in countries like India. Addressing the worldwide water scarcity issue in agriculture necessitates focusing on improving soybean drought adaptation. This includes the selection and cultivation of drought-resistant cultivars, ensuring better seed germination and vigor during reproductive stages, and ultimately maintaining seed quality under such challenging conditions. (Drummond *et al.*, 1983) [5].

Studying the relationship between seed size, weight, and quality in plants experiencing drought stress can provide valuable insights into their genetic and environmental factors. This knowledge can help researchers develop strategies to improve seed production and ensure better crop resilience under challenging conditions (Honeycutt *et al.*, 1989) [11]. This study aimed to investigate the impact of moisture stress on soybean seed vigor and related morphometric features, as well as assessing various soybean cultivars under diverse moisture conditions to understand their response to moisture stress.

Materials and Methods

The eleven cultivars of soybean were obtained from "Agricultural Research Station", Kasbe Digraj, Sangli. The cultivars *viz.*, KDS-753, KDS-980, NRC-130, NRC-131, JS-335, DS-228, KDS-726, JS-9305, KDS-344, NRC-132 and NRC-129 were used to screening under different moisture regimes for this study. The experiment was conducted during the *kharif season*-2018 at Rainout shelter Post Graduate Institute; M.P.K.V Rahuri in a factorial randomized block design (FRBD) with three replications and two factors *i.e.* eleven soybean cultivars and three different moisture regimes. The eleven soybean cultivars treated with Controlled moisture (Irrigation was provided to all the critical growth stages of soybean *viz.*, germination stage, seedling stage, before flowering stage, pod formation and pod filling stage), Terminal moisture stress (Irrigation was ceased at pod formation and pod filling stage) and Sever moisture stress (Irrigation was ceased at before flowering stage, pod formation and pod filling stage of soybean). The seeds of the soybean cultivars were sown with spacing of 30 X 10 cm. The harvested seeds of soybean cultivars of three different moisture regimes were taken for the assessment of seed vigour along with seed morphometry characteristics. The laboratory experiment was laid out in the Seed Technology Research Unit laboratory by using Factorial Completely Randomized Block Design (FCRD). The harvested seeds of *kharif season*-2018 were kept for evaluation of seed quality parameters *viz*., seed germination (%) , seedling length (cm), seedling dry weight (g), seed vigour index-I [seed germination percentage x seedling length (cm)], seed vigour index-II [seed germination percentage x seedling dry weight (g)], electrical conductivity (dsm^{-1}) and six seed morphometry parameters *i.e.*, seed length (mm), seed width(mm), seed area (mm^2), seed diameter (mm), seed perimeter (mm) and seed roundness(mm) were recorded by using the BOVIS seed image analyzer.

Result and Discussion

Seed germination (%)

The data pertaining to seed germination (%) of soybean as influenced by different moisture regimes and cultivars exhibited significant difference. Among the moisture regimes, controlled moisture (5 irrigations) exhibited maximum seed germination (93.20%) followed by terminal moisture stress (3 irrigation) (82.36%) while, severe moisture stress (2 irrigations) showed minimum seed germination (81.15%) irrespective of soybean cultivars. Among the cultivars, KDS-726 exhibited maximum seed germination (90.61%) followed by cultivar KDS-753 (89.56%) and minimum seed germination (80.67%) was recorded in the NRC-132 cultivar. The interaction of different moisture regimes and cultivars revealed that, no-significant difference. The seed germination (%) was ranged between 76.00 to 97.33 %. Among the moisture regimes, maximum seed germination (97.33%) was recorded at controlled moisture (5 irrigations) in the cultivar KDS-726 followed by terminal moisture stress (3 irrigations) (88.50%) and the minimum seed germination (76.00%) was observed at severe moisture stress (2 irrigations) in the cultivars NRC-132. The results of the present findings are in accordance Drummond *et al.*, (1983) [5], who observed that the increasing severity of moisture stress, the rate of seed germination, seedling length was reduced in soybean. Moisture stress has affected many aspects of plant growth and seed quality during the crop maturity. The seed quality reduced due to the moisture stress during the pod development and seed maturation. In soybean moisture stress during seed development reduced seed germination. The present investigations are in close agreement with Dombos and Mullen (1991) [4], Gibson and Mullen (1996) [8] in soybean.

Seedling length

The data pertaining to seedling length of soybean as influenced by different moisture regimes and cultivars exhibited significant difference. Among the moisture regimes, controlled moisture (5 irrigations) showed maximum seedling length (41.86 cm) followed by terminal moisture stress (3 irrigations) (31.13 cm) while; severe moisture stress (2 irrigations) showed minimum seedling length (22.11 cm) irrespective of soybean cultivars. Among the cultivars, KDS-726 exhibited maximum (39.61 cm) seedling length followed by cultivar KDS-753 (37.62 cm) while, minimum seedling length (25.65 cm) was recorded in the cultivar NRC-132 irrespective of moisture regimes. The interaction of different moisture regimes and cultivars revealed that, significant difference. The seedling length was ranged between 16.64 to 48.52 cm. Among the moisture regimes, maximum seedling length (48.52 cm) was recorded at controlled moisture (5 irrigations) in the cultivar KDS-726 followed by terminal moisture stress (3 irrigations) (39.11 cm) and minimum seedling length (16.64 cm) was observed at severe moisture stress (2 irrigations) in the cultivars NRC-132. The findings of the present investigation are in accordance with Arooj *et al.*, (2017) [1] who stated that lowest seedling length were recorded in moisture stress than the controlled moisture. Golezani *et al.*, (2018) [10] who observed that with increasing severity of moisture stress seedling length was reduced in soybean. Similar findings were reported by Wijewardana *et al.*, (2019) [14] in soybean.

Seedling dry weight (g)

The data pertaining to seedling dry weight of soybean as influenced by different moisture regimes and cultivars exhibited significant difference. Among the moisture regimes, controlled moisture (5 irrigation) registered maximum seedling dry weight (1.88 g) followed by terminal moisture stress (3 irrigations) (1.12 g) while, severe moisture stress (2 irrigation) showed minimum seedling dry weight (0.68 g) irrespective of soybean cultivars. Among the cultivars, KDS-726 exhibited maximum seedling dry weight (1.61 g) followed by cultivar KDS-753 (1.47 g) and minimum seedling dry weight (0.94 g) was recorded in the cultivar NRC-132 irrespective of moisture regimes. The interaction of different moisture regimes and cultivars revealed that significant difference. The seedling dry weight was ranged between 0.39 to 2.26 g. Among the moisture regimes, maximum seedling dry weight (2.26 g) was recorded at controlled moisture (5 irrigation) in the cultivar KDS-726 followed by terminal moisture stress (3 irrigation) (1.50 g) and minimum seedling dry weight (0.39 g) was observed at severe moisture stress (2 irrigation) in the cultivar NRC-132. Similar results were reported by the Gibson and Mullen (1996) [8] who revealed that maximum seedling dry weight might be due to good quality and vigorous seed, which was produced under sufficient moisture during the plant growth, seed maturity up to seed development. The seedling dry weight actually represents the mass in quantum of seed reservoir that could be converted into seedling. Similar findings were attributed by the earlier workers like Bonny *et al.*, (2015) [2], Golezani *et al.*, (2018) [10] and Wijewardana *et al.*, (2019) [14] in soybean.

Seed vigour index-I

The data pertaining to seed vigour index-I of soybean as influenced by different moisture regimes and cultivars exhibited significant difference. Among the moisture regimes, controlled moisture (5 irrigation) recorded maximum seed vigour index-I (3916.04) followed by terminal moisture stress (3 irrigations) (2623.07) while, severe moisture stress (2 irrigation) showed minimum seed vigour index-I (1807.21) irrespective of soybean cultivars. Among the cultivars, KDS-726 exhibited maximum seed vigour index-I (3622.01) followed by cultivar KDS-753 (3409.96) while, minimum seed vigour index-I (2099.46) was recorded in the cultivar NRC-132 irrespective of moisture regimes. The interaction of different moisture regimes and soybean cultivars revealed that, significant difference. The seed vigour index-I was ranged of 1264.64 to 4722.45. Among the moisture a regime, maximum seed vigour index-I (4722.45) was recorded at controlled moisture (5 irrigation) in the cultivar KDS-726 followed by terminal moisture stress (3 irrigation) (3461.24) and the minimum seed vigour index-I (1264.64) was observed at severe moisture stress (2 irrigation) in the cultivars NRC-132. Similar results were also reported by Pervez *et al.*, (2009) who reported that seed vigour was lowered in soybean which was harvested seed of moisture stress. Moisture stress is the most important constraints of quality seed production it is affecting on the seed vigor. Similar results were attributed by the Younesi and Moradi (2009) [15] in sorgum and Golezani (2016) [9] in spring safflower.

Seed vigor index-II

The data pertaining to seed vigour index-II of soybean as influenced by different moisture regimes and cultivars exhibited significant difference. Among the moisture regimes, controlled moisture (5 irrigation) recorded maximum seed vigour index-II (175.77) followed by terminal moisture stress (3 irrigations) (94.42) while, severe moisture stress (2 irrigation) showed minimum seed vigour index-II (55.70) irrespective of soybean cultivars. Among the cultivars, KDS-726 exhibited maximum seed vigour index-II (147.96) followed by cultivar KDS-753 (133.82) and minimum seed vigour index-II (77.68) was recorded in the cultivar NRC-132 irrespective of moisture regimes. The interaction of different moisture regimes and cultivars revealed that significant difference. The seed vigour index-II was ranged between 29.64 to 219.97. Among the moisture regimes, maximum seed vigour index-II (219.97) was recorded at controlled moisture (5 irrigation) in the cultivar KDS-726 followed by terminal moisture stress (3 irrigation) (132.75) while, minimum seed vigour index-II (29.64) was observed at severe moisture stress (2 irrigation) in the cultivars NRC-132. These results are in conformity with the findings of Bonny *et al.*, (2015) in soybean who revealed that different irrigation treatments disturbing, seed filling and during flowering and pod positions on seed quality soybean cultivars. He determined by seed weight, electrical conductivity of seed leachates, viability, germination rate and seedling dry weight significantly reduced under limited watering. Moisture stressed seed significantly reduced the speed of germination and ultimately effects on seedling vigour. Similar results were reported by Golezani (2016) [9] in safflower cultivars and Arooj *et al.*, (2017) [1] in wheat.

Electrical conductivity (dsm^{-1})

The data pertaining to electrical conductivity of soybean as influenced by the different moisture regimes and cultivars exhibited significant difference. Among the moisture regimes, severe moisture stress (2 irrigation) exhibited maximum electrical conductivity (0.61 dsm^{-1}) followed by terminal moisture stress (3 irrigations) (0.56 dsm^{-1}) while, controlled moisture (5 irrigation) noticed minimum electrical conductivity (0.56 dsm^{-1}) irrespective of soybean cultivars. Among the cultivars, NRC-132 exhibited maximum (0.56 dsm^{-1}) electrical conductivity followed by cultivar NRC-131 (0.55 dsm^{-1}) and minimum (0.43 dsm^{-1}) electrical conductivity was recorded in the cultivars KDS-726 irrespective of moisture regimes.

The data pertaining to electrical conductivity of soybean as influenced by interaction of different moisture regimes and cultivars revealed that significant difference. The electrical conductivity was ranged between 0.27 to 0.67 dsm^{-1}. Among the moisture regimes, maximum electrical conductivity (0.67 dsm^{-1}) was recorded at severe moisture stress (2 irrigation) in the cultivar NRC-132 followed by terminal moisture stress (3 irrigation) (0.62 dsm^{-1}) and the minimum electrical conductivity (0.27 dsm^{-1}) was observed at controlled moisture (5 irrigation) in the cultivar KDS-726. Similar results were obtain by Dombos and Mullen (1989) [4] who reported that electrical conductivity test results are significantly correlated with seed quality which has been produced in the field of varies environmental condition. Electrical conductivity is increases with decrease seed quality that means electrical conductivity show the quality characteristics of seed (Fougereux *et al.*, 1997). High quality seeds have been shown possess increased membrane integrity as a result of minimum storage deterioration and mechanical injury. These results were comparable with those obtained by earlier workers Egli *et al.*, (2005), Golezani *et al.*, (2018) [10] and Wijewardana *et al.*, (2019) [14] in soybean.

Seed morphometry

Seed length (mm)

The data pertaining to seed length of soybean as influenced by different moisture regimes and cultivars exhibited significant difference. Among the moisture regimes, controlled moisture (5 irrigations) exhibited maximum seed length (5.47 mm) followed by terminal moisture stress (3 irrigations) (2.93 mm) while, severe moisture stress (2 irrigations) showed minimum seed length (1.94 mm) irrespective of soybean cultivars.

Among the cultivars, KDS-726 exhibited maximum seed length (4.99 mm) followed by cultivar KDS-753 (4.27 mm) and the minimum seed length (2.29 mm) were recorded in the cultivar NRC-132 irrespective of moisture regimes. The interaction of moisture regimes and cultivars revealed that significant difference. The seed length was ranged between 0.80 to 7.00 mm. Among the moisture regimes, maximum seed length (7.00 mm) was recorded at controlled moisture (5 irrigations) in the cultivar KDS-726 followed by terminal moisture stress (3 irrigations) (4.48 mm) and minimum seed length (0.80 mm) was observed at severe moisture stress (2 irrigations) in the cultivars NRC-132.

Seed width

The data pertaining to seed width of soybean as influenced by different moisture regimes and cultivars exhibited significant difference. Among the moisture regimes, controlled moisture (5 irrigations) exhibited maximum seed width (6.02 mm) followed by terminal moisture stress (3 irrigations) (4.08 mm) and severe moisture stress (2 irrigations) showed the minimum seed width (2.96 mm) irrespective of soybean cultivars. Among the cultivars, KDS-726 exhibited maximum seed width (6.05 mm) followed by cultivar KDS-753 (5.43 mm) and minimum seed width (2.85 mm) was recorded in the cultivar NRC-132 irrespective of moisture regimes. The data pertaining to seed width of soybean as influenced by interaction of different moisture regimes and cultivars revealed that no-significant difference. The seed width was ranged from 1.45 to 7.70 mm. Among the moisture regimes, maximum seed width (7.70 mm) was recorded at controlled moisture (5 irrigations) in the cultivar KDS-726 followed by terminal moisture stress (3 irrigations) (5.80 mm) and the minimum seed width (1.45 mm) was observed at severe moisture stress (2 irrigations) in the cultivar NRC-132.

Seed area (mm^2)

The data pertaining to seed area of soybean as influenced by different moisture regimes and cultivars exhibited significant difference. Among the moisture regimes, controlled moisture (5 irrigations) exhibited maximum seed area (14.41 mm^2) followed by terminal moisture stress (3 irrigations) (7.75 mm^2) while, severe moisture stress (2 irrigations) showed minimum seed area (6.19 mm^2) irrespective of soybean cultivars. Among the cultivars, KDS-726 exhibited maximum seed area (16.05 mm^2) followed by cultivar KDS-753 (14.02 mm^2) and minimum seed area (5.44 mm^2) was recorded in the cultivar NRC-132 irrespective of moisture regimes. The data pertaining to seed area of soybean as influenced by interaction of different moisture regimes and cultivars revealed that significant difference. The seed area was ranged between 3.05 to 23.75 mm^2. Among the moisture regimes, maximum seed area (23.75 mm^2) was recorded at controlled moisture (5 irrigations) in the cultivar KDS-726 followed by terminal moisture stress (3 irrigations) (13.26 mm^2) and minimum seed area (3.05 mm^2) was observed at severe moisture stress (2 irrigations) in the cultivar NRC-132.

Seed diameter (mm)

The data pertaining to seed diameter of soybean as influenced by different moisture regimes and cultivars exhibited significant difference. Among the moisture regimes, controlled moisture (5 irrigations) exhibited maximum seed diameter (4.24 mm) followed by terminal moisture stress (3 irrigations) (3.09 mm) while, severe moisture stress (2 irrigations) showed the minimum seed diameter (2.75 mm) irrespective of soybean cultivars. Among the cultivars, KDS-726 exhibited maximum seed diameter (3.46 mm) followed by cultivar KDS-753 (4.16 mm) while, minimum seed diameter (2.56 mm) was recorded in the cultivar NRC-132 irrespective of moisture regimes. The interaction of different moisture regimes and cultivars revealed that no-significant difference (Table 4.36). The seed diameter was ranged from 1.97 to 5.50 mm. Among the moisture regimes maximum seed diameter (5.50 mm) was recorded at controlled moisture (5 irrigations) in the cultivar KDS-726 followed by terminal moisture stress (3 irrigations) (4.11 mm) and the minimum seed diameter (1.97 mm) was observed at severe moisture stress (2 irrigations) in the cultivar NRC-132.

Seed roundness (mm)

The data pertaining to seed roundness of soybean as influenced by different moisture regimes and cultivars exhibited significant difference. Among the moisture regimes, controlled moisture (5 irrigations) exhibited maximum seed roundness (2.32 mm) followed by terminal moisture stress (3 irrigations) (2.15 mm) while, severe moisture stress (2 irrigations) showed the minimum seed roundness (1.89 mm) irrespective of soybean cultivars. Among the cultivars, KDS-726 exhibited maximum seed roundness (3.32 mm) followed by cultivar KDS-753 (2.92 mm) and minimum seed roundness (1.32 mm) was recorded in the cultivar NRC-132 irrespective of moisture regimes. The data pertaining to seed roundness of soybean as influenced by interaction of different moisture regimes and cultivars revealed that significant difference. The seed roundness was ranged between 1.11 to 3.58 mm. Among the moisture regimes maximum seed roundness (3.58 mm) was recorded at controlled moisture (5 irrigations) in the cultivar KDS-726 followed by terminal moisture stress (3 irrigations) (3.17 mm) and minimum seed roundness (1.11 mm) was observed at severe moisture stress (2 irrigations) in the cultivars NRC-132.

Seed perimeter (mm)

The data pertaining to seed perimeter of soybean as influenced by different moisture regimes and cultivars exhibited significant difference. Among the moisture regimes, controlled moisture exhibited (5 irrigations) maximum seed perimeter (17.51 mm) followed by terminal moisture stress (3 irrigations) (10.65 mm) while, severe moisture stress (2 irrigations) showed minimum seed perimeter (7.85 mm) irrespective of soybean cultivars. Among the cultivars, KDS-726 exhibited maximum seed perimeter (16.93 mm) followed by cultivar KDS-753 (15.12 mm) while, minimum seed perimeter (7.83 mm) was recorded in the cultivar NRC-132 irrespective of moisture regimes. The interaction of different moisture regimes and cultivars revealed that no-significant difference. The seed perimeter was ranged between 3.70 to 22.40 mm. Among the moisture regimes maximum seed perimeter (22.40 mm) was recorded at controlled moisture (5 irrigations) in the cultivar KDS-726 followed by terminal moisture stress (3 irrigations) (15.60 mm) while, minimum seed perimeter (3.70 mm) was observed at severe moisture stress (2 irrigations) in the cultivar NRC-132.

Table 1: Effect of different moisture regimes on seed germination (%) of soybean cultivars during the *kharif* season – 2018

Cultivars / Treatments	*Kharif season*-2018			
	Moisture regimes			
	5-Irrigation (Controlled moisture)	3-Irrigation (Terminal moisture stress)	2-Irrigation (Severe moisture stress)	Mean
	Seed germination (%)			
KDS-753	96.67 (79.48)	87.00 (68.87)	85.00 (67.21)	89.56 (70.85)
KDS-980	95.50 (77.75)	85.00 (67.21)	82.33 (65.15)	87.61 (70.04)
NRC-130	93.50 (75.23)	83.33 (65.91)	82.33 (65.14)	86.39 (68.76)
NRC-131	88.50 (70.18)	80.00 (63.43)	77.67 (61.80)	82.06 (65.14)
JS-335	92.67 (74.29)	83.33 (65.91)	80.67 (63.92)	85.56 (68.04)
DS-228	95.67 (77.99)	85.33 (67.48)	82.33 (65.15)	87.78 (70.20)
KDS-726	97.33 (80.60)	88.50 (70.18)	86.00 (68.03)	90.61 (72.94)
JS-9305	96.50 (79.22)	86.50 (68.44)	83.00 (65.65)	88.67 (71.10)
KDS-344	90.17 (71.72)	81.17 (64.28)	78.00 (62.03)	83.11 (66.01)
NRC-132	86.33 (68.30)	79.67 (63.20)	76.00 (60.67)	80.67 (64.06)
NRC-129	92.33 (73.93)	83.00 (65.65)	79.33 (62.96)	84.89 (67.51)
Mean	93.20 (75.34)	83.89 (66.41)	81.15 (64.34)	86.08 (68.69)
	Cultivars	Treatments	Interaction	
SEM (±)	0.579	1.109	1.921	
CD at 1 %	1.639	3.139	NS	

*Figures in parenthesis are indicating Arc sine transformed values.

Table 2: Effect of different moisture regimes on seedling length (cm) and seedling dry weight (g) of soybean cultivars during the *kharif seasons* – 2018

Cultivars / Treatments	*Kharif season*-2018				*Kharif season*-2018			
	Moisture regimes				Moisture regimes			
	5-Irrigation (Controlled moisture)	3-Irrigation (Terminal moisture stress)	2-Irrigation (Severe moisture Stress)	Mean	5-Irrigation (Controlled moisture)	3-Irrigation (Terminal moisture stress)	2-Irrigation (Severe moisture Stress)	Mea n
	Seedling length (cm)				Seedling dry weight (g)			
KDS-753	48.32	36.45	28.09	37.62	2.12	1.36	0.92	2.12
KDS-980	42.55	32.14	22.22	32.30	1.94	1.18	0.74	1.94
NRC-130	42.40	29.99	20.07	30.82	1.88	1.12	0.68	1.88
NRC-131	36.02	26.61	17.39	26.67	1.65	0.89	0.45	1.65
JS-335	40.07	28.66	19.74	29.49	1.85	1.09	0.65	1.85
DS-228	44.66	33.25	24.33	34.08	1.96	1.20	0.76	1.96
KDS-726	48.52	39.11	31.19	39.61	2.26	1.50	1.06	2.26
JS-9305	45.97	35.56	27.64	36.39	2.04	1.28	0.84	2.04
KDS-344	37.20	26.79	17.87	27.29	1.68	0.92	0.48	1.68
NRC-132	34.36	25.95	16.64	25.65	1.59	0.83	0.39	1.59
NRC-129	40.34	27.93	18.01	28.76	1.70	0.94	0.50	1.70
Mean	41.86	31.13	22.11	31.70	1.88	1.12	0.68	1.88
	Cultivars	Treatments	Interaction		Cultivars	Treatments	Interaction	
SEM (±)	0.420	0.220	0.728		0.009	0.017	0.029	
CD at 1 %	1.190	0.621	2.061		0.025	0.048	0.083	

Table 3: Effect of different moisture regimes on seed vigour index-I and seed vigour index-II of soybean cultivars during the *kharif season*-2018

Cultivars / Treatments	*Kharif season*-2018				*Kharif season*-2018			
	Moisture regimes				Moisture regimes			
	5-Irrigation (Controlled moisture)	3-Irrigation (Terminal moisture stress)	2-Irrigation (Severe moisture Stress)	Mean	5-Irrigation (Controlled moisture)	3-Irrigation (Terminal moisture stress)	2-Irrigation (Severe moisture Stress)	Mean
	Seed vigour index-I				Seed vigour index-II			
KDS-753	4671.09	3171.15	2387.65	3409.96	204.94	118.32	78.20	133.82
KDS-980	4063.53	2731.90	1829.37	2874.93	185.27	100.30	60.92	115.50
NRC-130	3964.40	2499.07	1652.36	2705.28	175.78	93.33	55.98	108.36
NRC-131	3187.77	2128.80	1350.68	2222.42	146.03	71.20	34.95	84.06
JS-335	3713.29	2388.24	1592.43	2564.65	171.44	90.83	52.44	104.90
DS-228	4272.62	2837.22	2003.09	3037.64	187.51	102.40	62.57	117.49
KDS-726	4722.45	3461.24	2682.34	3622.01	219.97	132.75	91.16	147.96
JS-9305	4436.11	3075.94	2294.12	3268.72	196.86	110.72	69.72	125.77

KDS-344	3354.32	2174.54	1393.86	2307.58	151.49	74.68	37.44	87.87
NRC-132	2966.30	2067.44	1264.64	2099.46	137.26	66.13	29.64	77.68
NRC-129	3724.59	2318.19	1428.73	2490.51	156.96	78.02	39.67	91.55
Mean	3916.04	2623.07	1807.21	2782.11	175.77	94.42	55.70	108.63
	Cultivars		Treatments	Interaction	Cultivars		Treatments	Interaction
SEM (±)	37.424		19.544	64.820	1.531		0.800	2.652
CD at 1 %	105.910		55.310	183.442	4.333		2.263	7.505

Table 4: Effect of different moisture regimes on electrical conductivity (dsm^{-1}) and seed length (mm) of soybean cultivars during the *kharif season*- 2018

Cultivars / Treatments	***Kharif season*-2018**				***Kharif season*-2018**			
	Moisture regimes				**Moisture regimes**			
	5-Irrigation (Controlled moisture)	**3-Irrigation (Terminal moisture stress)**	**2-Irrigation (Severe moisture Stress)**	**Mean**	**5-Irrigation (Controlled moisture)**	**3-Irrigation (Terminal moisture stress)**	**2-Irrigation (Severe moisture Stress)**	**Mean**
	Electrical conductivity (dsm^{-1})				**Seed length (mm)**			
KDS-753	0.30	0.48	0.59	0.46	6.50	3.70	2.60	4.27
KDS-980	0.32	0.54	0.59	0.48	5.60	3.08	2.10	3.59
NRC-130	0.33	0.55	0.60	0.49	5.30	2.78	1.80	3.29
NRC-131	0.39	0.61	0.66	0.55	4.60	2.08	1.10	2.59
JS-335	0.36	0.58	0.63	0.52	5.10	2.58	1.60	3.09
DS-228	0.31	0.53	0.58	0.47	5.90	3.38	2.40	3.89
KDS-726	0.27	0.49	0.54	0.43	7.00	4.48	3.50	4.99
JS-9305	0.31	0.53	0.58	0.47	6.20	3.68	2.70	4.19
KDS-344	0.38	0.59	0.64	0.54	4.70	2.18	1.20	2.69
NRC-132	0.40	0.62	0.67	0.56	4.30	1.78	0.80	2.29
NRC-129	0.37	0.59	0.64	0.53	5.00	2.48	1.50	2.99
Mean	0.34	0.56	0.61	0.50	5.47	2.93	1.94	3.45
	Cultivars		Treatments	Interaction	Cultivars		Treatments	Interaction
SEM (±)	0.007		0.004	0.012	0.025		0.049	0.084
CD at 1 %	0.019		0.010	0.033	0.072		0.138	NS

Table 5: Effect of different moisture regimes on seed width (mm) and seed area (mm^2) of soybean cultivars during the *kharif season* - 2018

Cultivars / Treatments	***Kharif season*-2018**				***Kharif season*-2018**			
	Moisture regimes				**Moisture regimes**			
	5-Irrigation (Controlled moisture)	**3-Irrigation (Terminal moisture stress)**	**2-Irrigation (Severe moisture Stress)**	**Mean**	**5-Irrigation (Controlled moisture)**	**3-Irrigation (Terminal moisture stress)**	**2-Irrigation (Severe moisture Stress)**	**Mean**
	Seed width (mm)				**Seed area (mm^2)**			
KDS-753	7.23	4.90	4.15	5.43	21.23	11.40	9.45	14.02
KDS-980	6.20	4.30	3.15	4.55	14.51	8.09	6.47	9.69
NRC-130	6.00	4.10	2.95	4.35	13.20	7.11	5.60	8.63
NRC-131	5.00	3.10	1.95	3.35	9.62	4.56	3.36	5.85
JS-335	5.60	3.70	2.55	3.95	12.56	6.65	5.18	8.13
DS-228	6.50	4.60	3.45	4.85	15.20	8.60	6.92	10.24
KDS-726	7.70	5.80	4.65	6.05	23.75	13.26	11.16	16.05
JS-9305	6.90	5.00	3.85	5.25	17.34	10.23	8.39	11.99
KDS-344	5.20	3.30	2.15	3.55	10.75	5.35	4.05	6.71
NRC-132	4.50	2.60	1.45	2.85	9.07	4.19	3.05	5.44
NRC-129	5.40	3.50	2.25	3.72	11.34	5.77	4.41	7.17
Mean	6.02	4.08	2.96	4.35	14.41	7.75	6.19	9.45
	Cultivars		Treatments	Interaction	Cultivars		Treatments	Interaction
SEM (±)	0.030		0.057	0.099	0.069		0. 131	0.228
CD at 1 %	0.084		0.161	NS	0.194		0.372	0.644

Table 6: Effect of different moisture regimes on seed diameter (mm) and seed roundness (mm) of soybean cultivars during the *kharif season* - 2018

Cultivars / Treatments	*Kharif season*-2018				*Kharif season*-2018			
	Moisture regimes				Moisture regimes			
	5-Irrigation (Controlled moisture)	3-Irrigation (Terminal moisture stress)	2-Irrigation (Severe moisture Stress)	Mean	5-Irrigation (Controlled moisture)	3-Irrigation (Terminal moisture stress)	2-Irrigation (Severe moisture Stress)	Mean
	Seed diameter (mm)				Seed roundness (mm)			
KDS-753	5.20	3.81	3.47	4.16	3.28	2.87	2.61	2.92
KDS-980	4.30	3.21	2.87	3.46	2.38	2.27	2.01	2.22
NRC-130	4.10	3.01	2.67	3.26	2.18	2.07	1.81	2.02
NRC-131	3.50	2.41	2.07	2.66	1.58	1.47	1.21	1.42
JS-335	4.00	2.91	2.57	3.16	2.08	1.97	1.71	1.92
DS-228	4.40	3.31	2.97	3.56	2.48	2.37	2.11	2.32
KDS-726	5.50	4.11	3.77	4.46	3.58	3.17	2.91	3.22
JS-9305	4.70	3.61	3.27	3.86	2.78	2.67	2.41	2.62
KDS-344	3.70	2.61	2.27	2.86	1.78	1.67	1.41	1.62
NRC-132	3.40	2.31	1.97	2.56	1.48	1.37	1.11	1.32
NRC-129	3.80	2.71	2.37	2.96	1.88	1.77	1.51	1.72
Mean	4.24	3.09	2.75	3.36	2.32	2.15	1.89	2.12
	Cultivars	Treatments	Interaction		Cultivars	Treatments	Interaction	
SEM (±)	0.023	0.044	0.076		0.008	0.004	0.014	
CD at 1 %	0.065	0.124	NS		0.023	0.012	0.039	

Table 7: Effect of different moisture regimes on seed perimeter (mm) of soybean cultivars during the *kharif season* - 2018

Cultivars / Treatments	*Kharif season*-2018			
	Moisture regimes			
	5-Irrigation (Controlled moisture)	3-Irrigation (Terminal moisture stress)	2-Irrigation (Severe moisture Stress)	Mean
	Seed perimeter (mm)			
KDS-753	20.96	13.50	10.90	15.12
KDS-980	18.00	11.20	8.40	12.53
NRC-130	17.30	10.50	7.70	11.83
NRC-131	14.60	7.80	5.00	9.13
JS-335	16.30	9.50	6.70	10.83
DS-228	18.90	12.10	9.30	13.43
KDS-726	22.40	15.60	12.80	16.93
JS-9305	20.00	13.20	10.40	14.53
KDS-344	15.10	8.30	5.50	9.63
NRC-132	13.30	6.50	3.70	7.83
NRC-129	15.80	9.00	6.00	10.27
Mean	17.51	10.65	7.85	12.00
	Cultivars	Treatments	Interaction	
SEM (±)	0.085	0.162	0.281	
CD at 1 %	0.240	0.460	NS	

Conclusion

This study revealed that soybean seed quality and morphometric characteristics were notably impacted by varying moisture regime treatments. The difference in moisture regimes and their interaction significantly diminished the quality and morphometric traits of soybean seeds. Notably, there were apparent differences among soybean cultivars in response to these conditions. Seeds harvested from plants under terminal moisture stress (3 irrigations) and severe moisture stress (2 irrigations) showed inferior quality and morphometric characteristics compared to seeds from plants under controlled moisture conditions (5 irrigations). The findings highlight that parameters such as seed germination percentage, seedling length, seedling dry weight, seed vigor indexes I and II, electrical conductivity, along with seed morphometric parameters like seed length, width, area, diameter, perimeter, and roundness, could play a significant role in identifying soybean cultivars that are either resistant or susceptible to moisture stress based on seed quality metrics.

References

1. Arooj F, Qayyum A, Mahmood S. Responses of wheat seedling to varying moisture conditions and relationship between morphological and molecular characterization. International Journal of Environmental & Agriculture Research. 2017;3(4):121-135.
2. Bonny Sinha R, Pitale L, Mendhulkar VD. Effects of temperature stress on soybean seeds. Der Pharmacia Lettre. 2015;7(11):141-146.
3. Chowdhury JA, Karim MA, Khaliq QA, Solaiman ARM, Ahmed JUA. Genotypic variations in growth, yield and yield components of soybean genotypes under drought stress conditions. Bangladesh J Agril Res. 2015;40(4):537-550.
4. Dombos DL, Mullen RE. Influence of stress during

soybean seed fill on seed weight, germination, and seedling growth rate. Can J Plant Sci. 1991;71:373-383.
5. Drummond EA, Rabb JL, Melville DR. Effect of irrigation on soybean seed quality. La Agric. 1983;26:9.
6. Egli DB, TeKrony DM, Spears JF. Effect of high temperature stress during different stages of seed development in soybean [Glycine max (L.) Merrill]. Seed Tech. 2005;27(2):177-189.
7. Fougereux J, Dore T, Labdonne F, Fleury A. Water stress during reproductive stages affects seed quality and yield of pea (Pisum sativum). Crop Sci. 1997;37:1247-1252.
8. Gibson LR, Mullen RE. Soybean seed quality reductions by high day and night temperature. Crop Sci. 1996;36:1615-1619.
9. Golezani GK, Mohammadi M, Salmasi S. Changes in seed vigor of safflower (*Carthamus tinctorius* L.) cultivars during maturity in response to water limitation. Acta Agriculture Slovenica. 2016;107(1):132-143.
10. Golezani GK, Lotfi R, Norouzi R. Seed quality of soybean cultivars affected by pod position and water stress at reproductive stages. International Journal of Plant, Animal and Environmental Sciences. 2018;2(2):120.
11. Honeycutt RJ, Burton JW, Shoemaker RC, Palmer RG. Expression and inheritance of a shriveled-seed mutant in soybean. Crop Sci. 1989;29:704-707.
12. Nezhadahmadi A, Pradhan ZH, Faruq G. Drought tolerance in wheat. Scientific World J. 2013:610-721.
13. Pervez MA, Ayub CM, Khan HA, Shahid MA, Ashraf I. Effect of drought stress on growth, yield and seed quality of tomato (Lycopersicon esculentum L.). Pak J Agri Sci. 2009;46(3):287-298.
14. Wijewardanaa C, Alsajria FA, Trenton J, Jason IL, Goldenc KB, Henrya WB, Gaod W, Reddya KR. Physiological assessment of water deficit in soybean using midday leaf water potential and spectral features. Journal of plant interactions. 2019;14(1):533–543.
15. Younesi O, Moradi A. The effect of water limitation in the field on sorghum seed germination and vigor. Australian Journal of Basic and Applied Sciences. 2009;3(2):1156-1159.