Nature Environment and Pollution Technology
An International Quarterly Scientific Journal
p-ISSN: 0972-6268 (Print copies up to 2016)
e-ISSN: 2395-3454
Vol. 22 | No. 4 | pp. 2137-2144 | 2023
Original Research Paper
https://doi.org/10.46488/NEPT.2023.v22i04.039
Open Access Journal

Potassium Solubilizing Bacteria (KSB) and Osmopriming Mediated Morphological Changes and Triggers in Yield of Green Gram (*Vigna radiata* L.) Under Water-Limiting Conditions

A. Kalangutkar and A. Siddique†
Department of Agronomy, School of Agriculture, Lovely Professional University, Phagwara-144 411, Jalandhar, Punjab, India
†Corresponding author: A. Siddique; anaytullahsiddique@gmail.com

Nat. Env. & Poll. Tech.
Website: www.neptjournal.com

Received: 23-03-2023
Revised: 01-05-2023
Accepted: 05-05-2023

Key Words:
Potassium solubilizing bacteria
Harvest Index
Leaf Area Index
Osmopriming
SPAD

ABSTRACT

A field-based experiment was conducted to know the relevance of potassium solubilizing bacteria (KSB), and Osmo-priming mediated morphological changes and yielded recovery in green gram (*Vigna radiata* L.) under water-limiting conditions. Hence, the experiment was carried out at the research farm of Lovely Professional University. The characters like plant height, number of leaves, leaf area plant$^{-1,}$ and LAI were considered to track the morphological changes, while the primary branches, nodules, pods plant^{-1}, seeds pod^{-1}, the average length of the pod, test weight, biological yield, grain yield, and harvest index (HI) were used to determine the recovery of yield as compared to control. Among the treatments, T_8 was recorded as one of the best treatments for all the morphological parameters studied, *i.e.,* plant height (51.80 cm), number of leaves (42 plant^{-1}), leaf area (577.27 cm^2.plant^{-1}) and LAI (1.92) while most of the yield contributing characters were found better in T_6 *i.e.* nodules (8.3 plant^{-1}), seeds pod^{-1} (10) and length of the pod (7.65 cm) except for the primary branches and the number of pods plant^{-1} which was remain recorded maximum in T_8 (6.0 and 22). The yield of green gram and its biological yield were recorded as highest in T_6 and T_2 (6.83 and 24.23 g.plant^{-1}), while HI and test weight were also noted in T_6 (32.0% and 5.90 g). This study has concluded that the KSB, combined with $KNO_{3,}$ showed a strong potential to modify the morphological structure while the yield of green gram was in KSB + $Ca(NO_3)_2$ under water scarcity.

INTRODUCTION

The green gram (*Vigna radiata* L.) is a Leguminosae (Fabaceae) family member, widely grown as a pulse crop in arid and semi-arid regions. It is highly protein, easily digested, and can fix nitrogen with a symbiotic association with Rhizobia (Khiangte & Siddique 2022). India is the world's largest producer of green gram, producing 1.5 to 2.0 million tonnes of green gram from 3 to 4 million hectares of area annually (Pandey et al. 2019). Around 42% of India's land is under drought, thus simultaneously impacting agriculture production and yield. For several years, such conditioned priming has been a widely used technique for reviving seeds to increase agronomic production. Seed priming is a method of controlled hydration that exposes seeds to low water potentials, allowing pre-germinative physiological and biochemical changes that boost stand establishment and yield (Anaytullah & Bose 2007, Devika et al. 2021). In seed priming, seeds are treated with a variety of organic and inorganic compounds, *i.e.,* hydropriming, halopriming, osmo-priming, hormone priming, and solid-matrix priming for a predetermined amount of time under controlled conditions before sowing, which then causes biochemical changes by adjusting the temperature and moisture content of the seeds bringing them closer to germination before being dried back to its original moisture content (Singh et al. 2020, Zulfiqar 2021, Eshkab et al. 2021, Pawar & Laware 2018, Rhaman et al. 2022).

Osmo-priming is a pre-sowing approach that helps in maintaining the plasma membrane, which allows the osmo-primed seeds to germinate more rapidly, which is why seedlings grow more quickly, more aggressively, and better in complicated situations under specific physiological, biochemical, cellular, and molecular variations. Additionally, it solubilizes storage proteins, boosts antioxidant activity, and lowers lipid peroxidation (Marthandan et al. 2020).

Potassium is an essential nutrient that plants need for a wide range of processes, including antioxidative defense mechanisms. This element is present in the soil in bound form, and only 1%–2% of the total potassium in the earth's crust is available to plants (Meena et al. 2016). Many strains of soil microorganisms show efficiency in converting the insoluble form of potassium to solubilize or mobilize it into a usable form (Choudhary & Siddique 2020). Hence, in the present study, we used KSB in combination with osmopriming agents to overcome the impact of drought on green gram.

MATERIALS AND METHODS

An experiment was planned and executed over the Research Farm of Lovely Professional University, Punjab, in the summer of March 2020, wherein the SML-668 variety of green gram was used. The entire experiment was executed in Randomized Block Design (RBD) with three replications and eight treatments, while the total treatments were used in combinations of potassium solubilizing bacteria (KSB) and priming agents. The priming treatments were employed using nitrates of Ca and K in two different concentrations, i.e., $Ca(NO_3)_2$, 7.0 and 10 mM and KNO_3, 12.0 and 15 mM, by considering eight hours of priming duration. The culture of potassium solubilizing bacteria was used as a soil application in two concentrations, which were used as per the recommended dose of 3 to 5 $L.acre^{-1}$, respectively. Standard agronomic and cultural practices were followed during the entire growth period of the crop, like field preparation, sowing, weeding, fertilizer application, and plant protection measures. However, one irrigation was skipped before flowering in all treatments, including the control, to create water-limiting conditions. After the establishment of the plant over the field, randomly 5 plants were tagged from each plot to record morphological observations like plant height, number of leaves, number of primary branches $plant^{-1}$, and number of nodules $plant^{-1}$ while the leaf area $plant^{-1}$ was measured through the leaf area meter (Model No. 211) and the leaf area index (LAI) was derived as per the (Watson 1947).

$$\text{Leaf Area Index (LAI)} = \frac{\text{Leaf area (cm}^2\text{)}}{\text{Ground area (cm}^2\text{)}}$$

The estimation of yield and yield attributing characters, *i.e.*, the number of pods $plant^{-1}$, the number of seeds pod^{-1}, the length of pod $plant^{-1}$, biological yield, and grain yield, were measured at the maturity stage by considering the tagged plants of each plot. The formula given by (Donald & Hamblin 1976) was used to calculate HI% while 100 seeds were used to record the test weight.

$$\text{Harvest Index (\%)} = \frac{\text{Grain yield}}{\text{Biological yield}} \text{ X } 100$$

SPAD reading was measured using a SPAD meter (Model No-SPAD-502 Plus), which measures the greenness of chlorophyll in field conditions.

RESULTS

Morphological Changes due to KSB and Osmopriming Treatments

The impact of potassium solubilizing bacteria (KSB) and osmo-priming with nitrate-based salts Ca and K were studied in green grams under water-limiting conditions. Data depicted from (Table 1) revealed that the T_8 (KSB_2 + KNO_3, 15 mM) was recorded as significantly highest ($p<0.05\%$) plant height (cm), the number of leaves $plant^{-1}$, leaf area (cm^2) and LAI (51.80, 42, 577.27 and 1.924) compared to control set (39.5, 32.67, 483.30 and 1.61) while the second most significantly highest was recorded in T_4 (KSB_1 + KNO_3, 15 mM) for the plant height (cm) and the number of leaves $plant^{-1}$ (50.93 and 41.33) and T_6 (KSB_2 + $Ca(NO_3)_2$, 12 mM) for leaf area cm^2 and LAI (562.77 and 1.87) which T7 followed for plant height and the number of leaves $plant^{-1}$ (50.23 and 40) and T_4 for leaf area and LAI (549.17 and 1.83). The data % increase/decrease over the control was presented in parenthesis, which justifies the performance of the treatment concerning parameters. The % increase/decrease over the control showed that the treatment T_8 has maximum gain in growth for plant height, number of leaves $plant^{-1}$, leaf area (cm^2), and LAI (23.62, 22.22, 16.28, and 16.28). The scrutiny of the data for the performance of KSB revealed that KSB_2 is better than KSB_1 for most of the parameters (Table 1).

Influence of KSB and Osmopriming Treatments on Yield Attributes

Data presented in (Table 2) reveals the significance of KSB and Osmo-priming-based salts of nitrates, *i.e.*, Ca and K, under water-limiting conditions. Out of all the combinations of the treatment, again T_8 was recorded as one of the best combinations which was significantly highest ($p<0.05\%$) for the number of primary branches and pods $plant^{-1}$ (6.0 and 22), while T_6 for the nodules, length of pod $plant^{-1}$ (cm) and seeds pod^{-1} (8.33, 7.65 and 10.0) compared to control set (3.67, 4.33, 16.0, 6.63 and 6.10). The second most significantly highest number of primary branches and pods $plant^{-1}$ was recorded in T_6 (5.0 and 21), while nodules, length of pod $plant^{-1}$, and seeds pod^{-1} were recorded in T_8 (7.33, 7.37, and 9.13). The computed data of % increase/decrease over the control presented in (Table-2) justified the impact of treatment. They found that the highest % increase was recorded in T_8 for primary branches and pods $plant^{-1}$

Table 1: KSB and Osmo-priming-based changes on plant height (cm), number of leaves, leaf area plant$^{-1,}$ and LAI under water-limiting conditions.

Treatments	PH at harvest	No. of leaves plant^{-1}	Leaf area plant^{-1}	LAI
T_0	39.57 ± 2.46	32.67 ± *1.45*	483.30 ± 6.36	1.611 ± 0.02
T_1	46.07 ± 1.79 [8.13%]	33.33 ± *1.45* [2.00%]	523.27 ± 5.39 [7.64%]	1.744 ± 0.01 [7.64%]
T_2	41.80 ± 2.93 [9.67%]	35.00 ± *1.15* [6.67%]	535.67 ± 24.18 [9.78%]	1.786 ± 0.08 [9.78%]
T_3	46.40 ± 2.75 [14.73%]	35.33 ± *1.20* [7.55%]	490.83 ± 5.28 [1.53%]	1.636 ± 0.01 [1.53%]
T_4	50.93 ± 3.39 [20.76%]	41.331.38± [20.97%]	549.17 ± 4.98 [11.99%]	1.831 ± 0.02 [11.99%]
T_5	47.23 ± 3.67 [16.23%]	38.33 ± *3.38* [14.78%]	488.53 ± 3.21 [1.07%]	1.628 ± 0.01 [1.07%]
T_6	49.87 ± 1.07 [20.66%]	40.00 ± *1.52* [18.33%]	562.77 ± 18.12 [14.12%]	1.876 ± 0.06 [14.12%]
T_7	50.23 ± 0.86 [21.70%]	40.00 ± 1.15 [19.67%]	526.43 ± 17.09 [8.19%]	1.755 ± 0.05 [8.19%]
T_8	51.80 ± 1.34 [23.62%]	42.00 ± *2.40* [22.22%]	577.27 ± 22.44 [16.28%]	1.924 ± 0.07 [16.28%]
CD at (p<0.05)	7.58	6.55	44.25	0.14

Notes: 1. T_0 = Control, $T_1 = KSB_1 + Ca(NO_3)_2$ [7.0 mM], $T_2 = KSB_1 + Ca(NO_3)_2$ [10.0 mM], $T_3 = KSB_1 + KNO_3$ [12.0 mM], $T_4 = KSB_1 + KNO_3$ [15.0 mM], $T_5 = KSB_2 + Ca(NO_3)_2$ [7.0 mM], $T_6 = KSB_2 + Ca(NO_3)_2$ [10mM], $T_7 = KSB_2 + KNO_3$ [12mM], $T_8 = KSB_2 + KNO_3$ [15mM]

2. Data in parenthesis represent % increase/decrease over control.

Table 2: KSB and Osmo-priming-based changes on primary branches, nodules, pods plant^{-1}, seeds pod^{-1} and length of pods plant^{-1} in green gram under water-limiting conditions.

Treatments	Primary branches Plant^{-1} at harvest	Nodules plant^{-1} at harvest	Pods plant^{-1} at harvest	Seeds pod^{-1}	Length of pod plant^{-1} [cm]
T_0	3.67 ± 0.33	4.33 ± 0.33	16.00 ± 1.52	6.63 ± 0.32	6.10 ± 0.02
T_1	3.67 ± 0.33 [0.00%]	5.67 ± 0.33 [23.53%]	17.33 ± 0.88 [7.69%]	7.31 ±0.27 [9.22%]	6.47 ± 0.14 [5.77%]
T_2	4.33 ± 0.33 [15.3%]	7.33 ± 0.33 [40.91%]	20.00 ± 0.57 [20.00%]	8.37 ±0.18 [20.72%]	7.26 ± 0.17 [16.06%]
T_3	4.33 ± 0.33 [15.38%]	5.67 ± 0.33 [23.53%]	17.17 ± 0.33 [6.80%]	7.80 ±0.25 [14.96%]	6.90 ± 0.19 [11.60%]
T_4	5.0 ± 0.57 [26.67%]	5.67 ± 0.33 [23.53%]	20.17 ± 0.44 [20.66%]	7.90 ± 0.20 [16.03%]	7.20 ± 0.21 [15.28%]
T_5	4.33 ± 0.33 [15.38%]	5.67 ± 0.33 [23.53%]	18.17 ± 0.33 [11.93%]	8.17 ± 0.16 [18.78%]	7.11 ± 0.01 [14.29%]
T_6	5.0 ± 0.57 [26.67%]	8.33 ± 0.33 [48.00%]	21.00 ± 0.28 [23.81%]	10.00 ±0.57 [33.67%]	7.65 ± 0.09 [20.31%]
T_7	4.00 ± 0.00 [8.33%]	7.33 ± 0.33 [40.91%]	19.83 ± 1.16 [19.33%]	9.00 ± 0.57 [26.30%]	7.29 ± 0.14 [16.33%]
T_8	6.00 ± 0.00 [38.89%]	7.33 ± 0.33 [40.91%]	22.00 ± 0.57 [27.27%]	9.13 ± 0.59 [27.37%]	7.37 ± 0.21 [17.24%]
CD at (p<0.05)	1.10	1.06	2.31	1.18	0.48

(38.89 and 27.27) while T_6 for nodules, length pod plant$^{-1,}$ and seeds pod^{-1} (48, 23.31, and 33.67). Scrutiny about the impact of KSB showed that KSB_2 is performing well in combination with osmo-priming treatment compared to the combinations of KSB_1.

Influence of KSB and Osmopriming Treatments on Yield

Data presented in Table 3 was found significant (p<0.05%) for biological yield (g.plant^{-1}), grain yield (g.plant^{-1}), HI (%), and test weight (g) at harvest. The highest biological yield, g.plant$^{-1,}$ was obtained in T_2 (24.23), while the highest grain yield (g plant^{-1}), HI (%), and test weight(g) were found in T_6 (6.83, 32, and 5.90). The second highest value for biological yield was recorded in T_4 (21.87), and grain yield, HI (%), and test weight (g) were observed in T_6 (6.67, 67.72, and 5.67). The value of % increase/decrease over control was also found in T_2 for biological yield (21.60) while T_6 was detected for grain yield (27.80), HI and test weight (18.88 and 29.42) over control (Fig. 1). Close analysis of the data for the grain yield, HI and Test weight indicated that the combinations of the KSB_2 and osmopriming agent in combinations of osmo-priming agents performed better than combinations of KSB_1.

Trigger in SPAD Reading Due to KSB and Osmopriming Treatments

The impact of KSB in combination with osmo-priming agents showed a significant difference at ($p<0.05\%$) for the SPAD

Table 3: KSB and Osmo-priming-based triggers on biological yield, grain yield, harvest index (%), and test weight (g) in green gram under water-limiting conditions.

Treatments	Biological yield [g. plant^{-1}]	Grain yield [g.plant^{-1}]	HI %	Test weight [g]
T_0	19.0 ± 0.58	4.93 ± 0.29	25.95 ± 0.12	4.17 ± 0.12
T_1	20.10 ± 0.64 [5.47]	5.33 ± 0.17 [7.50]	26.54 ± 0.42 [2.21]	4.42 ± 0.06 [5.80%]
T_2	24.23 ± 0.41 [21.60]	6.33 ± 0.07 [22.10]	26.16 ± 0.70 [0.78]	4.50 ± 0.13 [7.48%]
T_3	21.60 ± 0.38 [12.04]	5.87 ± 0.12 [15.91]	27.20 ± 1.04 [4.57]	4.28 ± 0.04 [2.72%]
T_4	21.87 ± 1.13 [13.11]	6.27 ± 0.07 [21.28]	28.78 ± 1.22 [9.83]	4.64 ± 0.06 [10.14%]
T_5	20.97 ± 0.78 [9.38]	6.00 ± 0.12 [17.78]	28.70 ± 1.26 [9.56]	5.53 ± 0.01 [24.61%]
T_6	21.40 ± 0.55 [11.21]	6.83 ± 0.09 [27.80]	32.00 ± 1.25 [18.88]	5.90 ± 0.01 [29.42%]
T_7	21.13 ± 0.43 [10.09]	6.17 ± 0.18 [20.0]	29.18 ± 0.61 [11.06]	5.12 ± 0.01 [18.57%]
T_8	21.83 ± 1.04 [12.98]	6.67 ± 0.13 [26.0]	30.72 ± 1.98 [15.52]	5.67 ± 0.01 [26.51%]
CD at (p<0.05)	2.23	0.46	3.73	0.21

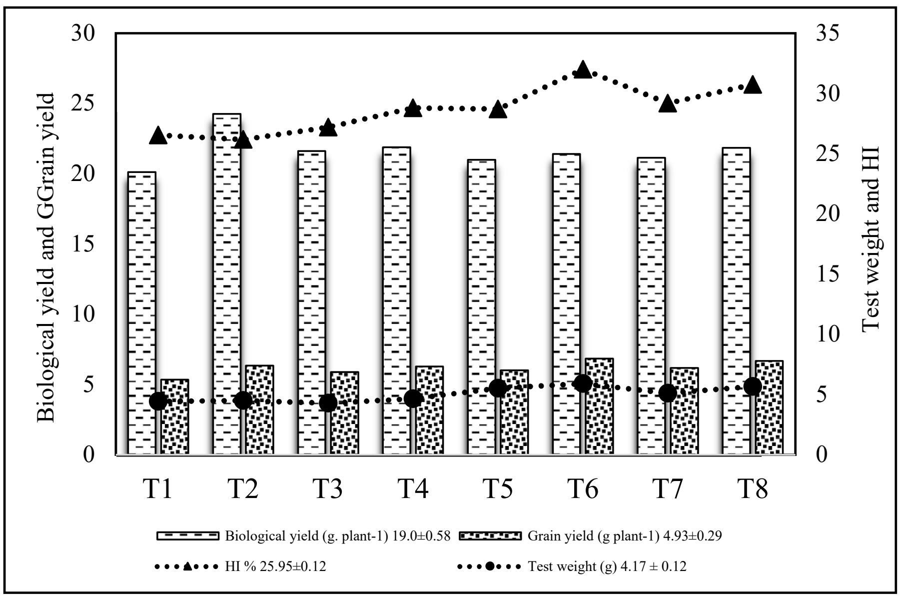

Fig. 1: KSB and Osmo-priming-based triggers on biological yield, grain yield, harvest index (%), and test weight (g) in green gram under water-limiting conditions.

Table 4: KSB and Osmo-priming-based triggers on SPAD reading in green gram under water-limiting conditions.

Treatments	SPAD Chlorophyll at 20 DAS	SPAD Chlorophyll at 40 DAS	SPAD Chlorophyll at harvest
T_0	35.43 ± 0.40	46.63 ± 0.96	25.23 ± 0.95
T_1	36.43 ± 0.37 [2.74%]	50.90 ± 0.75 [8.38%]	27.40 ± 0.25 [7.91%]
T_2	38.53 ± 0.88 [8.04%]	51.60 ± 0.11 [9.63%]	27.53 ± 0.99 [8.35%]
T_3	35.53 ± 0.63 [0.28%]	52.63 ± 0.41 [11.40%]	28.47 ± 0.94 [11.36%]
T_4	39.77 ± 0.26 [10.90%]	53.83 ± 0.46 [13.37%]	30.20 ± 1.42 [16.45%]
T_5	40.33 ± 0.06 [12.15%]	52.47 ± 1.46 [11.12%]	28.43 ± 2.11 [11.25%]
T_6	40.23 ± 0.86 [11.93%]	54.90 ± 0.83 [15.06%]	31.77 ± 0.84 [20.57%]
T_7	37.30 ± 0.55 [5.00%]	53.17 ± 1.03 [12.29%]	31.13 ± 0.88 [18.95%]
T_8	43.57 ± 0.57 [18.67%]	58.63 ± 0.53 [20.47%]	34.23 ± 0.24 [26.29%]
C.D at (p<0.05).	1.61	2.50	3.28

unit. The SPAD reading was recorded at regular intervals of 20, 40, and at the harvest stage, wherein the highest reading was recorded at 40 DAS in all the sets of treatment compared to 20 and at the harvest stage. Among the treatments, the highest SPAD reading was recorded in T_8 (43.57, 58.63, and 34.23), which represents the % increase/decrease over control of 18.67, 20.47, and 26.29% as compared to control at the regular intervals of 20, 40, and at harvest stage of the crop (Table 4). However, data depicted from (Fig. 1) also showed that the second highest SPAD reading was in T_6 (54.90 and 31.77) at 40 DAS and the harvest stage of the crop with % increase/decrease over control (15.06 and 20.57) as compared to controls. The response of KSB in combinations of priming treatment revealed KSB_2 support better than KSB_1 for SPAD reading.

Influence of the Treatments among the Studied Parameters

Relationships among the parameters were studied in the present work under water-limiting conditions. It seems from the data presented in (Table 5) that the arrows in the upward direction indicating parameters had a high level of positive correlation with each other and downward arrows indicating a high level of negative correlation among them, while the horizontal direction of arrows indicated that the parameters were positively correlated with a low level of significance due to the impact of KSB based osmopriming treatments under water limiting conditions.

DISCUSSION

The importance of nutrients is well known to regulate several metabolic processes in, which photosynthesis, respiration, transpiration, nutrients, and water uptakes are some. It also acts as a cofactor responsible for activating many enzymes for several other metabolic processes. Moreover, potassium and calcium play a vital role in water-limiting conditions, a kind of drought (Guo et al. 2019). The data pertaining in (Table 1) reveals that the morphological parameters like PH, Number of leaves, leaf area, and LAI studied in the present work were positively influenced by T_8 (KSB_2 + KNO_3, 15mM) concentration followed by T_6 (KSB_2 + $Ca(NO_3)_2$, 10mM) for most of the morphological parameters except to PH compared to a control set while KSB_2 was common in both the treatment. Archana et al. (2012) reported that the potassium-solubilizing bacteria (KSB) is capable of releasing the K from the inorganic source, while seed priming with potassium nitrate was well documented by (Siddique & Bose 2015, Moaaz et al. 2020, Zrig et al. 2022) and (Arun et al. 2016) who reported that priming treatment with KNO_3 and $Ca(NO_3)_2$ not only triggers seed germination but also influence the further morphological growth in plants. Therefore, the combined effect of KSB-based osmopriming agents reflected their impact on PH, number of leaves, leaf area, and LAI. It seems from the data presented in (Tables 2 and 3) that most of the yield and yield attributes like grain yield, HI, test weight, nodules plant^{-1}, seeds pod^{-1}, and length of pod plant^{-1} were found to be highest in T_6 and primary branches pods plant^{-1} were slightly higher in

Table 5: Correlation among the characters studied in green gram under water-limiting conditions.

	PH	No. of leaves plant-1	Leaf area plant-1	LAI	Primary branches plant-1	Nodules plant-1	Pods plant-1	Seeds pod-1	Length of pod plant-1	Biological yield	Grain yield plant-1	HI %	Test weight (g)	SPAD reading
PH	1													
No. of leaves plant-1	0.896	1.000												
Leaf area plant-1	0.642	0.684	1.000											
LAI	0.642	0.684	1.000	1.000										
Primary branches plant-1	0.674	0.796	0.771	0.770	1.000									
Nodules plant-1	0.512	0.568	0.749	0.749	0.523	1.000								
Pods plant-1	0.701	0.839	0.916	0.916	0.826	0.839	1.000							
Seeds pod-1	0.670	0.740	0.706	0.706	0.633	0.945	0.851	1.000						
Length of pod plant-1	0.697	0.808	0.689	0.689	0.690	0.869	0.885	0.929	1.000					
Biological yield	0.151	0.305	0.458	0.459	0.428	0.594	0.611	0.469	0.679	1.000				
Grain yield plant-1	0.694	0.814	0.773	0.773	0.797	0.867	0.929	0.920	0.982	0.688	1.000			
HI %	0.824	0.860	0.672	0.672	0.734	0.688	0.761	0.867	0.779	0.107	0.795	1.000		
Test weight (g)	0.672	0.754	0.552	0.550	0.638	0.687	0.708	0.848	0.748	0.135	0.745	0.912	1.000	
SPAD reading	0.863	0.849	0.779	0.778	0.890	0.692	0.863	0.783	0.814	0.461	0.866	0.801	0.726	1.000

T_8 while biological alone was recorded maximum in T_2 compared to the rest of the treatments. A similar trend was also found for the SPAD reading, whereas T8 was slightly higher than T_6 at all the intervals (Table 4). The results were similar to the outcomes received by Ghasemi-Golezani et al. (2013), who reported that seed priming is an innovative technique to accelerate and synchronize the establishment of plant population over the field even under water stress conditions and subsequent gain of morphological growth, yield attributes, and yield of pulse crops. The additional availability of K through the action of KSB in the soil helps in channelizing stress-related processes because K is an osmoregulatory compound in the plant (Tavakol et al. 2022, Cochrane & Cochrane 2009, Prajapati & Modi 2016, Meena et al. 2016.). The availability of Ca in the appropriate amount at the time of drought helps in maintaining the turgor pressure, improving the rate of photosynthesis, water use efficiency, and coordinating with ABA because Ca acts as a signaling molecule during the drought (Ali et al. 2020, Cardoso et al. 2020, Naeem et al. 2018, Hosseini et al. 2018). Moreover, the correlation studies presented in Table 5 also indicate the positive relevance of the treatments, *i.e.,* KSB + KNO_3 and $Ca(NO_3)_2$, which enabled the plant to survive and helped cover the yield loss due to wastewater-limiting conditions.

CONCLUSION

The present study was focused on finding out the impact of KSB and osmopriming-mediated morphological changes and triggers in the yield of green gram. As far as our findings are concerned, the combinations of KSB_2 and + KNO_3,15mM were among the best combinations for the morphological character studies. At the same time, most of the yield attributes and yield of green were better in T_6, which were combinations of KSB_2 and $Ca(NO_3)_2$. However, the SPAD reading was marginally better in T_8, followed by T_6, compared to the rest of the treatments. A remarkable result was that the KSB_2 greatly influences combinations of priming agents for all the characters studied in the present work compared to combinations of KSB_1.

REFERENCES

Ali, S., Hayat, K., Iqbal, A. and Xie, L. 2020. Implications of abscisic acid in the drought stress tolerance of plants. Agronomy, 10: 1323.

Anaytullah, M. and Bose, B. 2007. Nitrate-hardened seeds increase germination, amylase activity, and proline content in wheat seedlings at low temperatures. Physiol. Mol. Biol. Plants, 13: 199-207.

Archana, D.S., Nandish, M. S., Savalagi, V.P. and Alagawadi, A.R. 2012. Screening of potassium solubilizing bacteria (KSB) for plant growth promotional activity. Bioinfo. Quart. J. Life Sci., 9: 627-630.

Arun, M.N., Bhanuprakash, K., Hebbar, S.S. and Senthivel, T. 2016. Effect of seed priming with various chemicals on germination and vigor in cowpea (*Vigna unguiculata* (L.) Walp). Prog. Res. Int. J., 11: 2113-2117.

Cardoso, A.A., Gori, A., Da-Silva, C.J. and Brunetti, C. 2020. Abscisic acid biosynthesis and signaling in plants: Key targets to improve water use efficiency and drought tolerance. Appl. Sci., 10: 6322.

Choudhary, P. and Siddique, A. 2020. Role of potassium solubilizing bacteria in crop production: An overview. Int. J. Chem. Stud., 9: 542-544.

Cochrane, T.T. and Cochrane, T.A. 2009. The vital role of potassium in the osmotic mechanism of stomata aperture modulation and its link with potassium deficiency. Plant Sig. Behavior, 4: 240-243.

Devika, O.S., Singh, S., Sarkar, D., Barnwal, P., Suman, J. and Rakshit, A. 2021. Seed priming: a potential supplement in integrated resource management under fragile intensive ecosystems. Front. Sustai. Food Syst., 654001 :5.

Donald, C.M. and Hamblin, J. 1976. The biological yield and harvest index of cereals as agronomic and plant breeding criteria. Adv. Agron., 28: 361-405.

Eshkab, I.A. and Harris, P.J. 2020. Seed priming: Factors affecting efficacy. Int. J. Basic Appl. Sci., 8: 31-52.

Ghasemi-Golezani, K., Japparpour-Bonyadi, Z., Shafagh-Kolvanagh, J. and Nikpour-Rashidabad, N. 2013. Effects of water stress and hydro-priming duration on-field performance of lentil. Int. J. Farm. Allied Sci., 2: 922-925.

Guo, J., Jia, Y., Chen, H., Zhang, L., Yang, J., Zhang, J. and Zhou, Y. 2019. Growth, photosynthesis, and nutrient uptake in wheat are affected by differences in nitrogen levels, forms, and potassium supply. Sci. Rep., 12-9:1.

Hosseini, S.A., Réthoré, E., Pluchon, S., Ali, N., Billiot, B. and Yvin, J.C. 2019. Calcium application enhances drought stress tolerance in sugar beet and promotes plant biomass and beetroot sucrose concentration. Int. J. Mol. Sci., 20: 3777.

Khiangte, Z. and Siddique, A. 2022. Response of rhizobium inoculation and boron application on yield and its attributes and root morphology in Pea (*Pisum sativum* L.). Ann. Biol., 38: 188-192.

Marthandan, V., Geetha, R., Kumutha, K., Renganathan, V. G., Karthikeyan, A. and Ramalingam, J. 2020. Seed priming: A feasible strategy to enhance drought tolerance in crop plants. Int. J. Mol. Sci., 21: 8258.

Meena, V.S., Maurya, B.R., Verma, J.P. and Meena, R.S. 2016. Potassium Solubilizing Microorganisms for Sustainable Agriculture. Volume 331. Springer, New Delhi.

Moaaz Ali, M., Javed, T., Mauro, R.P., Shabbir, R., Afzal, I. and Yousef, A.F. 2020. Effect of seed priming with potassium nitrate on the performance of tomato. Agriculture, 10: 498.

Naeem, M., Naeem, M.S., Ahmad, R., Ihsan, M.Z., Ashraf, M.Y., Hussain, Y. and Fahad, S. 2018. Foliar calcium spray confers drought stress tolerance in maize via modulation of plant growth, water relations, proline content, and hydrogen peroxide activity. Arch. Agron. Soil Sci., 64: 116-131.

Pandey, O.P., Shahi, S.K., Dubey, A.N. and Maurya, S.K. 2019. Effect of integrated nutrient management of growth and yield attributes of green gram (*Vigna radiata* L.). J. Pharmacog. Phytochem., 8: 2347-2352.

Pawar, V.A. and Laware, S.L. 2018. Seed priming a critical review. Int. J. Sci. Res. Biol. Sci., *5*: 94-101.

Prajapati, K. and Modi, H. 2016. Growth promoting effect of potassium solubilizing *Enterobacter hormaechei* (KSB-8) on cucumber (Cucumis sativus) under hydroponic conditions. Int. J. Sci. Res. Biol. Sci., 3: 168-173.

Rhaman, M.S., Tania, S.S., Imran, S., Rauf, F., Kibria, M.G., Ye, W. and Murata, Y. 2022. Seed priming with nanoparticles: An emerging technique for improving plant growth, development, and abiotic stress tolerance. J. Soil Sci. Plant Nutri., 4062-4047 :22.

Siddique, A. and Bose, B. 2015. Effect of seed invigoration with nitrate salts on morpho-physiological and growth parameters of wheat crop sown on different dates in its cropping season. Vegetos, 28: 76-85.

Singh, V., Sharma, M., Upadhyay, H. and Siddique, A. 2020. Ameliorative effect of seed priming on germination, vigor index, and tolerance index against short-term moisture stress in maize (Zea mays L.). Indian J. Agric. Res., 382-378 :54.

Tavakol, E., Jákli, B., Cakmak, I., Dittert, K. and Senbayram, M. 2022. Optimization of potassium supply under osmotic stress mitigates oxidative damage in barley. Plants, 11: 55.

Watson, D. J. 1947. Comparative physiological studies on the growth of field crops: I. Variation in net assimilation rate and leaf area between species and varieties and within and between years. Ann. Bot., 76-41 :11.

Zrig, A., Saleh, A., Hamouda, F., Okla, M. K., Al-Qahtani, W.H., Alwasel, Y.A. and AbdElgawad, H. 2022. Impact of sprouting under potassium nitrate priming on nitrogen assimilation and bioactivity of three Medicago species. Plants, 11: 71.

Zulfiqar, F. 2021. Effect of seed priming on horticultural crops. Sci. Hort., 110197 :286.