



Research Paper

Growth and yield of lentil (*Lens culinaris* Medik.) as affected by stress-mitigating chemical spray and soil variability

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ABSTRACT

In the present investigation, the effect of various stress-mitigating chemicals on growth and yield of lentil (*cv. Moitree*) grown was studied under two diverse soil conditions. Lentils sown in new alluvial soil exhibited greater germination rates compared to those in coastal saline soil. The salicylic acid (SA) treatment resulted in the tallest plants of 21.00 and 39.50 cm heights at 30 and 40 days after sowing (DAS), respectively, followed by ABA application. Application of ABA led to the highest fresh and dry weights, followed by SA. Initially, ABA-treated plants had the longest roots, while at later stages SA-treated plants possessed greater root length surpassing others significantly. The stress-mitigating chemicals improved lentil yield attributes like branch/plant and pod/branch significantly, and SA foliar application enhanced both the attributes by 60.33% and 53.33%, respectively compared to control treatment. Additionally, lentils in alluvial soil had significantly higher chlorophyll content than those in coastal saline soil, and SA spray yielded the highest chlorophyll fractions. Application of all the stress-mitigating chemicals proved to enhance the overall performance of lentil grown under both coastal saline and new alluvial different soils. Specifically, salicylic acid spray (at 20 and 40 DAS) were found to be the best treatment with respect to lentil yield augmentation and salinity stress mitigation.

Key words: Abscisic acid, Coastal saline zone, New alluvial zone, Proline, Salicylic acid, Salinity, Seaweed extract

INTRODUCTION

Lentil (*Lens culinaris*) or masoor is one of the most consumed *Rabi* pulses across India, which possesses a good nutritional profile and high biological value of protein. Being a leguminous crop, it enhances soil health in terms of both physical and chemical properties. It also serves as a perfect catch crop to intensify the rice-fallow system and offers a huge scope to bring more area under pulses to achieve food and nutritional security (Banerjee *et al.* 2023a, Sarkar *et al.* 2024). However, the crop very often suffers from various biotic as well as abiotic stresses resulting in poor yield (Panuccio *et al.* 2022). Such a problem could be overcome by the use of stress-mitigating chemicals known to strengthen crops against various stresses. Seaweed extracts, salicylic acid, abscisic acid, and proline are some of the commonly used stress-mitigating chemicals in agriculture. Seaweed extracts are the saps derived from marine algae that contain various bioactive compounds like phytohormones, betaine, etc. apart from macro and micronutrients and serve

as a prominent tool for reducing stress in plants and enhancing their overall performance (Sengupta and Dhar 2024). Salicylic Acid, a plant phenolic is considered a hormone-like endogenous regulator having a role in defense mechanism against biotic and abiotic stress. It promotes proline synthesis in plants and regulates osmotic potential, thereby helping to mitigate salt stress (Misra and Saxena 2009). Proline is a key osmolyte that helps plants to maintain their cell turgidity. Being an osmoprotectant, it is involved in reducing oxidative damage by scavenging and/or reducing free radicals (Aqsa Talat *et al.* 2013). Abscisic acid (ABA) is a naturally occurring plant hormone that can mitigate the inhibitory effect of salinity by accelerating photosynthesis, growth, and translocation of assimilates (Chen *et al.* 2022). Lentil is widely cultivated both in the new alluvial zone (NAZ) and coastal saline zone (CSZ) of West Bengal having diverse soil characteristics (Banerjee *et al.* 2023a). Soil salinity level, as it increases during winter season, hinders lentil cultivation particularly in coastal saline soil (Banerjee *et al.* 2023a). Hence, the

present investigation hypothesized that the growth and productivity of lentils could be improved by the right choice of stress-mitigating chemical for both soil conditions.

MATERIALS AND METHODS

Experimental details

A pot experiment was conducted during *Rabi* season (2017-18) under shade net house conditions at Bidhan Chandra Krishi Vishwavidyalaya, Mohanpur, West Bengal to study the effect of various stress-mitigating chemicals on the growth and yield of lentil (*cv. Moitree*) grown on different soil types. The experiment was laid out in a completely randomized design (CRD) having two factors. Factor A consisted of foliar application of four salinity stress-mitigating chemicals i.e. seaweed (*Kappaphycus alvarezii*) sap (5% w/W), salicylic acid (SA) (1.0 mM), proline (50 mM), and abscisic acid (ABA) (250 ppm) along with a control treatment (only water spray). Factor B consisted of two soil types *viz.* coastal saline soil and new alluvial soil. The lentil seeds were sown on 25th November 2017 and harvested on 21st March 2018. The full amount of recommended fertilizer dose (20:40:40 kg N:P₂O₅:K₂O/ha) i.e., 1.76 g Urea, 10 g SSP and 2.56 g MOP in each pot was applied as a basal just before sowing. Each pot contains 8 kg of sterilized soil. The stress-mitigating chemicals were applied twice at 20 and 40 DAS. The stress-mitigating chemicals were applied twice at 20 and 40 DAS.

Soil sample analysis

The soils were collected from Rangabelia village of Gosaba (Coastal saline zone) and Mohanpur, Nadia (New alluvial zone) respectively. Then various physico-chemical properties like mechanical composition, soil texture, pH, and EC (soil: water: 1:2.5) were assessed for both soil samples (Table 1).

Recording biometrical observations

The germination percentage was estimated at 10 DAS by the ratio of the number of seeds germinated and the number of seeds shown in pots. Growth parameters like plant height, fresh weight, dry weight, root length, and leaf number were recorded at 30 and 40 DAS. Yield components like branch/plant, pod/branch, seed/pod, test weight, and yield/plant were recorded at harvest. Quantitative estimation of chlorophyll a, chlorophyll b, and total chlorophyll content was done from lentil leaves at

Table 1. Characteristics of experimental soils

Characteristics	Unit	Coastal saline soil	New alluvial soil
Sand	%	42.90	27.4
Silt	%	27.95	44.4
Clay	%	29.25	28.2
Soil texture	-	Clay loam	Sandy clay
pH	-	4.61	7.35
EC _{1:5}	dS/m	2.1	0.19
Available N	kg/ha	127.5	230.5
Available P ₂ O ₅	kg/ha	14.35	17.8
Available K ₂ O	kg/ha	460.9	224.7
Organic Carbon	%	0.50	0.32

harvest. A fresh leaf sample was extracted with 80% acetone. For spectrophotometry determination of the pigments, the absorbents of the extracts were measured at 645 and 663 nm, respectively following the method suggested by Gogoi and Basumatary (2018).

Statistical analysis

Statistical analysis was performed by the analysis of variance (ANOVA) for a two-factor completely randomized design and the significance of the difference of source of variance was tested by error mean square by Duncan multiple range test at a probability level of 0.05.

RESULTS AND DISCUSSION

Seed germination

Seed germination of lentils was significantly affected by soil types (Figure 1). Lentil crops sown on alluvial soil (86.31%) exhibited a higher germination rate than that of coastal saline soil

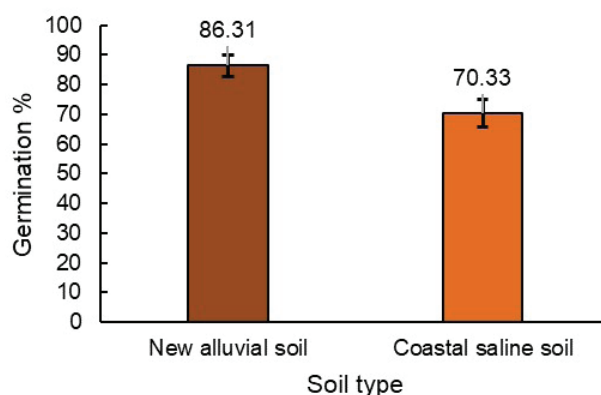


Fig. 1. Effect of soil types on seed germination of lentil (*cv. Moitree*) at 10 DAS during *rabi* season

(70.33%). Poor seed germination (70.33%) in coastal saline soil might be due to increased salinity that commonly exists in the dry season (winter). Salinity stress coupled with high osmotic potential results in poor imbibition of water by seed which leads to inappropriate metabolic activity and less mobilization of reserves (Ouji *et al.* 2015); hence the response in the present study.

Crop growth parameters

Both soil types and stress-mitigating chemicals exerted significant influence on the growth parameters of lentils namely plant height, plant weight, root length, and number of leaves/plant (Table 2). The plant height of lentils was significantly higher in new alluvial soil (17.25 cm and 31.80 cm at 30 and 40 DAS, respectively) as compared to coastal saline soil (17.07 cm and 25.33 cm at 30 and 40 DAS, respectively). Among stress-mitigating chemicals, salicylic acid spray resulted significantly in the highest plant height followed by abscisic acid spray. The lowest plant height was recorded with the control treatment (water spray only). Plants sown in new alluvial soil possessed higher biomass (both fresh and dry) than the crops grown in coastal saline soil (Table 2). Spraying of salicylic acid resulted significantly the highest fresh (0.306 g and 2.76 g at 30 and 40 DAS, respectively) and dry biomass of lentil plant (0.081g and 0.75 g at 30 and 40 DAS, respectively) followed by abscisic acid spray. The lowest weight accumulation was seen in the case of the control. The root length of the lentil crop was also significantly affected by the foliar spray of stress-mitigating chemicals, and the trend was almost similar to that of plant height and biomass (Table 2). Among the tested stress-mitigating chemicals, abscisic acid spray resulted in the highest root length (4.67 cm at 30 DAS) which was at par with salicylic acid spray (4.12 cm at 30 DAS). However, at 40 DAS salicylic acid spray resulted in the highest root length (15.55 cm), while the lowest root length was recorded in control plots. Lentil sown on alluvial soil produced more leaves/plants than that of coastal saline soils; however, the variation was non-significant. Like other growth parameters, leaf number/plant was also highest in the case of salicylic acid treatment (52.83) followed by proline treatment (43.17). Results suggest that salt stress negatively impacts the morphological and metabolic activities of lentil plants, which consequently influences plant growth attributes like plant height, leaf number per plant, plant dry weight, and root length. In addition to that, various

growth attributes of lentils including plant height, leaf number per plant, plant dry weight, and root length were improved significantly due to salicylic acid spray in both soil conditions. Therefore, the exogenous application of salicylic acid might have performed a potential role in mitigating the salinity stress of crops particularly in coastal saline soil. Similar results were also documented by Yildirim and Dursun (2008). Salicylic acid helps in increasing the accumulation of photosynthates and eases the mineral uptake even under stress conditions which in turn increases overall plant growth, and biomass accumulation (Khan *et al.* 2003). Salicylic acid enhances the overall growth of lentil due to the presence of soluble antioxidant compounds. Enhanced rate of photosynthesis and stability of membrane leads to plant height and biomass improvement (Laishram *et al.* 2020). On the contrary, the crop faced little or no stress in new alluvial soil, hence the crop growth was satisfactory.

Leaf chlorophyll content

The chlorophyll content of lentils in terms of chlorophyll a, chlorophyll b, and total chlorophyll was analyzed and it was observed that soil types and stress-mitigating chemicals significantly affect the leaf chlorophyll content (Figure 2). In the case of chlorophyll a, the highest value was observed in lentil plants sprayed with salicylic acid under new alluvial soil (6.96 mg/g fresh weight) which was at par with plants sprayed with abscisic acid under new alluvial soil (6.74 mg/g fresh weight). Plants sown in coastal saline soil receiving control treatment (water spray only) recorded the lowest value of chlorophyll a (1.20 mg/g fresh weight). The SA-treated lentil under new alluvial soil recorded the highest chlorophyll b content (5.81 mg/g fresh

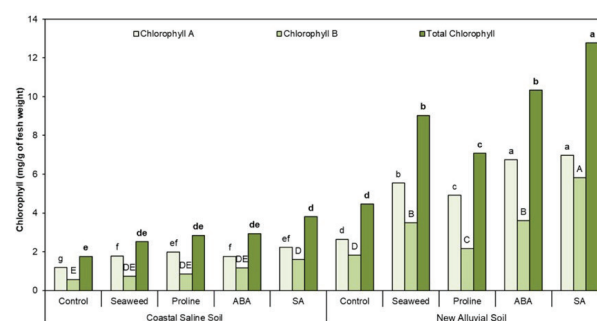


Fig. 2. Effect of soil types and stress mitigating chemicals on leaf chlorophyll content of lentil (cv. *Moitree*) at harvest during *rabi* season [Mean follows by different letters are significantly different by Duncan's Multiple Range Test (DMRT) at $P \leq 0.05$]

weight), while the lowest value was observed in the control treatment (0.56 mg/g fresh weight) under coastal saline soil. The total leaf chlorophyll content was recorded highest in lentil crops sown under new alluvial soil and treated with salicylic acid (12.78 mg/g fresh weight) followed by abscisic acid (10.34 mg/g fresh weight). The lowest value was seen in the case of the crop with control treatment (1.76 mg/g fresh weight) under coastal saline soil, which was at par with the spraying of seaweed extract (2.52 mg/g fresh weight), proline (2.84 mg/g fresh weight), and abscisic acid-treated plants (2.93 mg/g fresh weight). Therefore, salinity stress was seen to reduce the content of photosynthetic pigments in the lentil crop that was grown in coastal saline soils. Because salinity stress during the later phase of the crop's life cycle causes inhibition of chlorophyll synthesis and degeneration of chloroplast (Nadeem *et al.* 2019). Lower leaf chlorophyll content of lentil crops grown in coastal saline soil might be attributed to poor N assimilation in leaves from low-N coastal soil (Banerjee *et al.* 2023b). Stress-mitigating chemicals, salicylic acid in particular, have the potential to regulate the crucial biophysical processes in plants mainly antioxidant defense systems that prevent the breakdown of chlorophyll (Ogunsiji *et al.* 2023).

Similar observation was also recorded by Kaul *et al.* (2022) in the case of chickpeas.

Yield determining traits and crop yield

The number of branches/plant, number of pods/branch, number of seeds/pod, test weight, and grain yield were influenced by different soil types and various stress-mitigating chemicals (Table 3). The highest number of branches/plant was recorded due to the foliar application of salicylic acid (12.83) which was statistically at par with abscisic acid (10.83) and seaweed extract (10.67) sprays. The lowest value was observed in the control treatment (8). Crops grown in new alluvial soil produced more branches/plant than the crops grown in coastal saline soils. The highest number of pods/branch, number of seeds/pod, and test weight were recorded in plants treated with salicylic acid, closely followed by ABA-treated plants. For the above-mentioned traits, crops raised in new alluvial soil proved their superiority over crops raised in coastal saline soil.

The significantly highest grain yield/plant was obtained due to the application of salicylic acid (10.89 g) followed by abscisic acid (9.29 g); whereas the lowest grain yield (5.71 g/plant) was recorded in

Table 2. Effects of stress mitigating chemicals and soil types on growth parameters of lentil (cv. *Moitree*) during *rabi* season

Treatments	Plant height (cm)		Plant biomass (g)				Root length (cm)		Leaf number/ plant
	30 DAS	40 DAS	30 DAS		40 DAS		30 DAS	40 DAS	40 DAS
			Fresh	Dry	Fresh	Dry			
<i>Stress mitigating chemicals (STMC)*</i>									
Control (water spray)	12.83±2.15 d	19.33±5.76 d	0.130±0.03 d	0.033±0.003 d	1.53±0.08 e	0.430±0.05 d	2.22±0.69 d	10.36±1.33 b	22.00±5.09 c
Seaweed sap (5% w/W)	17.79±1.10 d	26.00±2.0 c	0.209±0.05 c	0.049±0.006 c	2.21±0.05 c	0.529±0.00 c	3.46±0.77 bc	12.40±2.51 b	39.17±4.13 b
Proline (1.0 mM)	15.41±1.84 c	26.33±7.06 c	0.157±0.00 d	0.050±0.006 c	2.16±0.00 d	0.615±0.08 b	3.09±0.44 c	11.95±1.43 b	43.17±8.05 b
ABA (50 mM)	18.75±1.68 b	31.67±6.10 b	0.252±0.06 b	0.065±0.007 b	2.50±0.38 b	0.607±0.21 b	4.67±0.42 a	12.36±2.04 b	40.50±7.20 b
SA (250 ppm)	21.00±2.78 a	39.50±4.46 a	0.306±0.12a	0.081±0.027 a	2.76±0.37 a	0.75±0.048 a	4.12±1.33 ab	15.55±1.48 a	52.83±7.17 a
LSD ($P \leq 0.05$)	2.20	4.83	0.030	0.006	0.03	0.066	0.75	2.53	7.32
<i>Soil types (ST)</i>									
Coastal saline soil	17.07±4.29	25.33±9.17	0.160±0.04	0.047±0.01	2.22±0.49	0.510±0.17	3.23±1.32	12.50±2.78	31.13±9.59
New alluvial soil	17.25±2.30	31.80±6.55	0.262±0.10	0.064±0.02	2.24±0.45	0.665±0.08	3.80±0.89	12.55±2.13	39.93±13.83
LSD ($P \leq 0.05$)	NS	3.06	0.019	0.004	NS	0.042	0.49	NS	NS
STMC × ST	NS	*	**	**	**	**	*	NS	*

*Each of them applied twice at 20 and 40 DAS; ABA: Abscisic acid; SA: Salicylic acid; DAS, Days after sowing; Mean follows by different letters are significantly different by Duncan's Multiple Range Test (DMRT) at $P \leq 0.05$, NS, Non-significant; *: significant at $P \leq 0.05$; **: significant at $P \leq 0.01$

control plots (Table 3). Crops raised in new alluvial soil produced higher grain yield (9.66 g/plant) than the crops raised in coastal saline soil (6.77 g/plant). Low photosynthetic activity of lentil crops due to less leaf chlorophyll content might be the reason for poor seed yield in low-N coastal saline soil (Banerjee *et al.* 2023b). It was evidenced that the exogenous application of salicylic acid has a tremendous positive impact on yield-determining traits and yield of lentils than any other stress-mitigation chemicals both in new alluvial and coastal saline soil. Salicylic acid has been found effective against several biotic and abiotic stresses, promotes better growth, and increases photosynthesis assimilation and cell division. Consequently, it enhances flowering, pod formation, leaf chlorophyll content, and yield of lentils while lowering the oxidative damage induced by stress and enhancing antioxidant properties in plants. Similar findings were earlier reported by other investigators (Kuchlan and Kuchlan 2019, Kuchlan and Kuchlan 2023). Salicylic acid is also known to reduce early flower drop because of the significant mobilization of photosynthates from source to sink (Laishram *et al.* 2020). In addition to this, oxidative stress produced within plants was found to be mitigated by salicylic acid spray which resulted in higher yield (Devi *et al.* 2011).

Correlation study

Pearson’s correlation between measured growth parameters, yield, and yield of lentils is depicted in Figure 3. The study clearly showed that the grain yield of lentils is positively correlated

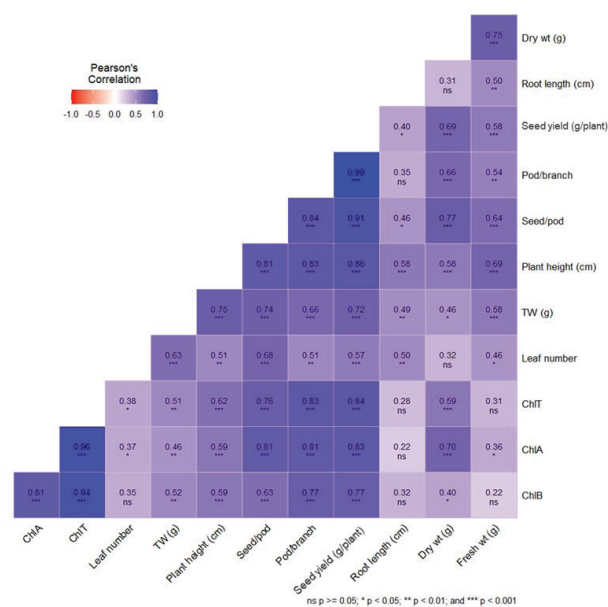


Fig. 3. Correlation between growth parameters, leaf chlorophyll content, yield determining traits, yield and of lentil (cv. Moitree)

($P < 0.001$) with key parameters like pod/branch, seed/pod, plant height, test weight, and leaf chlorophyll. Once again, it was proved that pods/branch influenced grain yield significantly and may be considered the most important yield-attributing traits of grain legumes including lentils (Sarkar *et al.* 2024). Root length has a negative correlation with chlorophyll content and pod/branch, while seed/pod ($R^2 = 0.46^*$) and grain yield ($R^2 = 0.40^*$) are positively correlated.

Table 3. Effects of stress mitigating chemicals and soil types on yield determining traits and yield of lentil (cv. Moitree) during *rabi* season

Treatments	Branches/plant	Pods/branch	Seeds/pod	Test weight (g)	Seed yield (g/plant)
<i>Salt stress mitigating chemicals (STMC)#</i>					
Control (water spray)	8.00±1.22 b	15.00±2.38 c	1.80±0.03 d	21.11±0.21 d	5.71±1.00 d
Seaweed sap (5% w/W)	10.67±0.99 ab	17.67±2.74 b	1.92±0.05 c	21.20±0.25 d	7.24±1.39 c
Proline (1.0 mM)	8.83±1.02 b	18.00±2.26 b	2.03±0.11 b	21.43±0.11 c	7.91±1.87 c
ABA (50 mM)	10.83±1.06 ab	20.33±4.38 b	2.07±0.11 b	21.89±0.15 b	9.29±2.39 b
SA (250 ppm)	12.83±1.17 a	23.00±2.58 a	2.13±0.08 a	22.09±0.09 a	10.89±1.55 a
LSD ($P \leq 0.05$)	2.67	2.56	0.04	0.10	1.16
<i>Soil types (ST)</i>					
Coastal saline Soil	9.13±1.21	16.27±2.86	1.92±0.09	21.45±0.18	6.77±1.63
New alluvial Soil	11.33±1.08	21.33±3.66	2.07±0.15	21.64±0.48	9.66±2.29
LSD ($P \leq 0.05$)	1.69	1.62	0.02	0.06	0.73
STMC × ST	NS	NS	*	*	NS

#Each of them applied twice at 20 and 40 DAS; ABA: Abscisic acid; SA: Salicylic acid; Mean follows by different letters are significantly different by Duncan’s Multiple Range Test (DMRT) at $P \leq 0.05$, NS, Non-significant; *: significant at $P \leq 0.05$; **: significant at $P \leq 0.01$

CONCLUSION

In summary, the application of various stress-mitigating chemicals proved to be beneficial for mitigating salinity stress in lentil cultivation. Among the tested stress-mitigating chemicals, salicylic acid (1.0 mM) spray (twice at 20 and 40 DAS) was found to be most effective for lentil (cv. Moitree) under both new alluvial and coastal saline soils of West Bengal. The present research also highlighted the effectiveness of salicylic acid in reducing the adverse effects of salinity and improving lentil productivity in coastal saline soil.

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