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Enhancing Leaf Nutrient Levels in Polyembryonic Mango (*Mangifera indica* L.) Seedlings: The Impact of Saline Water Irrigation and 28-Homobrassinolide Spray

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Authors' contributions

This work was carried out in collaboration among all authors. All authors read and approved the final manuscript.

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ABSTRACT

The leaf nutrients play a key role in the growth of a plant. Therefore, a study was undertaken to evaluate the effect of saline water and spray of 28-homobrassinolide on leaf nutrient status of polyembryonic mango (*Mangifera indica* L.) seedling during the years 2021-22 and 2022-23 at Agriculture Experimental Station, Navsari Agricultural University, Paria, (Gujarat). The experiment was laid out in Completely Randomized Design with factorial concept comprising of four salinity levels [S_1: Best available water (control), S_2: 2 dS m^{-1}, S_3: 4 dS m^{-1}, S_4: 6 dS m^{-1}] and three spray

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concentration of 28-homobrassinolide [H_1: No spray, (control), H_2 : 0.5 ppm and H_3 : 1 ppm]. Saline water application and 28-homobrassinolide spray was started at 80 days after sowing up to 240 days. The treatment containing application of water having lowest salinity (best available water) resulted in significantly higher leaf nutrient contents except Na up to 9 months after sowing during both years and in pooled analysis. Application of saline water having EC 6 dS m^{-1} adversely affected the growth of polyembryonic mango seedlings, reduced nutrient contents after 6 months of sowing. After 6 month of sowing, highest nutrient contents except Na was noted in mango seedlings treated with spray of 1 ppm 28-homobrassinolide during both years and in pooled analysis. The interactions of salinity levels and 28-homobrassinolide spray significantly affect leaf nutrient content of mango seedlings. Leaf nutrient contents except Na up to 9 months after sowing during both the years and in pooled analysis were recorded in treatment combination of best available water along with 1 ppm spray of 28-homobrassinolide. Maximum content of Na was observed in plants irrigated with 6 dS m^{-1} salinity level without spray of 28-homobrassinolide. Hence, it can be concluded that polyembryonic mango seedlings can be grown with saline irrigation having salinity up to 4 dS m^{-1} along with 1 ppm 28-homobrassinolide spray for better growth, biomass, nutrient contents and higher survival up to 9 months after sowing.

Keywords: Mango; salinity; 28-homobrassinolide; nutrient.

1. INTRODUCTION

Mango (*Mangifera indica* L., family Anacardiaceae) is one of the major fruit crops of Asia and has developed its own importance all over the world. It is recognized as national fruit of India and Bangladesh due to close association with culture and religion since the time immemorial, it’s delicious taste, pleasant flavour, colour and nutritive values [1]. India is the largest producer of mango in the world that occupies an area of 22.9 lakh hectares which is 35.4 per cent of the total area under the fruit cultivation and 204 lakh MT production with a productivity of around 8.92 MT/ha [2]. Mango production is faced by numerous challenges ranging from lack of quality planting material, poor agronomic practices, poor management of soil, nutrient and water, old and saline mango orchards with declining productivity. Additionally, various abiotic stresses like drought, salinity, etc. are becoming serious issues for crop production including mango. Among these stresses, salinity through soil and irrigation water is becoming a major problem in mango cultivation due to their negative effects on plant growth and production [3]. Salinity is defined as the presence of excessive amount of soluble salts that hinder or affect the normal function of plant growth. Under the situation of salinity plant growth is suppressed when the salt concentration exceeds threshold value. Growth rate and size of the plant progressively decreased with increased salinity. Accumulation of salts in leaves to toxic level inhibit growth, causes leaf injury, nutrients imbalance and reduce uptake of nutrients. Plant height and leaf area are drastically reduced due to salinity. Polyembryonic genotypes of mango have better salt tolerance potential than monoembryonic genotypes. Identifying the level of salt tolerance in polyembryonic mango genotypes can be helpful for its use as tolerant rootstocks for grafting and subsequent planting under salinity affected areas. Selection of salinity tolerant mango genotype is a potential solution for the salinity problem. Brassinosteroids (BRs) are group of naturally occurring phytohormones with growth promoting nature and are essential for normal growth and development. Exogenous application of BRs under salinity conditions, maintained cell organs ultrastructure including nucleus and chloroplast [4]. They control stress response either by activating or sustaining the enzymatic system of various biochemical pathways or by protein biosynthesis induction for the production of a wide range of defense imparting bio chemicals [5].

2. MATERIALS AND METHODS

The present investigation entitled Enhancing Leaf Nutrient Levels in Polyembryonic Mango (*Mangifera indica* L.) Seedlings: The Impact of Saline Water Irrigation and 28-Homobrassinolide Spray was carried out during the years 2021-22 and 2022-23 at Agriculture Experimental Station, Navsari Agricultural University, Paria, (Gujarat). The polyembryonic mango stones were sown in black polythene bags (9×11 inch size) with drainage holes containing media mixture of garden soil: biocompost (4:1). The stones were soaked for 30 minutes in solution containing fungicide and then used for sowing in black polythene bags containing media. Water with different levels of salinity was prepared by dissolving locally available raw salt in best available water (BAW) as per the respective treatments and desired salinity level adjusted with the help of EC meter. The product available in market with 0.04 % 28-homobrassinolide was used for the experiment during both years. A solution with 0.5 ppm 28-homobrassinolide was prepared by adding 1.25 ml of commercial product in one litre of water. Similarly, the solution containing 1.0 ppm 28-homobrassinolide was prepared by adding 2.50 ml of commercial product in one litre of water. Saline water application was started at 80 days after sowing and continued up to 9 months after sowing. Uniform volume of water was applied to all the plants in all treatments when irrigation required to maintain uniformity among salinity treatments. The experiment comprising four salinity levels [S_1: Best available water (Control), S_2: 2 dS m^{-1}, S_3: 4 dS m_{-}^{1} and S_4: 6 dS m^{-1}] along with three spray concentration of 28-homobrassinolide [H_1: No spray, (control), H_2: 0.5 ppm and H_3: 1 ppm] which formed twelve treatment combination which were replicated thrice. The leaf samples were determined as per the standard methods given by Trivedi *et al*. [6] and Jackson [7]. The experiment was set up in a Completely Randomized Design with factorial concept. The standard method of analysis of variance technique appropriate to Completely Randomized Design was used for individual years as well as for pooled analysis over the year described by Panse and Sukhatme [8]. The means of all the treatment were compared using Duncan's Multiple Range Test (DMRT).

3. RESULTS AND DISCUSSION

3.1 Nitrogen Content (kg/ha)

3.1.1 Effect of salinity

Results revealed that the nitrogen content in plant at 3 MAS was found non significant at first and second years of experiment whereas it was found significant and recorded highest (1.38) in best available water treatment (S_1) in pooled analysis. The plants from treatment S_1 recorded significantly higher nitrogen content at 6 MAS (1.35, 1.38 and 1.37 %) and 9 MAS (1.39, 1.35 and 1.37 %) during individual year and pooled analysis, respectively. Treatment S_1 was statistically at par with S_2 (2 dS m^{-1} saline water application). Significantly lower content of nitrogen 6 MAS (1.20, 1.24 and 1.22 %) and 9 MAS (1.11, 1.05 and 1.08 %) during both the years and pooled analysis, respectively was recorded in leaves from treatment S_4. The plants raised with irrigation water having higher salinity had significantly lower nitrogen content in plant parts. This may be due to high levels of sodium which hindered the uptake of nitrogen, phosphorous, potassium, calcium and magnesium by the roots and might also disturbed the root membranes and altered their selectivity (Rengel, 1992). A decrease in the concentration of all the primary and secondary nutrients in leaves of ber cultivars with increasing levels of salinity may be due to their presence of high concentration of salinity in the soil. A decrease in N, P and K^+ content of foliage has also been reported in ber and bael [9,10]. Saline conditions cause reduction in water uptake and results in chloride-nitrate antagonism due to which plants face decreased N availability [11].

3.1.2 Effect of 28-Homobrassinolide spray

The nitrogen content in plant at 3 MAS was found non significant. The plants under treatment of 1 ppm 28-Homobrassinolide spray recorded considerably higher content of nitrogen at 6 MAS (1.36, 1.51 and 1.49 %) and 9 MAS (1.34, 1.27 and 1.31 %) during both the year as well as pooled analysis, respectively. Lower nitrogen content at 6 MAS (1.31, 1.31 and 1.31 %) and 9 MAS (1.22, 1.19 and 1.20 %) during 1st year, 2nd year and pooled findings, respectively was found in seedlings without spray (H_1) at 9 MAS. Miao *et al*. (2007) proved that BRs application improved root nodulation capacity and nitrogenase activity, resulting in increasing N % in plant tissues. The results are in accordance with results obtained for grape [12].

3.1.3 Interaction effect

The nitrogen content was not affected significantly due to interaction effects of different salinity levels and spray concentration of 28-Homobrassinolide at 3 and 6 MAS. The treatment combination of best available water and spray of 1 ppm 28-Homobrassinolide (S_1H_3) resulted in statistically higher nitrogen content (1.42) which was also found at par with S_1H_1, S_1H_2, S_2H_3, S_3H_2 and S_3H_3 during first year of experiment while, it was found non signiciant during second year and pooled analysis. Lower nitrogen content (1.05) was noticed in treatment combination S_4H_1 during first year at 9 MAS. It is reported by El-Banna *et al.* [12] that nutrient concentrations except Na^+ drastically reduced under salinity conditions; however, BL application mitigated salinity injuries and concentration of Na^+ reduced whereas N, P and K increased in grapevine seedlings. The outcomes were compatible with Hatami and Pourakbar [13] in grape for salinity and Karlidag *et al*. [14] in strawberry for brassinolide.

3.2 Phosphorous Content (%)

3.2.1 Effect of salinity

Phosphorous content in leaves of mango seedlings was not affected significantly due to application of irrigation having different salinity levels at 3 MAS whereas it was affected significantly at 6 and 9 MAS. The plants raised with best available water had significantly higher phosphorous content at 6 MAS (0.26,0.23 and 0.24 %) and 9 MAS (0.33, 0.29 and 0.31 %) MAS during both studied years along with pooled analysis whereas, significantly lower content of phosphorous at 6 MAS (0.17, 0.14 and 0.15 %) and 9 MAS (0.12, 0.11 and 0.11 %) during both experimental years along with pooled analysis was observed with S_4 treatment. Lower phosphorous content under higher salinity treatments might be associated with ionic strength effect that reduced the activity of phosphate, concentration dependent sorption process of phosphorus from soil solution and low solubility of Ca-P minerals [15]. In most of the cases, salt-stressed plants show deficient P levels with adverse consequences for photosynthesis and other energy-dependent growth processes [16]. The results were in accordance with earlier studies in mango [17] grape Bybordi *et al*., [18] and in phalsa Singh *et al*., [19].

3.2.2 Effect of 28-Homobrassinolide spray

The data regarding phosphorous content clearly showed that mango seedlings sprayed with 28-Homobrassinolide had non significant influence at 3 MAS and it has significant influence at 6 and 9 MAS. The higher phosphorous content 6 MAS (0.24, 0.21 and 0.22 %) and 9 MAS (0.25, 0.22 and 0.24 %) during couple of years and pooled analysis, respectively was noted in H_3 treatment. This treatment was found at par with 0.5 ppm spray (H_2) during 6 MAS. Lower phosphorous content at 6 MAS (0.18, 0.17 and 0.17 %) and 9 MAS (0.18, 0.17 and 0.17) during both years and pooled findings, respectively was found in no spray treatment. Exogenous application of 24-EBL alters the accumulation of mineral contents in the leaves and roots of both cultivars. 24-EBL application under saline conditions significantly increased N, P, K, Ca, Mg, Fe, Mn, Zn, Cu, and B content of leaves and root of strawberry plants [14].

3.2.3 Interaction effect

The phosphorous content due to the interaction effects of different salinity levels and spray concentration of 28-Homobrassinolide was found non significant at 3, 6 and 9 MAS.

3.3 Potassium Content (%)

3.3.1 Effect of salinity

The results revealed that potassium content in the leaves of mango seedlings was altered significantly due to different salinity levels at 6 and 9 MAS while it was not altered significantly at 3 MAS. The plants under treatment S_1 had significantly higher potassium content at 6 MAS (0.83, 0.78 and 0.81 %) and 9 MAS (0.88, 0.84 and 0.86 %) during both years and pooled analysis, respectively that was noticed at par with 2 dS m^{-1} salinity level at 6 MAS. Significantly lower potassium content at 6 MAS (0.72, 0.64 and 0.67 %) and 9 MAS (0.70, 0.57 and 0.64 %) during individual years and pooled findings, respectively was observed in plants from treatment S_4. Under saline conditions, high level of Na not only interfered with K acquisition by the roots, but also disturbed the integrity of root membrane and altered their selectivity [15]. It may be due to the reduction in K^+ uptake through competitive process by Na^+ in plant roots Maathuis and Amtaman, [20]. Salinity enhance the accumulation of Na^+, which is connected with reduced uptake of K^+, leading to a decline in K^+/Na^+ ratio. The decrease in K content due to salinity was also reported in mango [17] aonla (Rao and Singh, 2006), ber Verma *et al*., [21] and citrus Alam *et al*., [22].

3.3.2 Effect of 28-Homobrassinolide spray

Significantly higher content of potassium at 6 MAS (0.83, 0.75 and 0.79 %) and 9 MAS (0.81, 0.77 and 0.79 %) during both the year and pooled analysis, respectively was observed in treatment H_3 while, lower potassium content at 6 MAS (0.72, 0.67 and 0.70 %) and 9 MAS (0.74, 0.64 and 0.69 %) during both studied years and pooled analysis, respectively was recorded in treatment H_1. The potassium content at 3 MAS was found non significant. Exogenous EBR significantly decreased the accumulation of Na^+ and Cl^- while enhanced that of K^+ and Ca^{2+} as well as K^+/Na^+ and Ca^{2+}/Na^+ ratios [23].

Table 1. Effect of salinity levels and 28-homobrassinolide spray on nitrogen content (%) in leaf of polyembryonic mango seedlings at 6 MAS

Nitrogen content in leaf (%) at 6 MAS												
28-HBR spray (ppm)	**2021-22**			**Mean**	**2022-23**			**Mean**	**Pooled**			**Mean**
Salinity levels	**H_1: Cont**	**H_2: 0.5**	**H_3: 1.0**		**H_1: Cont**	**H_2: 0.5**	**H_3: 1.0**		**H_1: Cont**	**H_2: 0.5**	**H_3: 1.0**	
S_1: BAW	1.34	1.29	1.42	1.35^{a}	1.28	1.36	1.52	1.38^{a}	1.31	1.33	1.47	1.37^{a}
S_2: 2 dS/m	1.23	1.31	1.41	1.32^{a}	1.28	1.38	1.44	1.36^{a}	1.26	1.34	1.42	1.34^{a}
S_3: 4 dS/m	1.22	1.25	1.33	1.27^{a}	1.21	1.26	1.37	1.28^{a}	1.22	1.26	1.35	1.27^{a}
S_4: 6 dS/m	1.11	1.21	1.26	1.20^{a}	1.16	1.25	1.30	1.24^{a}	1.14	1.23	1.28	1.22^{a}
Mean	1.23^{a}	1.26^{a}	1.36^{a}		1.31^{b}	1.41^{ab}	1.51^{a}		1.31^{b}	1.39^{ab}	1.49^{a}	
	S	**H**	**S×H**		**S**	**H**	**S×H**		**S**	**H**	**S×H**	
SEm ±	0.02	0.02	0.04		0.02	0.02	0.03		0.01	0.01	0.02	
CD at 5 %	0.10	0.09	NS		0.08	0.07	NS		0.05	0.04	NS	
CV (%)	5.81				4.60				2.69			

Values in a column bearing different superscripts are significantly different at 0.05 level

Table 2. Effect of salinity levels and 28-homobrassinolide spray on nitrogen content (%) in leaf of polyembryonic mango seedlings at 9 MAS

Nitrogen content in leaf (%) at 9 MAS												
28-HBR spray (ppm)	**2021-22**			**Mean**	**2022-23**			**Mean**	**Pooled**			**Mean**
Salinity levels	**H_1: Cont**	**H_2: 0.5**	**H_3: 1.0**		**H_1: Cont**	**H_2: 0.5**	**H_3: 1.0**		**H_1: Cont**	**H_2: 0.5**	**H_3: 1.0**	
S_1: BAW	1.37^{ab}	1.39^{ab}	1.42^{a}	1.39^{a}	1.44	1.48	1.51	1.35^{a}	1.33^{ab}	1.37^{a}	1.41^{a}	1.37^{a}
S_2: 2 dS/m	1.28^{abc}	1.26^{abcd}	1.38^{ab}	1.31^{a}	1.34	1.32	1.48	1.32^{a}	1.29^{ab}	1.28^{ab}	1.38^{a}	1.32^{a}
S_3: 4 dS/m	1.16^{cde}	1.30^{abc}	1.36^{ab}	1.27^{ab}	1.21	1.35	1.41	1.19^{ab}	1.15^{bcd}	1.24^{abc}	1.31^{ab}	1.23^{ab}
S_4: 6 dS/m	1.05^{e}	1.08^{de}	1.21^{bcde}	1.11^{b}	1.05	1.17	1.25	1.05^{b}	1.04^{d}	1.06^{cd}	1.14^{bcd}	1.08^{b}
Mean	1.22^{a}	1.26^{a}	1.34^{a}		1.19^{a}	1.22^{a}	1.27^{a}		1.20^{a}	1.24^{a}	1.31^{a}	
	S	**H**	**S×H**		**S**	**H**	**S×H**		**S**	**H**	**S×H**	
SEm ±	0.02	0.02	0.03		0.02	0.02	0.04		0.02	0.01	0.03	
CD at 5 %	0.08	0.07	0.14		0.08	0.07	NS		0.06	0.05	NS	
CV (%)	4.71				5.14				3.77			

Values in a column bearing different superscripts are significantly different at 0.05 level

Table 3. Effect of salinity levels and 28-homobrassinolide spray on phosphorous content (%) in leaf of polyembryonic mango seedlings at 6 MAS

	Phosphorous content in leaf (%) at 6 MAS											
28-HBR spray (ppm)	**2021-22**			**Mean**	**2022-23**			**Mean**	**Pooled**			**Mean**
Salinity levels	**H_1: Cont**	**H_2: 0.5**	**H_3: 1.0**		**H_1: Cont**	**H_2: 0.5**	**H_3: 1.0**		**H_1: Cont**	**H_2: 0.5**	**H_3: 1.0**	
S_1: BAW	0.23	0.25	0.28	0.26^{a}	0.21	0.22	0.26	0.23^{a}	0.22	0.24	0.27	0.24^{a}
S_2: 2 dS/m	0.21	0.23	0.24	0.22^{a}	0.17	0.21	0.23	0.20^{a}	0.19	0.22	0.24	0.21^{a}
S_3: 4 dS/m	0.16	0.21	0.24	0.20^{a}	0.15	0.20	0.19	0.18^{a}	0.15	0.21	0.21	0.19^{a}
S_4: 6 dS/m	0.13	0.18	0.19	0.17^{a}	0.13	0.14	0.16	0.14^{a}	0.13	0.16	0.17	0.15^{a}
Mean	0.18^{ab}	0.22^{a}	0.24^{a}		0.17^{ab}	0.19^{a}	0.21^{a}		0.17^{ab}	0.21^{a}	0.22^{a}	
	S	**H**	**S×H**		**S**	**H**	**S×H**		**S**	**H**	**S×H**	
SEm ±	0.01	0.01	0.01		0.01	0.01	0.01		0.01	0.01	0.01	
CD at 5 %	0.03	0.02	NS		0.02	0.02	NS		0.02	0.02	NS	
CV (%)	9.80				7.77				6.85			

Values in a column bearing different superscripts are significantly different at 0.05 level

Table 4. Effect of salinity levels and 28-homobrassinolide spray on phosphorous content (%) in leaf of polyembryonic mango seedlings at 9 MAS

	Phosphorous content in leaf (%) at 9 MAS											
28-HBR spray (ppm)	**2021-22**			**Mean**	**2022-23**			**Mean**	**Pooled**			**Mean**
Salinity levels	**H_1: Cont**	**H_2: 0.5**	**H_3: 1.0**		**H_1: Cont**	**H_2: 0.5**	**H_3: 1.0**		**H_1: Cont**	**H_2: 0.5**	**H_3: 1.0**	
S_1: BAW	0.29	0.33	0.36	0.33^{a}	0.26	0.28	0.33	0.29^{a}	0.27	0.31	0.34	0.31^{a}
S_2: 2 dS/m	0.17	0.23	0.27	0.22^{ab}	0.18	0.21	0.25	0.21^{a}	0.18	0.22	0.26	0.22^{ab}
S_3: 4 dS/m	0.16	0.20	0.22	0.19^{ab}	0.15	0.18	0.19	0.17^{a}	0.16	0.19	0.21	0.18^{ab}
S_4: 6 dS/m	0.09	0.13	0.14	0.12^{b}	0.09	0.11	0.13	0.11^{a}	0.09	0.12	0.13	0.11^{b}
Mean	0.18^{ab}	0.22^{a}	0.25^{a}		0.17^{ab}	0.19^{a}	0.22^{a}		0.17^{ab}	0.21^{a}	0.24^{a}	
	S	**H**	**S×H**		**S**	**H**	**S×H**		**S**	**H**	**S×H**	
SEm ±	0.01	0.01	0.01		0.01	0.01	0.01		0.01	0.01	0.01	
CD at 5 %	0.03	0.02	NS		0.02	0.02	NS		0.02	0.01	NS	
CV (%)	9.39				8.30				5.90			

Values in a column bearing different superscripts are significantly different at 0.05 level

Table 5. Effect of salinity levels and 28-homobrassinolide spray on potassium content (%) in leaf of polyembryonic mango seedlings at 6 MAS

	Potassium content in leaf (%) at 6 MAS											
28-HBR spray (ppm)	**2021-22**			**Mean**	**2022-23**			**Mean**	**Pooled**			**Mean**
Salinity levels	**H_1: Cont**	**H_2: 0.5**	**H_3: 1.0**		**H_1: Cont**	**H_2: 0.5**	**H_3: 1.0**		**H_1: Cont**	**H_2: 0.5**	**H_3: 1.0**	
S_1: BAW	0.80	0.83	0.85	0.83[a]	0.74	0.78	0.83	0.78[a]	0.77	0.80	0.84	0.81[a]
S_2: 2 dS/m	0.73	0.77	0.86	0.79[a]	0.69	0.73	0.77	0.73[a]	0.71	0.75	0.82	0.76[a]
S_3: 4 dS/m	0.69	0.76	0.81	0.75[a]	0.65	0.69	0.71	0.68[a]	0.67	0.72	0.76	0.72[a]
S_4: 6 dS/m	0.67	0.73	0.77	0.72[a]	0.61	0.63	0.67	0.64[a]	0.64	0.68	0.72	0.68[a]
Mean	0.72[a]	0.77[a]	0.83[a]		0.67[a]	0.71[a]	0.75[a]		0.70[a]	0.74[a]	0.79[a]	
	S	**H**	**S×H**		**S**	**H**	**S×H**		**S**	**H**	**S×H**	
SEm ±	0.01	0.01	0.02		0.02	0.02	0.03		0.01	0.01	0.02	
CD at 5 %	0.06	0.05	NS		0.07	0.06	NS		0.04	0.04	NS	
CV (%)	5.48				7.64				4.19			

Values in a column bearing different superscripts are significantly different at 0.05 level

Table 6. Effect of salinity levels and 28-homobrassinolide spray on potassium content (%) in leaf of polyembryonic mango seedlings at 9 MAS

	Potassium content in leaf (%) at 9 MAS											
28-HBR spray (ppm)	**2021-22**			**Mean**	**2022-23**			**Mean**	**Pooled**			**Mean**
Salinity levels	**H_1: Cont**	**H_2: 0.5**	**H_3: 1.0**		**H_1: Cont**	**H_2: 0.5**	**H_3: 1.0**		**H_1: Cont**	**H_2: 0.5**	**H_3: 1.0**	
S_1: BAW	0.85[abc]	0.87[ab]	0.91[a]	0.88[a]	0.83[a]	0.83[a]	0.87[a]	0.84[a]	0.84	0.85	0.89	0.86[a]
S_2: 2 dS/m	0.77[abcd]	0.78[abcd]	0.84[abc]	0.80[a]	0.59[bc]	0.82[a]	0.86[a]	0.76[ab]	0.68	0.80	0.85	0.78[ab]
S_3: 4 dS/m	0.70[bcd]	0.80[abcd]	0.71[bcd]	0.74[a]	0.60[bc]	0.61[bc]	0.76[ab]	0.65[bc]	0.65	0.71	0.73	0.69[ab]
S_4: 6 dS/m	0.63[d]	0.67[cd]	0.80[abcd]	0.70[a]	0.55[c]	0.58[bc]	0.59[bc]	0.57[c]	0.59	0.63	0.69	0.64[b]
Mean	0.74[a]	0.78[a]	0.81[a]		0.64[a]	0.71[a]	0.77[a]		0.69[a]	0.74[a]	0.79[a]	
	S	**H**	**S×H**		**S**	**H**	**S×H**		**S**	**H**	**S×H**	
SEm ±	0.01	0.01	0.02		0.02	0.02	0.03		0.01	0.01	0.02	
CD at 5 %	0.05	0.05	0.09		0.08	0.07	0.14		0.05	0.04	NS	
CV (%)	5.32				8.48				4.90			

Values in a column bearing different superscripts are significantly different at 0.05 level

Table 7. Effect of salinity levels and 28-homobrassinolide spray on magnesium content (%) in leaf of polyembryonic mango seedlings at 6 MAS

Magnesium content in leaf (%) at 6 MAS												
28-HBR spray (ppm)	**2021-22**			**Mean**	**2022-23**			**Mean**	**Pooled**			**Mean**
Salinity levels	**H_1: Cont**	**H_2: 0.5**	**H_3: 1.0**		**H_1: Cont**	**H_2: 0.5**	**H_3: 1.0**		**H_1: Cont**	**H_2: 0.5**	**H_3: 1.0**	
S_1: BAW	0.49	0.51	0.52	0.51[a]	0.56	0.58	0.59	0.56[a]	0.53	0.55	0.55	0.54[a]
S_2: 2 dS/m	0.44	0.46	0.49	0.46[a]	0.51	0.55	0.56	0.54[a]	0.48	0.51	0.52	0.50[a]
S_3: 4 dS/m	0.43	0.45	0.46	0.44[a]	0.48	0.51	0.54	0.51[a]	0.45	0.48	0.50	0.47[a]
S_4: 6 dS/m	0.39	0.41	0.43	0.41[a]	0.47	0.48	0.50	0.48[a]	0.43	0.45	0.46	0.45[a]
Mean	0.44	0.46	0.47		0.51	0.53	0.55		0.47	0.49	0.51	
	S	**H**	**S×H**		**S**	**H**	**S×H**		**S**	**H**	**S×H**	
SEm ±	0.01	0.01	0.02		0.01	0.01	0.02		0.01	0.01	0.02	
CD at 5 %	0.04	NS	NS		0.05	NS	NS		0.04	NS	NS	
CV (%)	7.34				7.40				6.13			

Values in a column bearing different superscripts are significantly different at 0.05 level

Table 8. Effect of salinity levels and 28-homobrassinolide spray on magnesium content (%) in leaf of polyembryonic mango seedlings at 9 MAS

Magnesium content in leaf (%) at 9 MAS												
28-HBR spray (ppm)	**2021-22**			**Mean**	**2022-23**			**Mean**	**Pooled**			**Mean**
Salinity levels	**H_1: Cont**	**H_2: 0.5**	**H_3: 1.0**		**H_1: Cont**	**H_2: 0.5**	**H_3: 1.0**		**H_1: Cont**	**H_2: 0.5**	**H_3: 1.0**	
S_1: BAW	0.57	0.56	0.55	0.56[a]	0.61	0.62	0.64	0.63[a]	0.59	0.59	0.60	0.59[a]
S_2: 2 dS/m	0.46	0.54	0.51	0.51[a]	0.59	0.58	0.57	0.58[a]	0.53	0.56	0.54	0.54[a]
S_3: 4 dS/m	0.45	0.48	0.51	0.48[a]	0.50	0.54	0.56	0.53[a]	0.48	0.51	0.53	0.51[a]
S_4: 6 dS/m	0.40	0.42	0.47	0.43[a]	0.44	0.50	0.51	0.48[a]	0.42	0.46	0.49	0.46[a]
Mean	0.47	0.50	0.51		0.54	0.56	0.57		0.50	0.53	0.54	
	S	**H**	**S×H**		**S**	**H**	**S×H**		**S**	**H**	**S×H**	
SEm ±	0.01	0.01	0.02		0.01	0.01	0.02		0.01	0.01	0.02	
CD at 5 %	0.05	NS	NS		0.05	NS	NS		0.04	NS	NS	
CV (%)	7.52				7.31				5.49			

Values in a column bearing different superscripts are significantly different at 0.05 level

Table 9. Effect of salinity levels and 28-homobrassinolide spray on sodium content (%) in leaf of polyembryonic mango seedlings at 6 MAS

28-HBR spray (ppm) / Salinity levels	Sodium content in leaf (%) at 6 MAS											
	2021-22			Mean	2022-23			Mean	Pooled			Mean
	H_1: Cont	H_2: 0.5	H_3: 1.0		H_1: Cont	H_2: 0.5	H_3: 1.0		H_1: Cont	H_2: 0.5	H_3: 1.0	
S_1: BAW	0.21	0.22	0.24	0.22^a	0.19	0.20	0.22	0.20^a	0.20	0.21	0.23	0.21^a
S_2: 2 dS/m	0.30	0.25	0.22	0.26^a	0.26	0.23	0.22	0.24^a	0.28	0.24	0.22	0.25^a
S_3: 4 dS/m	0.32	0.28	0.25	0.28^a	0.29	0.26	0.24	0.26^a	0.31	0.27	0.24	0.27^a
S_4: 6 dS/m	0.34	0.30	0.28	0.31^a	0.32	0.28	0.25	0.29^a	0.33	0.29	0.27	0.30^a
Mean	0.29^a	0.26^a	0.25^a		0.27^a	0.24^a	0.23^a		0.28^a	0.25^a	0.24^a	
	S	**H**	**S×H**		**S**	**H**	**S×H**		**S**	**H**	**S×H**	
SEm ±	0.01	0.01	0.01		0.01	0.01	0.01		0.01	0.01	0.01	
CD at 5 %	0.03	0.03	NS		0.03	0.03	NS		0.02	0.02	NS	
CV (%)	9.10				8.34				6.65			

Values in a column bearing different superscripts are significantly different at 0.05 level

Table 10. Effect of salinity levels and 28-homobrassinolide spray on sodium content (%) in leaf of polyembryonic mango seedlings at 9 MAS

28-HBR spray (ppm) / Salinity levels	Sodium content in leaf (%) at 9 MAS											
	2021-22			Mean	2022-23			Mean	Pooled			Mean
	H_1: Cont	H_2: 0.5	H_3: 1.0		H_1: Cont	H_2: 0.5	H_3: 1.0		H_1: Cont	H_2: 0.5	H_3: 1.0	
S_1: BAW	0.24^b	0.25^b	0.23^b	0.24^a	0.22^b	0.22^b	0.21^b	0.21^a	0.23^b	0.24^b	0.22^b	0.23^a
S_2: 2 dS/m	0.30^{ab}	0.31^{ab}	0.29^{ab}	0.30^a	0.28^{ab}	0.29^{ab}	0.27^{ab}	0.28^a	0.29^{ab}	0.30^{ab}	0.28^{ab}	0.29^a
S_3: 4 dS/m	0.39^{ab}	0.34^{ab}	0.29^a	0.34^a	0.39^{ab}	0.32^{ab}	0.27^{ab}	0.33^a	0.39^{ab}	0.33^{ab}	0.28^{ab}	0.34^a
S_4: 6 dS/m	0.47^a	0.38^{ab}	0.35^{ab}	0.40^a	0.42^a	0.37^{ab}	0.35^{ab}	0.38^a	0.45^{ab}	0.38^{ab}	0.35^{ab}	0.39^a
Mean	0.35^a	0.32^a	0.29^a		0.33^a	0.30^a	0.2^7		0.34^a	0.31^a	0.28^a	
	S	**H**	**S×H**		**S**	**H**	**S×H**		**S**	**H**	**S×H**	
SEm ±	0.01	0.01	0.02		0.01	0.01	0.01		0.01	0.01	0.01	
CD at 5 %	0.03	0.03	0.06		0.03	0.03	0.05		0.03	0.02	0.04	
CV (%)	8.14				7.35				6.19			

Values in a column bearing different superscripts are significantly different at 0.05 level

3.3.3 Interaction effect

Interactions of different salinity levels and spray concentration of 28-Homobrassinolide created non significant influence on potassium content at 3 and 6 MAS. The treatment combination of best available water and spray of 1 ppm 28-homobrassinolide (S_1H_3) resulted in much higher content of potassium (0.91 and 0.87 %) whereas lower content of potassium (0.63 and 0.55 %) was noted in S_4H_1 treatment combination during both trial years and it was also found statistically at par with S_1H_1, S_1H_2 and S_2H_3. In pooled analysis N content was found non significant. Growth promotive effect of BRs might have also been due to its role in ion homeostasis, which is necessary for various biochemical or physiological processes controlling growth [14]. The K^+/Na^+ ratio significantly decrease with salinity, but BL spraying at 2 mg l^{-1} improved the K^+/Na^+ ratio in leaves of grape [12].

3.4 Calcium Content (%)

3.4.1 Effect of salinity

The results concerning effect of salinity levels on calcium content of mango seedlings was found non significant.

3.4.2 Effect of 28-homobrassinolide spray

Different spray concentration 28-homobrassinolide does not affect calcium content significantly.

3.4.3 Interaction effect

The interaction of saline irrigation water and spray concentration of 28-homobrassinolide has non significant influence on calcium content of polyembryonic mango seedlings.

3.5 Magnesium Content (%)

3.5.1 Effect of salinity

Magnesium content in plant at 3 MAS was found non significant. The magnesium content was significantly higher at 6 MAS (0.51, 0.56 and 0.5 %) and 9 MAS (0.56, 0.63 and 0.59 %) during both years and pooled analysis, respectively in treatment of best available water (S_1) which was found at par with 2 dS m^{-1} (S_2) at 6 and 9 MAS. The plants under higher salinity treatments showed decreasing trend for magnesium content in plants and the treatment S4 (6 dS m-1) had significantly lower magnesium content at 6 MAS (0.41, 0.48 and 0.45 %) and 9 MAS (0.43, 0.48 and 0.46 %) MAS during both studied years and pooled findings, respectively. Magnesium serves as a chlorophyll component and activator of enzymes, involved in photosynthesis, and therefore decrease of leaf Mg concentration might be one of the reason for photosynthesis impairment [24]. Reduction in Mg concentration due to salinity was reported by Ruiz *et al*., [25] in citrus and Salem *et al*., [26] in grape).

3.5.2 Effect of 28-Homobrassinolide spray

Different concentrations of 28-Homobrassinolide spray has non significant affect on magnesium content of polyembryonic mango seedlings.

3.5.3 Interaction effect

The interaction effects of different salinity levels and spray concentration of 28-homobrassinolide on magnesium content was found non significant.

3.6 Sodium Content (%)

3.6.1 Effect of salinity

The results revealed that sodium content in mango seedlings was altered considerably due to the different levels of water salinity at 6 and 9 MAS while it was found non significant at 3 MAS. The plants in treatment S_1 had significantly lower sodium content in plant parts 6 MAS (0.22, 0.20 and 0.21 %) and 9 MAS (0.24, 0.21 and 0.23 %) during both experimental years and pooled analysis, respectively. This treatment was found at par with 4 dS m^{-1} salinity level during both years at 6 MAS. The sodium content increased with increase in salinity and significantly highest sodium content 6 MAS (0.31, 0.29 and 0.30 %) and 9 MAS (0.40, 0.38 and 0.39 %) during both trail years and pooled findings, respectively was noted in treatment S_4 (6 dS m^{-1}). Irrigation with saline water produced a transient increase in the EC of the root weighted with saturated soil solution. This increase cause decline in leaf water potential and increase in leaf petiole Na^+ and Cl^- contents. Stevens *et al*., [27]. In saline water, Na^+ and Cl- are the major salts in composition of sea water. When the plants irrigated withdifferent water salinity levels, they accumulated higher concentration of these salts in different plant parts [28].

3.6.2 Effect of 28-Homobrassinolide spray

Different concentrations of 28-Homobrassinolide spray significantly affect sodium content at 6 and

9 MAS while it has non significant influence at 3 MAS. The lower sodium content at 6 MAS (0.25, 0.23 and 0.24 % and 9 MAS (0.30, 0.28 and 0.2 %) MAS during both years and pooled analysis, respectively was noted in plants treated with spray of 1 ppm28-Homobrassinolide whereas, significantly higher content of sodium at 6 MAS (0.29, 0.27 and 0.28 %) and 9 MAS (0.35, 0.33 and 0.34 %) during both studied years along with pooled analysis, respectively was observed in treatment H_1. Sodium contents of leaves and root significantly decrease by 24-EBL application. Brassinolide was more effective in increasing ion percentage of N, P and K and decreasing Na^+ percentage. The K^+/Na^+ ratio significantly decreased with salinity but conversely BL spraying improved the K^+/Na^+ ratio in leaves at 2 mg l^{-1} [12].

3.6.3 Interaction effect

The interaction effects of different salinity levels and spray concentration of 28-Homobrassinolide on sodium content was affected non significantly at 3 and 6 MAS whereas it was affected significantly at 9 MAS. The treatment combination of best available water and 28-homobrassinolide spray of 1 ppm resulted in lower sodium content (0.23, 0.21 and 0.22 %) while, higher sodium content (0.47, 0.42 and 0.45 %) was revealed in treatment combination S_4H_1 during both the years as well as pooled analysis, respectively at 9 MAS. Nutrient contents except Na^+ drastically decreased under salinity; however, brassinolide application mitigated salinity injuries via decreasing Na^+ and increased N, P and K content of grapevine seedlings [12]. Epibrassinolide increase in growth was accompanied with corresponding increase in K/Na ratio in the salt stressed egg plants [23]. The outcomes were compatible Hatami and Pourakbar [13] in grape for salinity and Karlidag *et al*. [14] in strawberry for BL.

4. CONCLUSION

From the results of two years study, it can be concluded that different salinity levels and spray concentration of 28-Homobrassinolide significantly influenced the leaf nutrient status of polyembryonic mango seedlings. Application of water having EC less than 2 dS m^{-1} resulted highest leaf nutrient content of polyembryonic mango seedlings While, application of water having 6 dS m^{-1} salinity reduced the leaf nutrient content of mango seedlings. Spray of 28-homobrassinolide at 1 ppm promoted the growth of polyembryonic mango seedlings and recorded higher leaf nutrient content after 9 months of sowing.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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