Yield response of *Limonium sinuatum* cultivars under salinity stress

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Abstract

Aim: This research was carried out to determine the effects of different salinity levels on plant growth, yield, quality and certain stress parameters during cultivation of *Limonium sinuatum* 'Compindi White' and 'Compindi Deep Blue' in a greenhouse. Further, the study also aimed to provide an insight into future studies to reveal the magnitude of the effect of different salinity levels on the commercial cultivation of these plants.

Methodology: This study was conducted during 2016-2017 in a greenhouse in Mugla Sıtkı Kocman University, Turkey. Different concentrations (control, 5, 10, and 20 dS m⁻¹) of salinity source in the form of NaCl were used. To examine the physiological characteristics of plants, relative water content (RWC) of leaves was evaluated as stress parameter. The tips of the leaves were examined for the following parameters: chlorophyll a and b, total chlorophyll, carotenoid values, proline and lipid peroxidation.

Results: It was observed that increased salinity level negatively affected the plant growth, yield, quality and some stress parameters. Compared with the control, the marketable yield losses at 20 dS m⁻¹ salinity level were 59.11% for *L. sinuatum* 'Compindi White', 72.43% for *L. sinuatum* 'Compindi Deep Blue'. *L. sinuatum* showed higher salt resistance than other ornamental plants.

Interpretation: The results of analysis of salinity levels of 20 dS m⁻¹ suggest that using saline-resistant plants as ornamental plants in landscape designs rather than cut flowers would be more appropriate.

Keywords: *Limonium sinuatum*, Quality, Salinity, Salt stress, Yield

L. sinuatum 'Compindi White' and *L. sinuatum* 'Compindi Deep Blue'

Application of different NaCl concentrations (Control, 5dSm⁻¹, 10dSm⁻¹ and 20 dSm⁻¹),

Effect on

- plant growth
- yield
- quality
- some stress parameters

Use of such plants can contribute to plant variation as an alternative in terms of visualization of saline soils.

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Introduction

Salinity is an important environmental stress parameter that limits plant production by negatively affecting the plant growth, development and productivity, leading to economic loss (Zahra et al., 2010; Shahi et al., 2015; Vibhuti et al., 2015). The salinity problem mostly occurs in irrigated areas, arid and semi-arid areas, as well as in greenhouses (Sivritepe and Eris, 1998; Hasanuzzaman et al., 2013). As most cut flowers are produced in greenhouses in Turkey, the problem of salinity-limiting cultivation is an important issue. In this context, *Limonium sinuatum* is a newly developed cut flower species, used both as a flowering filler material and as a parent material while making bouquets of intense dense flower clusters and different color choices (Akat, 2012; Ozmen et al., 2012). This halophytic ornamental plant can grow on saline soils as well as when irrigated with high saline waters (30 dS m⁻¹) (Carter et al., 2005; Dinga et al., 2010). This study was therefore carried out with the aim of determining the plant growth, quality, yield, and problems that occur under certain stress parameters in *L. sinuatum* 'Compindi White' and 'Compindi Deep Blue' under different salinity levels. Further, this study aimed to provide an insight into future studies to reveal the magnitude of effect of different salinity levels on the commercial cultivation of ornamental plants.

Materials and Methods

The study was conducted during 2016-2017 in the greenhouse. Experimental design used included randomized parcels with three replicates, with 12 plants in each replicate. The seeds of the most preferred white flowered *L. sinuatum* 'Compindi White' and purple flowered 'Compindi Deep Blue' were sown on 09.18.2016. The seedlings were planted in 0.5 l pots containing 1:1 peat : perlite mixture. After 1 month, the seedlings were transferred to 26 l pots, and the seedlings were exposed saline conditions. The physical and chemical properties of the soil were determined (Table 1).

The Hoagland solution (pH: 5.5–6.5) was modified for plant nutrition and was applied to the plants once a week after planting (Brohi et al., 1994). The electrical conductivity (EC) value of the irrigation water used was 0.67 dS m⁻¹. The EC value of the nutrient solution, obtained by adding nutrient to water, was regarded as control. A total of four salinity levels were tested by increasing the salinity of the control to 5, 10, and 20 dS m⁻¹ NaCl at each application. In all plants, the number of harvested flowers (plant) and the length (cm), thickness (mm), and weight (g) of the peduncles were determined. The experiment was completed on 10.06.2017 when salinity level had risen in the soil and the flower quality decreased depending on the increasing temperatures. The length (cm) and fresh weight (g) of the roots was determined, and root dry weights (g) were determined by drying the samples at 65°C and weighing using precision scales. To examine the physiological characteristics of the plants, the relative water content (RWC) of the leaf (Yamasaki and Dillenburg, 1999) was determined as a stress parameter and expressed in percentages. One month after salt application in five periods and 3 months after salt application, the tips of the plant leaves were examined for the following parameters: chlorophyll a and b, total chlorophyll (Arnon, 1949), and carotenoid values (Strain and Svec, 1966) were expressed as mg l⁻¹; proline was expressed as µmol g⁻¹ (Bates et al., 1973); and lipid peroxidation was presented as nmol ml⁻¹ (Hodges et al., 1999). During the experimental period, the minimum temperature was 10.1°C, maximum temperature was 38.2°C, and the average temperature was 22.5°C; the average relative humidity was approximately 75.60%. The data was analyzed with the SPSS version 15.0 statistical package program.

Results and Discussion

An increase in salt levels negatively affected the number of leaves and dry weight of upper plant parts in the both cultivars.

Table 1 : Physical and chemical properties of soil

Parameters	Values
pH	7.35
Total salt (%)	0.019
Calcium carbonate (%)	10.84
Texture	Sandy loam
Organic matter (%)	3.72
Total nitrogen (%)	0.16
Available phosphorus (ppm)	34.21
Available potassium (ppm)	149
Available calcium (ppm)	2983
Available magnesium (ppm)	261
Available sodium (ppm)	75
Available iron (ppm)	9.17
Available zinc (ppm)	3.12
Available copper (ppm)	3.37
Available manganese (ppm)	9.15

The effect was statistically significant. The highest values in terms of all measured parameters were observed in the control and 5 dS m⁻¹ level in the same statistical group. The values of measured parameters suggested that the lowest growth rate of the upper plant part was observed at 20 dS m⁻¹ in which the saline level was highest. Compared with the control, at 20 dS m⁻¹, the number of leaves, fresh weight and dry weight of the upper plant parts decreased by 43.93%, 58.99% and 55.49% in 'Compindi White' whereas the decrease in 'Compindi Deep Blue' was 55.41%, 69.90% and 67.58%, respectively. Similarly, at different salinity levels, the number of leaves and fresh and dry weights of the upper plant parts decreased at different rates (Table 2).

Zurayk et al. (1993) reported that in *Begonia* sp., *Chlorophytum* sp., *Coleus* sp., *Geranium* sp. and *Mesembryanthemum* sp. increased salinity levels (0.5, 5 and 15 dS m⁻¹) of the irrigation water decrease the plant length, fresh weight, and dry weight, and the effect on the fresh weight of the plant was more than that on the dry weight. Gunes et al. (2000) suggested that salinity stress affects the upper plant parts more than the root. These findings are in accordance with our study. According to Grieve et al. (2005), rosettes of *Limonium perezii* decreased by 50% compared with those of controls when salinity increased from 2.5 to 7 dS m⁻¹ and decreased to 25% when salinity was 30 dS m⁻¹. The findings of many studies are similar, although salinity level of 20 dS m⁻¹ was very high in terms of regressing plant development (Carter and Grieve, 2006). Different salinity levels produce statistically significant changes in terms of root development. The root length decreased with increasing salinity level and the lowest value was obtained at the highest salinity level. Similar to the root length, the fresh and dry root weights were also negatively affected by an increase in salinity level.

Compared with the control and similar to the increase in salinity level in 'Compindi White', the root length, fresh root weight, and dry root weight decreased by 20.70%, 4.56% and 6.08% at 5 dS m⁻¹; 34.52%, 17.89% and 16.41% at 10 dS m⁻¹, and 46.61%, 50.17% and 45.24% at 20 dS m⁻¹ respectively. Compared with the controls following an increase in the salinity level, root length, fresh and dry root weights in 'Compindi Deep Blue' decreased by 17.30%, 5.91% and 4.75% at 5 dS m⁻¹; 30.22%, 19.34% and 10.61% at 10 dS m⁻¹; and 50.00%, 65.15% and 47.87% at 20 dS m⁻¹ level, respectively (Table 3). Prabucki et al. (1999) examined the root development of *Chrysanthemum* sp. under saline conditions and reported 45% decrease in root number, 70% decrease in root length, and 52% decrease in root weight.

The harvest of 'Compindi White' was initiated approximately 70 days after planting whereas that of 'Compindi Deep Blue' after 90 days. The effect of salt levels on the total and marketable yield was statistically significant for both cultivars. In terms of total and marketable yield, the salt levels in the 'Compindi White' decreased by 17.05% and 26.78% at 5 dS m⁻¹, 23.85% and 38.28% at 10 dS m⁻¹, and 42.13% and 59.11% at 20 dS m⁻¹ salinity level, respectively. In 'Compindi Deep Blue,' the total and marketable yields decreased by 8.31% and 22.43% at 5 dS m⁻¹, 16.40% and 33.29% at 10 dS m⁻¹, and 44.60% and 72.43% at 20 dS m⁻¹ salinity level, respectively (Table 4).

Akat and Ozzambak (2013) reported a loss of efficiency in *L. sinuatum* in saline soils (EC: 0.674%). Compared with the control, 'Compindi White' had 61.65% loss and 'Compindi Deep Blue' had 79.47% loss. These results are consistent with those of current study. In a study conducted by Carter and Grieve (2006), it was observed that the flowers of *Celosia argentea* cv. Cristata, *L.*

Table 2 : Effect of different salinity levels on the growth of upper plant parts

<i>L. sinuatum</i> 'Compindi White'			
Concentrations	Number of leaf (piece/plant)	Fresh weight of upper parts (g)	Dry weight of upper parts (g)
EC0 (1 dS m ⁻¹)	130.50 ^a	122.37 ^a	47.72 ^a
EC1 (5 dS m ⁻¹)	120.16 ^a	115.30 ^a	39.94 ^{ab}
EC2 (10 dS m ⁻¹)	92.25 ^b	88.08 ^b	31.92 ^{bc}
EC3 (20 dS m ⁻¹)	73.17 ^c	50.18 ^c	21.24 ^c
LSD	11.90**	18.86**	10.94**
<i>L. sinuatum</i> 'Compindi Deep Blue'			
Concentrations	Number of leaf (piece/plant)	Fresh weight of upper parts (g)	Dry weight of upper parts (g)
EC0 (1 dS m ⁻¹)	109.81 ^a	101.70 ^a	39.92 ^a
EC1 (5 dS m ⁻¹)	104.15 ^a	97.83 ^a	36.74 ^a
EC2 (10 dS m ⁻¹)	74.70 ^b	61.92 ^b	21.90 ^b
EC3 (20 dS m ⁻¹)	48.96 ^c	30.61 ^c	12.94 ^c
LSD	5.76**	18.17**	8.05**

Within each column, values followed by same letters are not significantly different according to LSD test, ** Significant at $p < 0.01$, * Significant at $p < 0.05$ level, ns: non-significant

Table 3 : Effect of different salinity levels on root growth

<i>L. sinuatum</i> 'Compindi White'			
Concentrations	Root length (cm)	Root fresh weight (g)	Root dry weight (g)
EC0 (1 dS m ⁻¹)	17.87 ^a	28.50 ^a	19.56 ^a
EC1 (5 dS m ⁻¹)	14.17 ^b	27.20 ^b	18.37 ^b
EC2 (10 dS m ⁻¹)	11.70 ^{bc}	23.40 ^c	16.35 ^c
EC3 (20 dS m ⁻¹)	9.54 ^c	14.20 ^d	10.71 ^d
LSD	3.06**	0.14**	0.61**

<i>L. sinuatum</i> 'Compindi Deep Blue'			
Concentrations	Root length (cm)	Root fresh weight (g)	Root dry weight (g)
EC0 (1 dS m ⁻¹)	16.18 ^a	25.17 ^a	11.78 ^a
EC1 (5 dS m ⁻¹)	13.38 ^b	23.68 ^b	11.22 ^b
EC2 (10 dS m ⁻¹)	11.29 ^c	20.30 ^c	10.53 ^c
EC3 (20 dS m ⁻¹)	8.09 ^d	8.77 ^d	6.14 ^d
LSD	1.63**	0.40**	0.63**

Within each column, values followed by same letters are not significantly different according to LSD test; ** Significant at $p < 0.01$, * Significant at $p < 0.05$ level, ns: non-significant

Table 4 : Effect of different salinity levels on yield

<i>L. sinuatum</i> 'Compindi White'		
Concentrations	Total yield (piece/plant)	Marketable yield (piece/plant)
EC0 (1 dS m ⁻¹)	9.85 ^a	9.22 ^a
EC1 (5 dS m ⁻¹)	8.17 ^b	6.75 ^b
EC2 (10 dS m ⁻¹)	7.50 ^c	5.69 ^c
EC3 (20 dS m ⁻¹)	5.70 ^d	3.77 ^d
LSD	0.65**	1.00**

<i>L. sinuatum</i> 'Compindi Deep Blue'		
Concentrations	Total yield (piece/plant)	Marketable yield (piece/plant)
EC0 (1 dS m ⁻¹)	8.90 ^a	8.20 ^a
EC1 (5 dS m ⁻¹)	8.16 ^b	6.36 ^b
EC2 (10 dS m ⁻¹)	7.44 ^c	5.47 ^c
EC3 (20 dS m ⁻¹)	4.93 ^d	2.26 ^d
LSD	0.67**	0.56**

Within each column, values followed by same letters are not significantly different according to LSD test; ** Significant at $p < 0.01$, * Significant at $p < 0.05$ level, ns: non-significant

perezii cv. Chief Rose and Chief Gold, *Matthiolain cana* and *Hellianthus annuus* were marketable after grown under moderate salinity conditions, although peduncle length tended to decrease because of increased salinity conditions. It has been reported that saline wastewater and groundwater resources can be used as an alternative irrigation water sources during the production of marketable cut flowers. In this study, peduncle lengths decreased because of increased salt levels; however, even if grown at the highest salinity levels, in terms of the market value, half of the total harvest is marketable. This finding was similar to that of Grieve et al. (2006).

Developmental delay to a certain extent in ornamental plants occurs because of salinity stress. It may sometimes be acceptable provided the plants do not lose their healthy and attractive appearance. Although damages to plant leaves and flowers appear mild on development, these damages may lead to unacceptable consequences in terms of market quality of cut flowers. When unmarketable yield is evaluated, the minimum loss was seen in 'Compindi White' cultivar as 0.63 per plant in the control, 1.42 per plant at 5 dS m⁻¹ level, 1.81 per plants at 10 dS m⁻¹ level, and 1.93 per plant at 20 dS m⁻¹ level. In the case of 'Compindi Deep Blue' cultivation; undergoing the highest loss;

Table 5 : Effect of different salinity levels on flower quality

<i>L. sinuatum</i> 'Compindi White'			
Concentrations	Flower peduncle length (cm)	Flower peduncle thickness (cm)	Flower peduncle weight (g)
EC0 (1 dS m ⁻¹)	51.03 ^a	12.36 ^a	17.01 ^a
EC1 (5 dS m ⁻¹)	45.98 ^{ab}	11.95 ^b	13.32 ^b
EC2 (10 dS m ⁻¹)	43.31 ^b	11.75 ^c	12.73 ^{bc}
EC3 (20 dS m ⁻¹)	33.76 ^c	11.62 ^c	9.55 ^c
LSD	5.89**	0.16**	3.41**

<i>L. sinuatum</i> 'Compindi Deep Blue'			
Concentrations	Flower peduncle length (cm)	Flower peduncle thickness (cm)	Flower peduncle weight (g)
EC0 (1 dS m ⁻¹)	50.70 ^a	11.30 ^a	16.38 ^a
EC1 (5 dS m ⁻¹)	48.31 ^a	9.44 ^b	15.72 ^a
EC2 (10 dS m ⁻¹)	39.55 ^b	8.42 ^{bc}	12.41 ^b
EC3 (20 dS m ⁻¹)	31.15 ^c	7.39 ^c	8.95 ^c
LSD	3.93**	1.81**	1.07**

Within each column, values followed by same letters are not significantly different according to LSD test; ** Significant at $p < 0.01$, * Significant at $p < 0.05$ level, ns: non-significant

Table 6 : Effect of different salinity levels on relative water content of leaf

<i>L. sinuatum</i> 'Compindi White'					
Concentrations	RWC1(%)	RWC2 (%)	RWC3 (%)	RWC4 (%)	RWC5 (%)
EC0 (1 dS m ⁻¹)	94.51 ^a	92.49	90.82 ^a	88.79 ^a	81.95 ^a
EC1 (5 dS m ⁻¹)	91.42 ^b	91.50	89.30 ^b	86.13 ^b	79.97 ^{ab}
EC2 (10 dS m ⁻¹)	89.57 ^{bc}	89.95	86.01 ^c	81.57 ^c	77.22 ^b
EC3 (20 dS m ⁻¹)	87.96 ^c	85.13	82.80 ^d	78.45 ^d	72.75 ^c
LSD	1.88**	ns	1.18**	2.09**	3.34**

<i>L. sinuatum</i> 'Compindi Deep Blue'					
Concentrations	RWC1(%)	RWC2 (%)	RWC3 (%)	RWC4 (%)	RWC5 (%)
EC0 (1 dS m ⁻¹)	90.20 ^a	88.56 ^a	87.49 ^a	86.20 ^a	84.26 ^a
EC1 (5 dS m ⁻¹)	88.15 ^a	86.84 ^a	85.71 ^a	83.87 ^a	81.68 ^a
EC2 (10 dS m ⁻¹)	85.34 ^b	83.64 ^b	81.66 ^b	79.71 ^b	78.41 ^b
EC3 (20 dS m ⁻¹)	81.57 ^c	79.23 ^c	77.33 ^c	75.67 ^c	73.14 ^c
LSD	2.06**	2.35**	2.41**	2.48**	2.86**

Within each column, values followed by same letters are not significantly different according to LSD test; ** Significant at $p < 0.01$, * Significant at $p < 0.05$ level, ns: non-significant

results were as follows 0.70 per plant in control, 1.80 per plant at 5 dS m⁻¹, 1.97 per plant at 10 dS m⁻¹, and 2.67 per plant at 20 dS m⁻¹ salinity level, respectively. The unmarketable yield was higher in 'Compindi Deep Blue' than in 'Compindi White' because they were more affected by salt stress. These results were reflected also as the negative effects on other parameters in terms of both numerical dimension and the percentage loss depending on the increased salinity levels.

Findings for the peduncles were statistically significant with a decrease in length because of increased salinity levels.

The salinity effect was statistically significant on length, thickness, and weight of peduncles, which constitute the quality criteria for cut flower cultivation. Parallel to the increasing salinity levels, all values of measured parameters decreased. At 20 dS m⁻¹ salinity level compared to controls, 33.84% decrease in peduncle length, 5.98% decrease in peduncle thickness, and 38.56% decrease in peduncle weight was observed in 'Compindi White' cultivation whereas 34.60% decrease in peduncle length, 38.56% decrease in peduncle thickness and 45.36% decrease in peduncle weight was observed in 'Compindi Deep Blue' cultivation (Table 5).

Table 7 : Effect of different salinity levels on chlorophyll and carotenoid content

<i>L. sinuatum</i> 'Compindi White'				
Concentrations	Chlorophyll a (mg l ⁻¹)	Chlorophyll b (mg l ⁻¹)	Total Chlorophyll (mg l ⁻¹)	Carotenoid (mg l ⁻¹)
EC0 (1 dS m ⁻¹)	10.47 ^a	4.76 ^a	15.23 ^a	34.19 ^a
EC1 (5 dS m ⁻¹)	8.05 ^b	4.13 ^b	12.18 ^b	28.49 ^b
EC2 (10 dS m ⁻¹)	7.58 ^{bc}	3.87 ^b	11.46 ^b	27.08 ^{bc}
EC3 (20 dS m ⁻¹)	6.48 ^c	3.30 ^c	9.78 ^c	25.84 ^c
LSD	1.21**	0.39**	1.52**	2.58**
<i>L. sinuatum</i> 'Compindi Deep Blue'				
Concentrations	Chlorophyll a (mg l ⁻¹)	Chlorophyll b (mg l ⁻¹)	Total Chlorophyll (mg l ⁻¹)	Carotenoid (mg l ⁻¹)
EC0 (1 dS m ⁻¹)	8.35 ^a	3.81 ^a	12.22 ^a	28.95 ^a
EC1 (5 dS m ⁻¹)	7.71 ^b	3.22 ^b	10.94 ^b	27.89 ^{ab}
EC2 (10 dS m ⁻¹)	7.05 ^c	3.26 ^b	10.31 ^b	26.25 ^b
EC3 (20 dS m ⁻¹)	6.24 ^d	2.80 ^b	9.05 ^c	23.34 ^c
LSD	0.59**	0.50*	0.90**	2.34**

Within each column, values followed by same letters are not significantly different according to LSD test; ** Significant at $p < 0.01$, * Significant at $p < 0.05$ level, ns: non-significant

The characteristics associated with the salinity levels in both cultivars showed statistically significant decrease. The decrease in the peduncle characteristics were more remarkable in 'Compindi Deep Blue'. Akat (2008) also reported the negative effects of salt applications on the peduncle length of *Gerbera jamesonii*. Akat and Ozzambak (2013) suggested that the peduncle thicknesses of plants grown in saline soil (EC: 0.674%) decreased by 10.61% in 'Compindi White' and 19.64% in 'Compindi Deep Blue' compared with that of controls. Bass *et al.* (1995) found that in carnations, the peduncle length decreased at 23 mM salinity level whereas in gerberas, which have lower salt tolerance, the number of flower, the peduncle length and weight decreased at 8 mM NaCl level. Several studies have revealed that saline conditions negatively affect the yield and flower quality (Grieve *et al.*, 2005; Dogan *et al.*, 2009; Aydinsakir, 2010). All these are consistent with the findings presented here. The values of length, thickness, and weight of peduncles in this study decreased, which are in agreement with those reported previously.

Leaves are generally the plant parts that visibly respond to stress. Under stressful conditions, the relative water content (RWC) decreases, and plant growth falls and if this situation continues, it stops (Kanter *et al.*, 1992; Gungor and Erozel, 1994). In this study, the RWC values, measured on five different dates, were the least at 20 dS m⁻¹ level for both cultivars. The effect of salinity on RWC was only insignificant in the second period (RWC2) of 'Compindi White' and was found to be significant in the remaining periods. In addition, as expected, RWC decreased because of the salt deposits and increase in temperature associated with increase in salinity levels and the progression of periods. When RWC of 'Compindi White' was

examined at 20 dS m⁻¹ level, there was a decrease of 6.93% in RWC1, 7.95% in RWC2, 8.83% in RWC3, 11.64% in RWC4, and 11.22% decrease in RWC5 compared with those of the controls. Similarly, RWC values of 'Compindi Deep Blue' decreased 9.56%, 10.53%, 11.61%, 12.21% and 13.19%, respectively (Table 6).

Salinity stress causes a decrease in relative water content, and amount of chlorophyll and also damages the chlorophyll structure (Durdu, 2007). This study has suggested that the amount of chlorophyll a, chlorophyll b, and total chlorophyll of both cultivars decreased and it was statistically significantly but in different proportions. The lowest values were observed at highest salinity level, *i.e.*, 20 dS m⁻¹. In 'Compindi White', chlorophyll a, chlorophyll b and total chlorophyll level decreased by 38.2%, 30.67%, and 35.78%, whereas in 'Compindi Deep Blue', decrease was 25.26%, 26.50% and 25.94%, respectively (Table 7). Studies have reported that the potential of plants to photosynthesize is determined by the total amount of chlorophylls and carotenoids in the leaves, which decreases under saline stress conditions (Kocacaliskan, 2002; Akat, 2012). In this context, when leaf carotenoid amounts are considered, both cultivars showed a decline in the values. There are significant differences because of an increase in salinity levels. The lowest amount of carotenoid was determined at the highest salinity level (20 dS m⁻¹). The amount of carotenoid was found to be higher in 'Compindi White'; however, higher decrease were observed with increased salinity level. Compared with the control, the effects of salt levels in 'Compindi White' carotenoid decreased by 16.67% at 5 dS m⁻¹, 20.79% at 10 dS m⁻¹, and 24.42% at 20 dS m⁻¹ level. In addition, the decrease in 'Compindi Deep Blue' were 3.66%, 9.32%, and 19.37%, respectively (Table 7). The increase

Table 8 : Effect of different salinity levels on proline and MDA content

Concentrations	<i>L. sinuatum</i> 'Compindi White'		<i>L. sinuatum</i> 'Compindi Deep Blue'	
	Proline level ($\mu\text{M g}^{-1}$)	MDA level (nM ml^{-1})	Proline level ($\mu\text{M g}^{-1}$)	MDA level (nM ml^{-1})
EC0 (1 dS m ⁻¹)	7.89 ^c	26.28 ^c	7.01 ^c	27.63 ^d
EC1 (5 dS m ⁻¹)	8.31 ^{bc}	29.51 ^c	8.12 ^{bc}	32.31 ^c
EC2 (10 dS m ⁻¹)	9.17 ^b	34.15 ^b	8.83 ^b	37.83 ^b
EC3 (20 dS m ⁻¹)	11.26 ^a	38.86 ^a	10.51 ^a	42.10 ^a
LSD	1.63**	4.63**	1.65**	3.97**

Within each column, values followed by same letters are not significantly different according to LSD test, ** Significant at $p < 0.01$, * Significant at $p < 0.05$ level, ns: non-significant

in salinity decreased the amounts of chlorophyll and carotenoid. This negative association has been reported in previous studies (Yakit and Tuna, 2006; Kusvuran et al., 2008; Akat and Ozzambak, 2013). Their findings are similar with the present study.

Proline supports the ability of the plant to grow under saline conditions and activates the plant's defense and endurance mechanisms to resist stress (Tuna et al., 2007; Dolatabadian et al., 2008; Ozturk et al., 2011; Akat, 2012; Turkyilmaz et al., 2013; Ahmad et al., 2013). In this study, changes in proline content showed significant differences in both varieties under all salinity levels. According to the salinity levels, in 'Compindi White,' proline content was 5.32% at 5 dS m⁻¹, 16.22% at 10 dS m⁻¹, and 42.71% at 20 dS m⁻¹ level whereas the increases in 'Compindi Deep Blue' was 15.83% at 5 dS m⁻¹, 25.96% at 10 dS m⁻¹, 49.92% at 20 dS m⁻¹ level, respectively (Table 8). Determination of the amount of malondialdehyde (MDA), a product of lipid peroxidation, similar to the detection of proline content, is also used as a simple indicator of oxidative damage (Dolatabadian et al., 2008). In this study, the increase in salinity level and MDA content were found to be statistically significant in all applications for both cultivars. In 'Compindi White,' the salt effect was 12.29% at 5 dS m⁻¹, 29.94% at 10 dS m⁻¹, and 47.86% at 20 dS m⁻¹ level. In addition, in 'Compindi Deep Blue,' it was 16.93% at 5 dS m⁻¹, 36.91% at 10 dS m⁻¹, and 52.37% at 20 dS m⁻¹ level, respectively (Table 8). These results are in accordance with those reported previously (Kusvuran et al., 2008; Tuna et al., 2007; Akat and Ozzambak, 2013). Evaluation of all findings of this study suggest that increase in salinity levels negatively affected the plant growth, yield, quality and some stress parameters.

We observed that 20 dS m⁻¹ salinity all examined parameters were negatively affected at different rates. Multi-economical *L. sinuatum* showed higher salt resistance than other ornamental plants. In addition, the cultivar 'Compindi White' was more tolerant to salt as it showed statistically significant differences in terms of plant growth, yield, quality, and some stress parameters. The effect of flower quality and total and marketable yields in different plant cultivars demonstrated that at 20 dS m⁻¹, productivity decreased by half, and salinity conditions

of >10 dS m⁻¹ economically limited the cultivation of *L. sinuatum* as cut flowers.

All the results of analysis of salinity levels of 20 dS m⁻¹ suggest that using saline-resistant plants as ornamental plants in landscape designs rather than cut flowers would be more appropriate. Moreover, the use of such plants could contribute to plant variation as an alternative in terms of visualization of saline soils.

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