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Evaluation of guava (*Psidium guajava*) and bael (*Aegle marmelos*) under shallow saline watertable conditions

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ABSTRACT

Growth, physiological activities and leaf ionic relations were studied in guava (*Psidium guajava* L.) cv. Allahabad Safeda and bael (*Aegle marmelos* Correa) cv. NB-5 planted under shallow saline watertable conditions. Marginally saline (MSW; EC_{IW} 4 dS/m) and saline (SW; 6 dS/m) waters were applied either in cyclic (C) mode with the best available water (BAW; 2.8 dS/m) or regularly (R) to impose five salinity levels: control (BAW), C_{MSW} (MSW and BAW in cyclic mode), R_{MSW} (regular application of MSW), C_{SW} (SW and BAW in cyclic mode) and R_{SW} (regular application of SW). Data were recorded 120 days after salt treatment (DAST). In C_{SW} and R_{SW} treatments, salt injury symptoms (leaf yellowing, marginal scorch and chlorosis) appeared around 60 DAST in both the crops. Although plant height and stem girth were relatively less affected, branch and leaf emergence considerably decreased with increase in salinity giving the salinized plants a sparse look. Regular irrigation with 6 dS/m water caused substantial reductions in net photosynthesis (37-45%), photochemical efficiency (Fv/Fm ratio; 11-21%) and total soluble sugars (≈30%); and increase in proline, Na^+ and Cl^- levels in leaves. Leaf proline was nearly fivefold higher in guava and threefold higher in bael at 6 dS/m salinity than BAW irrigated plants. Both the crops exhibited ≈8 fold higher leaf Na^+/K^+ ratio and considerable increase in leaf Cl^- when continuously irrigated with 6 dS/m water. Plant growth, physiological attributes and leaf ionic composition in C_{MSW} treatment were comparable to BAW treated plants indicating that marginally saline water ($EC_{IW} \approx$ 3-4 dS/m) can be used to irrigate guava cv. Allahabad Safeda and bael cv. NB-5 planted in saline soils.

Key words: Bael, Growth, Guava, Ion toxicity, Proline, Saline watertable, Salinity

Saline and sodic soils having excess soluble salts and exchangeable sodium, respectively, are collectively referred to as the salt-affected soils (SAS). In many situations, SAS are also underlain with saline water further exacerbating the salt stress in plants. Moderate reductions in crop yields are common even in slightly salt affected soils necessitating the adoption of improved management practices to minimize such losses (Sharma and Singh 2015, Sharma and Singh 2017). The expanse of SAS in India is predicted to increase from the currently estimated 6.73 m ha to 16.2 m ha by 2050 mainly due to planned expansion in irrigated area and the use of saline groundwater in irrigation (ICAR-CSSRI 2015).

Salinity problem has become more intricate in the past few decades as evidenced by co-existence of problems such as soil erosion, excess salts and waterlogging in several parts of India. It has been estimated that out of 1.72 m ha irrigated area adversely affected by waterlogging (watertable lying within 2 m of the land surface), nearly 1 m ha also suffers from salinity to varying extents (NAAS 2015). Irrigation-induced salinity has gradually emerged as a serious hurdle in many fruit growing areas of India. In Maharashtra and Karnataka, groundwater salinity has consistently increased to the levels considered harmful to vineyard health and productivity (Bhargava *et al*. 2006). High salinity in soil and groundwater is a major impediment to mango cultivation in the Saurashtra region of Gujarat (Nathwani 2014). Development of shallow watertables (< 0.5-1.0 m) and the concurrent increase in soil salinity has caused large scale Kinnow decline in many parts of south-western Punjab (India). Irrigation with saline groundwater is also a major cause of yield reduction and low profitability even in crops like Indian jujube otherwise considered to be salt tolerant (ICAR-CSSRI 2016).

Ideally, fruit crops should be raised in lands having relatively deeper watertables to prevent the anticipated damage by the elevated moisture levels in the root zone. In lands having watertable below 2 m and preferably at 4-5 m depth from the surface, direct contact between tree roots and saline water will not occur (Sharma and Singh 2017). Plant growth is adversely affected under shallow (≤ 1.5 m below the surface) watertable conditions as rising watertable brings dissolved salts to the root zone. Watertable depth is a critical factor governing the rate of evaporation and salt accumulation. In areas where watertable depth

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is 1.5-3.0 m, evaporation induced salt accumulation will be minimal (Salama *et al*. 1999). Lands suffering from shallow watertables, salinity and, in extreme cases, water inundation on the surface are designated as waterlogged salt-affected lands. While primary salinity affected lands having deeper watertables and moderate salinity can be managed by leaching with fresh water, an 'ensemble of technologies' including land shaping, storage of rain/canal water, use of salt tolerant cultivars and drip irrigation is suggested to enhance the economic value of waterlogged saline lands (ICAR-CSSRI 2016). Despite the fact that most of the commercially grown fruit crops are salt sensitive, considerable genetic differences have been detected for salinity tolerance in many species. Guava (*Psidium guajava* L.) and bael (*Aegle marmelos* Correa) crops perform well in arid climates suffering from constraints such as low soil fertility, fresh water scarcity and salinity. However, information regarding their performance in saline soils underlain with saline watertable is lacking. In view of these facts, an experiment was conducted in saline soils underlain with shallow saline watertable to assess the suitability of guava cv. Allahabad Safeda and bael cv. NB-5 for such conditions.

MATERIALS AND METHODS

This experiment was conducted during 2014-15 and 2015-16 at ICAR-CSSRI Nain Experimental Farm, Panipat, India. Farm area (~11 ha area) extends between latitudes 29°19'7.09" and 29°19'10.0"N, longitudes 76°47'30.0" and 76°48'0.0"E, and is located at an elevation of 230-231 m above the mean sea level. Soil surface is mostly highly saline and is also underlain with saline water. Besides high salinity, impeded drainage and poor horizon development are other characteristic features of the soil (Mandal *et al*. 2013). The experiment was laid out in a randomized complete block design with twelve replications and the data were recorded on four randomly selected plants. One-year old plants of guava cv. Allahabad Safeda and bael cv. NB-5 procured from ICAR-CISH, Lucknow, India were used as the experimental material. Planting was done in farm yard manure (FYM) ameliorated pits (5 kg/pit) on raised beds (~ 2 feet height) to avoid the direct contact between plant roots and saline water. After transplanting, the plants were pruned to a uniform height. Before initiating the saline irrigation treatments, electrical conductivity (EC_e) in soil saturation extract was determined up to 100 cm depth using glass electrode EC meter (Eutech Instruments, Singapore). Soil EC_e ranged between ≈3.9-8.4 dS/m in case of guava and ≈4.0-10.5 dS/m in case of bael. Plants were initially irrigated with the best available water (BAW; EC_{IW} ≈2.8 dS/m). Saline irrigations were imposed in the second year of experiment. In addition to irrigation with BAW in control plants, marginally saline water (MSW; 4.0 dS/m) and saline water (SW; 6.0 dS/m) were also applied either in cyclic (C) mode with BAW or regularly (R) to impose five different salt treatments: control (BAW), C_{MSW} (MSW and BAW in cyclic mode), R_{MSW} (regular application of MSW), C_{SW} (SW and BAW in cyclic mode) and R_{SW} (regular application of SW). Plants were irrigated at weekly intervals and data were recorded 120 days after salt treatment (DAST).

Effects of salinity on plant growth, physiological parameters and ionic relations in leaves were determined. Stem length (SL) and plant spread (PS) in north-south (N-S) and east-west (E-W) directions were recorded using the measuring tape while stem girth (SG) was measured using the Vernier scale. For estimating the gas exchange characteristics, two leaves in middle layer of plants were tagged and readings were taken from the centre of leaves (excluding mid-rib) between 10.30 AM and 12.30 PM using a portable photosynthetic system. Photochemical efficiency of leaves (F_v/F_m- chlorophyll fluorescence, Φ_{PSII}- Photon Quantum Yield) was estimated from the fluorescent analysis of chlorophyll on the same leaves used for gas exchange measurements using a portable pulse modulated fluorescence meter (Junior PAM Chlorophyll Fluorometer, Germany) after dark adaptation of the leaves for 15 min. Same leaves were gently detached from the plants, placed in an ice box and brought to the laboratory for estimating total chlorophyll, proline, total soluble sugars and mineral ions (Na^+, K^+ and Cl^-). Total leaf chlorophyll was determined using the method of Hiscox and Israelstam (1979). Proline content was estimated using the method of Bates *et al*. (1973). Total soluble sugars were measured by the colorimetric method using anthrone reagent (Yemm and Wills 1954). Leaves were dried at 60 ºC for 48 h, weighed and crushed in a hammer mill and stored at the room temperature. Approximately 50 mg of powdered leaf was extracted with 1 M HNO_3 at 100ºC. Na^+ and K^+ contents were determined through flame photometry. Leaf chloride content was determined volumetrically by the modified method of Chhabra (1973). Data were analyzed using Indian NARS Statistical Computing Portal (http://stat.iasri.res.in/sscnarsportal). For comparison of means, Duncan's test was used at 5% level of significance.

RESULTS AND DISCUSSION

Effects on plant growth

Visible symptoms of salt injury initially appeared as the yellowing and marginal scorching of leaves albeit with a different timing under different treatments. At EC_{iw} level of 6 dS/m, leaves became pale, scorched and partly chlorotic as early as 60 days after salt treatment (DAST) in both guava cv. Allahabad Safeda and bael cv. NB-5. In contrast, these symptoms developed between 90-120 DAST when plants were irrigated with 4 dS/m water. None of the plants in control treatment (BAW) showed salt injury symptoms. In guava, inward curling of leaves was observed at ≥ 4 dS/m salinity. With increase in the duration of salt treatment, leaves gradually abscised off the plants giving them a bare look. Salt injury symptoms described here for guava are consistent with the findings of Desai and Singh (1980) who observed that marginal scorching of leaves was a characteristic symptom in salt stressed guava plants. They also noted inward curling of leaves in chloride salinization compared to outward cupping in carbonate salinization. Similarly, salt treated bael plants exhibit marginal scorching and development of chlorotic spots in leaves (Singh *et al.* 2015). In both guava and bael, plant height and stem girth were relatively less affected but branch emergence and leaf production significantly decreased with increase in salinity imparting the salinized plants an upright and sparse look. In comparison, BAW irrigated plants maintained a compact appearance. For example, plant height, stem girth, canopy spread and number of branches in guava decreased by ≈18%, 31%, 45-55% and 64%, respectively, with the regular application of 6 dS/m water compared to control (Table 1). In both the crops, decreases in different plant growth parameters up to 4 dS/m salinity level were either non-significant or only marginal. While all the bael plants survived in C_{MSW} treatment, plant survival in guava decreased by 25% under the same treatment. However, only about half of the guava and bael plants survived when regularly irrigated with 4 and 6 dS/m water, respectively. Guava could not endure continuous exposure to 6 dS m^{-1} salinity as none of the plants survived 120 DAST in this treatment (data not shown). Patil *et al.* (1984) recorded 50% and 80% reductions in plant growth in guava at EC_e levels of ≈ 9 dS/m and 11 dS/m, respectively. Singh *et al.* (2015) observed that $EC_e \geq 7$ dS/m had a detrimental effect on plant growth and survival in bael cultivars NB-5, NB-9, CB-1 and CB-2.

Table 1 Effect of salinity on plant growth in guava cv. Allahabad Safeda and bael cultivar NB-5.

Treatment	Plant height (cm)	Stem girth (cm)	Plant spread N-S (cm)	Plant spread E-W (cm)	Branches/ plant
		Guava cv. Allahabad Safeda			
BAW (Control)	102.33^{ab}	4.40^{a}	148.83^{a}	143.03^{a}	9.33^{a}
C_{MSW}	110.90^{a}	4.37^{a}	134.47^{b}	116.93^{b}	8.67^{a}
R_{MSW}	93.60^{bc}	4.00^{a}	114.13^{c}	98.83^{c}	6.67^{b}
C_{SW}	92.77^{bc}	3.40^{b}	93.60^{d}	85.93^{d}	5.33^{b}
R_{SW}	83.67^{c}	3.03^{b}	81.67^{e}	64.57^{e}	3.33^{c}
		Bael cv. NB-5			
BAW (Control)	152.97^{a}	3.63^{a}	126.87^{a}	143.27^{a}	5.33^{a}
C_{MSW}	143.17^{a}	3.57^{a}	129.53^{a}	131.10^{a}	4.33^{b}
R_{MSW}	128.97b	3.20^{b}	101.40^{b}	116.30^{b}	4.00^{bc}
C_{SW}	107.07^{c}	2.80^{c}	94.43^{b}	104.27^{b}	3.33^{cd}
R_{SW}	86.20^{d}	2.53^{c}	80.93^{c}	84.27^{c}	3.00^{d}

BAW- best available water (EC_{iw}, 2.8 dS/m), C_{MSW} - marginally saline water (4 dS/m) and BAW in cyclic mode, R_{MSW} - regular irrigation with MSW, C_{SW} - saline water (6 dS/m) and BAW in cyclic mode, and R_{SW} - regular irrigation with SW. Means (n=4) with at least one letter common are not statistically significant using Duncan's Multiple Range Test at 5% level of significance.

Physiological relations in leaves

Salinized guava and bael plants had significantly lower leaf chlorophyll than control (Fig 1). Nonetheless, decreases in total chlorophyll at a given salinity level were much larger for bael than for guava. It can be explained by relatively higher soil EC_e in case of bael (average ≈ 7.3 dS/m) than in guava (≈ 6 dS/m). Furthermore, control plants of guava had much higher (1.45 mg/g FW) total chlorophyll than bael (0.94 mg/g FW) indicating inherent genetic differences for chlorophyll biosynthesis. Leaf chlorophyll in guava decreased by about one third as salinity increased from 3 dS/m to 6 dS/m possibly due to reduced availability of N and Ca^{2+}. Supplemental application of 10 mM $Ca(NO_3)_2$ considerably improved chlorophyll levels in salinized guava plants (Ebert *et al.* 2002). Chlorophyll loss in salt stressed bael cultivars can be attributed to higher cell membrane injury, excessive leaf Na^+ and decrease in leaf hydration (Singh *et al.* 2015). Salinity induced cell membrane disintegration and loss of enzymatic activities can hasten the depletion of leaf chlorophyll in salinized plants (Singh *et al.* 2014).

Salt treated plants showed consistent decline in net photosynthesis (P_N), stomatal conductance (*g*S), transpiration (*E*), chlorophyll fluorescence (Fv/Fm) and photon quantum yield (Φ_{PSII}) (Table 2). Nonetheless, the decreases were only nominal when marginally saline water (4 dS/m) was applied in alternation with BAW. Application of 6 dS/m water, either in cyclic mode with BAW or regularly, caused marked reductions in gas exchange characteristics. For example, P_N dropped by 26% and 37% in guava, and by 26% and 45% in bael when SW was used in cyclic and regular modes, respectively, compared to BAW (control). In order to maintain leaf hydration, salinized plants tended to arrest *E* by lowering the *g*S. At the highest salinity level (EC_{IW} 6 dS/m), both the crops exhibited ≈35% reduction in *E* compared to the respective control. Low transpiration rates may reduce salt translocation from root zone to the foliage to protect the actively photosynthesizing leaves from salt injury (Kumar *et al.* 2016, Singh *et al.* 2016). Salt stress diminishes photosynthetic assimilation in guava (Ebert *et al.* 2002) and bael (Singh *et al.* 2016) which often coincides with marked reductions in *g*S, *E* and leaf chlorophyll levels. Increased stomatal resistance and decline in photochemical efficiency seem to be responsible

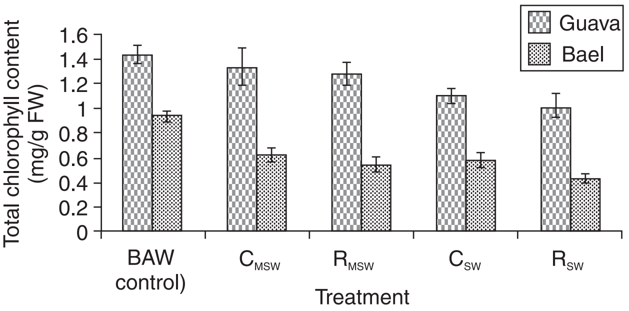

Fig 1 Salinity induced reductions in total leaf chlorophyll in guava cv. Allahabad Safeda and bael cv. NB-5. Bars represent SD of the means of four replicates.

Table 2 Salinity induced changes in gas exchange and chlorophyll fluorescence attributes in guava cv. Allahabad Safeda and bael cv. NB-5

Treatment	PN	gS	E	Fv/Fm	ΦPSII
		Guava cv. Allahabad Safeda			
BAW (Control)	6.61^a	0.41^a	8.01^a	0.71^a	0.59^a
C_{MSW}	6.01^b	0.37^b	7.56^b	0.69^b	0.56^b
R_{MSW}	5.56^c	0.29^c	6.36^c	0.67^c	0.52^c
C_{SW}	4.84^d	0.27^d	5.70^d	0.65^d	0.52^c
R_{SW}	4.11^e	0.23^e	5.14^e	0.63^e	0.50^d
		Bael cv. NB-5			
BAW (Control)	6.53^a	0.37^a	7.04^a	0.76^a	0.67^a
C_{MSW}	5.86^b	0.31^b	6.31^b	0.72^b	0.63^b
R_{MSW}	5.40^c	0.28^c	5.49^c	0.68^c	0.56^c
C_{SW}	4.78^d	0.19^d	5.07^d	0.65^d	0.52^d
R_{SW}	3.53^e	0.17^e	4.50^e	0.60^e	0.51^d

P_N- net photosynthesis (µmol/m^2/sec), gS- stomatal conductance (mmol/m^2/sec), E- transpiration rate (mmol/m^2/sec), F_v/F_m- chlorophyll fluorescence, Φ_{PSII}- Photon quantum yield.

Means (n=4) with at least one letter common are not statistically significant using Duncan's Multiple Range Test at 5% level of significance.

for decrease in photosynthesis in salinized guava plants (Walker *et al*. 1979). Under moderate salinity conditions, low stomatal and mesophyll conductivities result in reduced availability of CO_2 in chloroplasts (Chartzoulakis 2005). When salinity exceeds the critical threshold, toxic levels of leaf Na^+ and Cl^- can disrupt electron transport and other bioenergetic processes in chloroplast cells (Sudhir and Murthy 2004).

Photochemical efficiency, expressed as the ratio of variable: maximal chlorophyll fluorescence (Fv/Fm) ranged from 0.63 to 0.71 in guava and from 0.60 to 0.76 in bael under different treatments (Table 2). Although Fv/Fm values steadily declined with increase in salinity, reductions were rather small up to 4 dS/m salinity compared to control. Guava and bael receiving 4 dS/m water showed only 5% and 10% less Fv/Fm, respectively, compared to BAW irrigated plants. When regularly treated with 6 dS/m water, however, Fv/Fm dropped by about 11% in guava and by 21% in bael vis-à-vis control (BAW) plants. Fv/Fm ratio in non-stressed healthy plants generally ranges between 0.75 and 0.85 (Lucena *et al*. 2012). These values are very close to our results for BAW irrigated (control) plants. In moderately salt tolerant fruits such as sapota, salinity depresses net CO_2 assimilation but does not influence diurnal Fv/Fm patterns suggesting that decrease in photosynthesis may not increase leaf sensitivity to high irradiance stress (Mickelbart and Marler 1996). Even in salt sensitive species like sugar apple, mild salinity may not impair Fv/Fm ratio on clear days with full sunlight while reverse is true for partly cloudy days when reductions in photochemical efficiency of salt stressed plants could be greater than salt free plants (Marler and Zozor 1996). Photon quantum yield in photosynthesis (Φ_{PSII}) refers to the moles of CO_2 fixed per mole of photons absorbed. In the present experiment, Φ_{PSII} decreased with increase in salinity in both the crops in a pattern similar to that of Fv/Fm ratio. Guava and bael plants continuously receiving 6 dS/m water exhibited about 15% and 23% reductions in Φ_{PSII} than respective control. Salt induced reductions in Φ_{PSII} due to increase in non-photochemical quenching have been reported in citrus (López-Climent *et al*. 2008).

Saline irrigations led to increased proline and decreased total soluble sugars (TSS) contents in the leaves of both guava and bael plants (Fig 2). At the highest salinity (6 dS/m), leaf proline content was nearly five fold higher in guava and three fold higher in bael relative to control. Total soluble sugars invariably declined with increase in salinity. Guava plants continuously exposed to 4 dS/m and 6 dS/m saline waters displayed ≈21% and 30% less TSS than control while the corresponding reductions for bael were ≈12% and 28%. Proline plays a critical role in osmotic adjustment in salt stressed plants. Furthermore, it may also act as an antioxidant and a signaling molecule (Yaish 2015). Proline is synthesized from ornithine and glutamate in normal and saline soils, respectively. As chlorophyll is also synthesized from glutamate, its use by the salt stressed plants in proline biosynthesis may lead to chlorophyll loss as noted in Yaghooti and 1103P grapevines (Sohrabi *et al*. 2017). This observation corroborates our finding that leaf chlorophyll decreased while proline levels increased in salinized guava and bael plants. Salt stressed plants may exhibit relatively higher soluble sugar concentrations for cellular osmotic adjustment. However, reduced sugar levels in salinized plants have been noted in many crops. Increase in salinity caused the progressive depletion of glucose, fructose and sucrose in the leaves and roots of Clementina citrus grafted on Carrizo citrange (Arbona *et al*. 2005), and in the leaves of salt tolerant citrus rootstock Cleopatra mandarin, and in both leaves and roots of salt sensitive Troyer citrange (Anjum 2008). Total soluble sugars in leaves increased with increasing salinity (up to 80 mM NaCl) but decreased with the further increase in salinity in olive cultivars Zard and Roghani (Mousavi *et al*. 2008). These findings suggest that sugar accumulation may not always be the major component of osmotic adjustment. Decline in soluble carbohydrates in the leaves of salt stressed plant may result due to decrease in photosynthetic assimilation which may even change the status of leaves from 'source' to 'sink' organ under saline

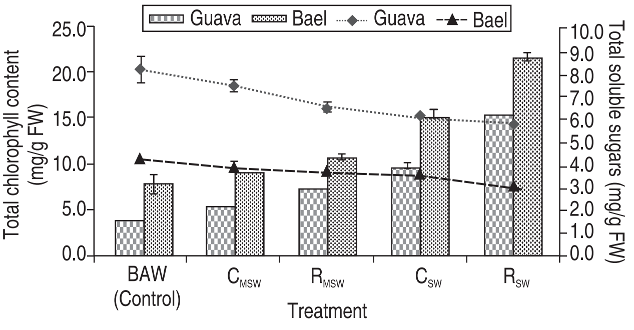

Fig 2 Accumulation patterns of proline and total soluble sugars in leaves of salt stressed guava cv. Allahabad Safeda and bael cv. NB-5. Bars represent SD of the means of four replicates.

Table 3 Effect of saline irrigation on leaf Na^+ and K^+ (% D.W.) in guava cv. Allahabad Safeda and bael cv. NB-5.

Treatment	Na^+ (% DW)	K^+ (% DW)	Na^+/K^+ ratio	Na^+ (% DW)	K^+ (% DW)	Na^+/K^+ ratio
	Guava cv. Allahabad Safeda			Bael cv. NB-5		
BAW (Control)	0.08^{e}	0.47^{a}	0.16^{d}	0.25^{d}	0.76^{a}	0.33^{c}
C_{MSW}	0.10^{d}	0.45^{b}	0.21^{d}	0.30^{cd}	0.63^{b}	0.48^{c}
R_{MSW}	0.16^{c}	0.44^{b}	0.36^{c}	0.39^{c}	0.58^{b}	0.67^{c}
C_{SW}	0.26^{b}	0.36^{c}	0.73^{b}	0.61^{b}	0.41^{c}	1.49^{b}
R_{SW}	0.35^{a}	0.26^{d}	1.35^{a}	0.75^{a}	0.27^{d}	2.76^{a}

Means (n=4) with at least one letter common are not statistically significant using Duncan's Multiple Range Test at 5% level of significance.

conditions (Arbona *et al*. 2005).

Leaf ionic composition

Data on leaf Na^+ and K^+ concentrations in salt stressed plants (Table 3) revealed that Na^+ concentration marginally increased while K^+ levels declined up to 4 dS/m salinity in both guava and bael. However, leaf Na^+ increased by 225% in guava and by 144% in bael when SW and BAW were applied in cyclic mode compared to control resulting in excessive leaf Na^+/K^+ ratio unfavourable to plant growth. Regular application of SW further increased Na^+ accumulation in leaves with concurrent decrease in K^+ levels resulting in heavy leaf abscission and wilting in both the crops. While leaf K^+ levels were somewhat stable in guava, marginal reductions occurred in bael up to 4 dS/m salinity. With further increase in salinity from 4 to 6 dS/m, leaf K^+ levels steeply decreased such that plants receiving 6 dS/m water showed ≈8 times higher leaf Na^+/K^+ ratio than control.

Leaf Cl^- concentrations also invariably increased with the increase in salinity (Fig 3). However, the increases in leaf Cl^- content at a given salinity relative to control were much larger for guava than for bael. For example, regular irrigation with 4 dS/m water led to nearly three fold higher leaf Cl^- in guava while it was about two fold in bael compared to the respective control. Similarly, leaf Cl^- concentrations increased by about seven times in guava but only about four times in bael when continuously irrigated with 6 dS/m water. In saline soils, excessive Na^+ ions impair the cytosolic K^+/Na^+ balance. At concentrations ≥ 100 mM, Na^+ and Cl^- suppress the functions of several important enzymes compelling the salinized plants to sequester excess salt ions in vacuoles. It is subsequently followed by the accumulation of organic and inorganic solutes in the cytoplasm to balance the osmotic pressure of the ions in the vacuole through osmotic adjustment. However, accumulation of organic metabolites is rather energy expensive while inorganic ions may cause cellular injury in salt sensitive species (Munns 2002). Certain fruit species and genotypes preferentially accumulate K^+ in leaf and stem tissues to lessen Na^+ toxicity (Melgar *et al*. 2008, Schmutz 2000). Preferential uptake of K^+ plays an important role in the salt tolerance of plants by partly alleviating the toxic effects of Na^+ in leaves and other parts. Moreover, higher leaf K^+ levels can contribute to osmotic adjustment with relatively lesser energy expenditure compared to the accumulation of organic (compatible) solutes like proline (Melgar *et al*. 2008). Salt excluder scion and rootstock cultivars have been identified in fruit crops. However, salt exclusion capacity often breaks down at excess salinity levels (Sharma *et al*. 2011) resulting in higher translocation of Na^+ and Cl^- to the leaves and the consequent salt injury symptoms. In the present experiment, both guava and bael crops showed restricted uptake of Na^+ and Cl^- up to 4 dS/m salinity but failed to retain salt ions in lower plant parts when irrigated with 6 dS/m saline water.

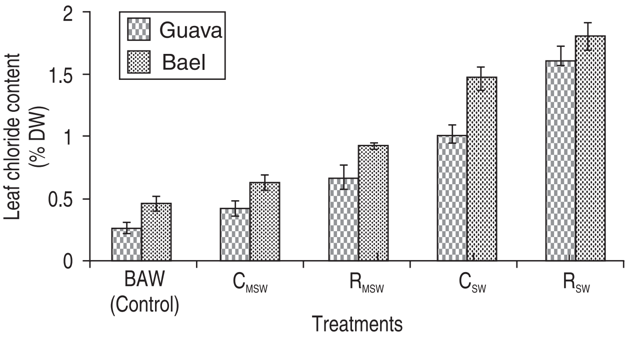

Fig 3 Leaf chloride content (% D.W.) in saline irrigated guava cv. Allahabad Safeda and bael cv. NB-5. Bars represent SD of the means of four replicates.

Conclusions

In saline soils, plant growth is adversely affected initially by the osmotic stress and subsequently by specific ion toxicities. In this experiment, guava cv. Allahabad Safeda and bael cv. NB-5 endured continued irrigation with marginally saline water (EC_{IW} 3-4 dS/m) by preventing excess Na^+ and Cl^- accumulations in leaves, accumulating higher levels of proline and maintaining higher photosynthesis. At EC_{IW} of 6 dS/m, however, salt tolerance diminished apparently due to excessive build up of toxic ions, especially Cl^-, in the leaves. Based on these results, it appears that marginally saline water (EC_{IW} ≈4 dS/m) can be used to irrigate these crops planted in saline soils.

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