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# Physiological Studies in Salinity Tolerance of *Sesbania aculeata* POIR.

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**Abstract.** A pot culture experiment was performed to evaluate salt tolerance potential of *Sesbania aculeata* POIR. The plant can tolerate salinity levels up to electrical conductivity (ECe), 10 mS $cm^{-1}$ and at 15 mS $cm^{-1}$ there is about 40% reduction in dry matter production. The analysis of inorganic constituents in different plant parts revealed that the plant has the capacity to regulate sodium uptake under saline conditions and chloride uptake always exceeded that of sodium. The potassium: sodium ratio is also maintained at a fairly constant level in leaflets while it is reduced in leaf rachis, stem and roots. Salt stress caused accumulation of calcium and magnesium in all plant parts. A considerable decline in phosphorus uptake was observed due to salinity. Iron was found to be accumulated more in salt stressed roots only. Nitrogen accumulated in both roots and leaves while considerable proline accumulation was observed in leaves of salt stressed plants. The amount of soluble sugars was increased in roots and leaves due to salt stress, while starch content of roots decreased. These changes induced by salinity are discussed in relation to salt tolerance capacity of the plant.

Modern agriculture is endangered by the ever growing threat of soil salinity. In India about 11 million hectares of agricultural land has become unproductive due to soil salinization. According to EPSTEIN *et al.* (1980), besides an engineering approach, the development of crops, tolerant to salinity, is a better strategy for meeting this challenge. *Sesbania* has long been known as a salt and alkali tolerant fodder crop. BERNSTEIN (1956) observed that *Sesbania* can tolerate ECe of 8 mS $cm^{-1}$ quite well and is sensitive to salinity especially at seedling stage. BHARADWAJ (1974) recorded that *S. aculeata* possesses a good nodulation ability even under saline conditions. Apart from these attempts not much attention has been paid to the mechanisms of salt tolerance in this plant. The present investigation is devoted to this aspect.

## MATERIAL AND METHODS

*S. aculeata* plants were raised from seeds in fertile soil in pots. Plants were watered regularly with an equal amount of water. After establishment of seedlings for one month the salinity treatments were commenced. The

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plants were treated with mixtures of NaCl and $CaCl_2$ in equal amounts so as to produce the electrical conductivity of 5, 10 and 15 mS $cm^{-1}$. To maintain the ECe of the soil medium in pots and to compensate for the loss of moisture from soil due to evaporation, plants were alternatively watered with the same amount of water. Plants were treated twice a week alternating with watering. Control plants received only water.

After two months' growth plants were carefully uprooted and analysed for biomass (fresh and dry matter). Organic and inorganic constituents were determined from the oven-dried plant material. The methods followed for estimation of carbohydrates, proline and titratable acidity (TAN) are described elsewhere (KARADGE and CHAVAN 1981). Total nitrogen was determined following the method of HAWK *et al.* (1948). Inorganic constituents were determined according to methods mentioned earlier (CHAVAN and KARADGE 1980).

## RESULTS AND DISCUSSION

The salt stress has caused a considerable decrease in growth of *Sesbania aculeata* seedlings in terms of average height, biomass and dry matter production, only at the highest salinity level *i.e.* ECe 15 mS $cm^{-1}$ (Fig. 1). However, there is stimulation of growth at lower salinity regimes. This is evident from increased height, biomass, dry matter, number of leaves and average leaf area of the plants grown up to 10 mS $cm^{-1}$ salinity level. These findings are in consistency with those of BERNSTEIN (1956). He has observed that *Sesbania exaltata* is sensitive to salinity especially during germination stage. So it appears that transplantation of young, well established seedlings to saline fields will be a better practice for cultivation of *Sesbania* under saline conditions.

The influence of salinity on mineral constituents in different parts of *S. aculeata* is recorded in Table 1. It is evident that sodium and chloride contents

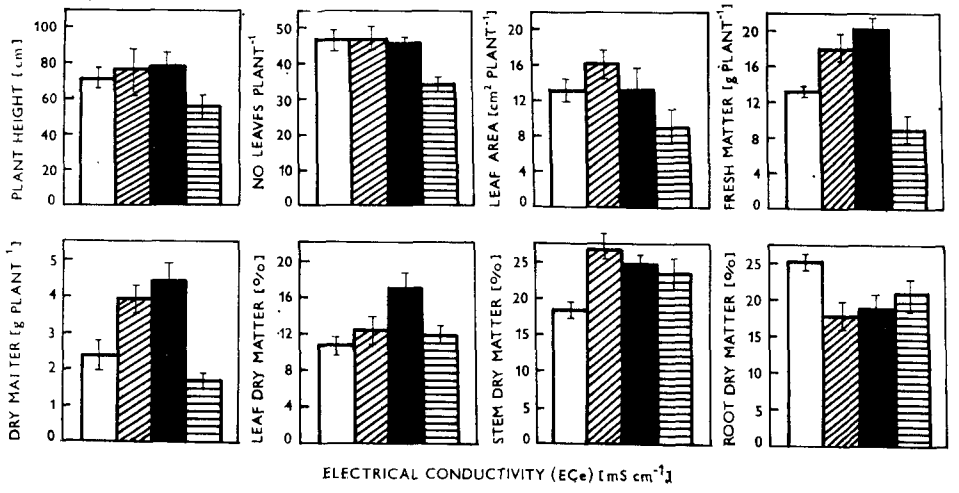


Fig. 1. Effect of sodium chloride salinity on some growth features of *Sesbania aculeata*. — Control: empty symbols; 5 mS $cm^{-1}$: diagonal ruling; 10 mS $cm^{-1}$: full symbols; 15 mS $cm^{-1}$: horizontal ruling.

TABLE 1
Effect of NaCl salinity on the uptake and distribution of mineral nutrients* in different parts of *Sesbania aculeata*

| Element | NaCl salinity [mS cm$^{-1}$] | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | Control | 5 | 10 | 15 | Control | 5 | 10 | 15 |
| | Leaflet | | | | Leaf-rachis | | | |
| Na | 5.65 | 5.65 | 6.09 | 8.26 | 5.22 | 6.52 | 7.39 | 15.22 |
| K | 104.09 | 157.54 | 100.00 | 74.68 | 188.23 | 233.24 | 105.37 | 79.79 |
| Ca | 105.29 | 209.58 | 210.58 | 233.03 | 64.37 | 99.80 | 110.78 | 276.95 |
| Cl | 31.30 | 50.48 | 60.07 | 93.62 | 40.89 | 69.65 | 93.62 | 169.20 |
| Mg | 23.19 | 24.85 | 25.67 | 31.47 | 19.05 | 25.67 | 25.67 | 38.10 |
| P | 200.16 | 125.91 | 104.92 | 79.10 | 72.64 | 61.34 | 58.11 | 64.57 |
| Fe | 2.63 | 2.58 | 2.04 | 2.04 | 1.50 | 1.56 | 1.29 | 3.55 |
| Mn | 0.80 | 0.95 | 0.69 | 0.66 | 0.36 | 0.47 | 0.48 | 0.33 |
| K/Na | 31.31 | 47.38 | 27.93 | 15.37 | 61.33 | 60.80 | 24.24 | 8.91 |
| | Stem | | | | Root | | | |
| Na | 3.91 | 4.78 | 6.96 | 10.44 | 1.92 | 1.61 | 1.90 | 1.43 |
| K | 71.87 | 80.82 | 74.93 | 80.82 | 49.10 | 41.18 | 48.59 | 36.32 |
| Ca | 30.94 | 31.94 | 38.92 | 48.90 | 24.45 | 28.94 | 31.94 | 29.94 |
| Cl | 36.10 | 50.48 | 55.27 | 64.86 | 55.27 | 60.07 | 64.86 | 60.07 |
| Mg | 10.77 | 11.59 | 15.74 | 16.56 | 11.59 | 14.91 | 17.39 | 19.05 |
| P | 71.02 | 67.80 | 75.87 | 46.81 | 64.57 | 56.50 | 56.50 | 56.50 |
| Fe | 2.15 | 3.06 | 1.99 | 1.83 | 4.40 | 4.78 | 7.52 | 5.96 |
| Mn | 0.11 | 0.07 | 0.25 | 0.07 | 0.11 | 0.36 | 0.07 | 0.18 |
| K/Na | 31.22 | 28.73 | 18.31 | 13.17 | 19.20 | 10.06 | 8.64 | 3.74 |

* Values are expressed as meq (100 g)$^{-1}$ dry tissue.
Each value is a mean of three determinations.

in all plant parts are increased due to salt stress. Between these ions, however, chloride accumulation is considerably higher and their distribution pattern in different plant parts also differs. Sodium is relatively more in roots while it is chloride in stem, leaf-rachis and leaflets. These observations support the view that no stoichiometry is maintained between sodium and chloride ions (LESSANI and MARSCHNER 1978). Our observations further suggest that *Sesbania* possesses very good capacity for regulation of sodium uptake as sodium contents are considerably lower than the corresponding chloride contents over the entire range of salt treatment and thus *Sesbania* resembles the halophytes belonging to the family *Zygophyllaceae* (LESSANI and MARSCHNER 1978). Sodium has been shown to be a relatively more harmful component of salinity (GATES *et al.* 1970) and possibly by checking its uptake and translocation the plant can adapt to saline conditions. However, this may be energy consuming in some way (LESSANI and MARSCHNER 1978). It can be seen that both sodium and chloride accumulate to a greater degree in the leaf-rachis than in the leaflets or leaf-lamina. This can also be considered as one of the adaptive features of *Sesbania* because the assimilatory tissue of leaflets might have been protected from high accumulation of salt.

TABLE 2
Effect of NaCl salinity on total nitrogen, proline, carbohydrate contents and titratable acidity of different parts of *Sesbania aculeata*

| Constituent | NaCl salinity [mS cm$^{-1}$] | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Control | 5 | 10 | 15 | Control | 5 | 10 | 15 | Control | 5 | 10 | 15 |
| | Root | | | | Stem | | | | Leaf | | | |
| Total Nitrogen* | 0.30 | 0.33 | 0.73 | 1.21 | 0.91 | 0.45 | 0.10 | 0.24 | 1.06 | 1.36 | 1.67 | 1.15 |
| Proline** | 219 | 188 | 125 | 188 | 163 | 156 | 188 | 94 | 2875 (1625) | 3500 (1844) | 3500 (3281) | 4063 (3438) |
| Soluble sugars* | 2.19 | 2.55 | 2.27 | 2.49 | 1.48 | 0.65 | 0.29 | 1.79 | 1.06 | 1.14 | 1.19 | 1.34 |
| Starch* | 14.77 | 8.50 | 11.00 | 10.50 | 12.67 | 10.00 | 14.00 | 17.85 | 4.16 | 4.16 | 4.42 | 2.75 |
| Total Carbohydrates* | **16.96** | **11.05** | **13.27** | **12.99** | **14.15** | **10.65** | **14.29** | **19.64** | **5.22** | **5.30** | **5.61** | **4.09** |
| TAN*** | 132.00 | 112.00 | 105.00 | 119.00 | 77.00 | 95.00 | 98.00 | 88.00 | 224.00 | 142.50 | 187.00 | 121.00 |

* Values in g (100 g)$^{-1}$ dry tissue. ** Values in $\mu$g g$^{-1}$ dry tissue. *** ml 0.1 N NaOH required to neutralize acids present in 100 g dry tissue. Values for proline in bracket are of the leaf-rachis. Each value is a mean of three determinations.

The salt stress lowers the potassium uptake significantly only at salt-concentrations where the growth retardation is observed (Table 1). K/Na ratio, however, is decreased due to salt stress. It is interesting to note here that potassium content in control plants is quite high when we compare it with the optimum value, 1%, suggested by EPSTEIN (1972) and it can be seen that at all salinity levels the potassium value is maintained above this optimum. Such high levels of potassium (5—10% of dry matter) have been reported for halophytes and in particular the *Chenopodiaceae* members (FLOWERS *et al.* 1977). Potassium has been shown to play a key role in salt tolerance of halophilic bacteria and halophytes (LARSEN 1967, EPSTEIN 1972). It appears that the same situation also prevails in *Sesbania.*

Salt stress causes an increase in calcium uptake which is quite significant in leaf rachis and leaflets (Table 1). A reduction in calcium uptake under saline conditions in salt sensitive plants is observed by several workers (MATAR *et al.* 1975, LASZLO and KUIPER 1979, CHAVAN and KARADGE 1980). At the same time there are reports on increase in Ca contents in some plant species under saline conditions (AYOUB 1977). Calcium has been shown to regulate membrane properties and it is proposed that calcium and sodium probably compete for common uptake sites (LESSANI and MARSCHNER 1978). It appears that in *Sesbania* calcium suppresses sodium uptake and contributes to ionic balance with chloride ions. However, it cannot be overruled that the effect may probably be due to inclusion of $CaCl_2$ in the saline medium.

Not much attention has been paid to the role of magnesium in salt tolerance, though there are reports that magnesium adds to the salt tolerance capacity in mangroves and other plants (BERNSTEIN 1975). In all parts of *S. aculeata* seedlings grown in saline media there is an increase in magnesium content (Table 1). Similar increase in magnesium content due to salt stress has been reported by several workers (GUILLEN *et al.* 1978). Such an increment of magnesium will be certainly beneficial in view of the essentiality of this element in various biochemical processes.

Phosphorus uptake has been severely affected by salt stress and this effect is more pronounced in leaflets (Table 1). These findings are in agreement with the findings of KLEINKOPF *et al.* (1975) and DAHIYA and SINGH (1976). According to WILSON *et al.* (1970), the resistance to secondary salt induced stress in *Glycine falcata* is due to its ability to maintain high phosphorus content in the presence of salts in the medium. It appears from our observations, however, that *Sesbania* lacks such ability. Salt stress has caused a lowering of iron content in the leaves, but an increase in the roots. This is possibly due to an inhibition of iron translocation by salinity. Such iron accumulation under saline conditions has been observed by MAAS *et al.* (1972), DAHIYA and SINGH (1976), and CHAVAN and KARADGE (1980). The manganese content in leaves is slightly reduced due to salt stress while in other organs no definite pattern can be seen.

The effect of salinity on organic constituents in different parts of *S. aculeata* seedlings has been recorded in Table 2. It can be seen that salinity causes accumulation of total nitrogen especially in the roots and to a slight extent in the leaves. On the other hand, there is a reduction in total nitrogen content of the stem. Thus it appears that the overall nitrogen uptake is not adversely affected by salt stress. These findings support the observations of BHARADWAJ (1974) that *S. aculeata* possesses good nodulation ability even

under saline conditions. According to ALBERT and FALTER (1979) restricted nitrogen uptake from highly salt-damaged urban soils is the main reason for unbalanced nitrogen metabolism, and further growth retardation of *Tilia cordata*. It seems that enhanced nitrogen uptake under saline conditions may be an adaptive feature in *Sesbania* in the light of this suggestion.

The level of free proline is increased considerably in the leaves while there is a lowering of it in the root and stem parts (Table 2). These findings indicate that leaf tissue in *Sesbania* is the major site of proline accumulation under saline conditions, which is in close agreement with the suggestion by WEIMBERG *et al.* (1982). According to them, if proline accumulates in the cytoplasm it can play a key role in osmotic adjustment. In contrast to proline we can see that the level of organic acids is lowered in roots as well as leaves of *S. aculeata* under saline conditions, while it is on the decline in the stem. It is suggested by BERNSTEIN (1975) that organic acids can play a role in osmotic adjustment. An increase in organic acids due to salt stress has been reported by RUSH and EPSTEIN (1976). At the same time there are few reports on reduction in organic acid levels under saline conditions (ROZEMA 1976). It is apparent from the present observations that organic acids form only a small contribution in osmotic adjustment of *Sesbania*.

Salt stress considerably affects carbohydrate metabolism in roots and there are only slight and inconsistent changes in the stem and leaves (Table 2). In the roots the starch content is considerably decreased by salt stress while an opposite trend is observed in the stem. In the leaves the starch content is significantly reduced only at an inhibitory dose of NaCl. The soluble sugar content is increased to a slight extent in both roots and leaves. It is suggested by MATAR *et al.* (1975) that even a small increase in sodium content can cause considerable changes in carbohydrate metabolism and this action is indicated through the influence of sodium on both synthesis and translocation of carbohydrates. A comparison by STEINER (1935) of the contribution of sucrose, reducing sugars, $Na^+$ and $Cl^-$ to the osmotic potential of various glycophytes and halophytes indicated that the organic materials played a relatively minor role. FLOWERS *et al.* (1977) have also expressed a serious doubt about the role of sugars in osmotic adjustment under saline conditions. In *Sesbania* there is only a small rise in soluble sugar level due to salt stress, which may not be sufficient to account for any significant osmotic adjustment.

In conclusion it can be said that *S. aculeata* possesses very good salt tolerance potential which is mainly due to ionic balance achieved by restricted sodium uptake, accumulation of calcium and magnesium and unrestricted nitrogen uptake. Proline may be playing a supporting role in salt tolerance capacity of the plant.

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