

**EFFECTS OF SALINE WATER IRRIGATION ON GROWTH
AND MINERAL DISTRIBUTION IN GUAR
(*CYAMOPSIS TETRAGONOLOBA* (L.) TAUB.)**

D. KHAN, R. AHMAD, S. ISMAIL AND S. H. ZAHEER

*Department of Botany,
University of Karachi, Karachi-75270, Pakistan.*

Abstract

Growth and mineral distribution of a local strain of guar (*Cyamopsis tetragonoloba* (L.) Taub) were investigated in relation to salinity. Growth in terms of height and dry matter of different plant parts decreased significantly under salinity. Threshold EC_w inducing 50% reduction in seed production was 5.76 dS.m^{-1} . Net reproductive effort of the plants treated with 30% sea water was 10.85%, as compared to 27.32% in control. Salinity decreased number of pods and seeds per plant, whereas, number of seeds per pod were unaffected and averaged around 7-8 seeds. Distribution of seeds among pods was leptokurtic in all the cases but with salinity variance increased and distribution tended to be more negatively skewed. Absorption of Na^+ and K^+ increased with salinity, whereas K^+ declined at high salinity. Absorption of these ions was almost equal at 20% sea water treatment. Ca^{++} absorption although declined with salinity, Mg^{++} behaved indifferently. Distribution patterns of ions showed that plant responded to salinity by excluding ions from reproductive parts specifically from the seeds. All cations were generally more allocated in leaves.

Introduction

Guar (*Cyamopsis tetragonoloba* (L.) Taub.) is an annual semelparous legume of great economic importance in arid and semi-arid areas. (Whisler & Hymowitz, 1979. The plant thrives best in sandy soils (Raychaudhuri, 1952) and may survive at fairly high salinity (Mehta & Desai, 1958; Yadava *et al.*, 1975). In arid areas good quality water is scarce and sub-soil water is generally brackish to varying extent. This paper describes the effects of saline irrigation on the growth and mineral bionomics of guar on sandy soil.

Materials and Methods

Dilutions of sea water (10-30%; EC_w : $4.5\text{-}14.0 \text{ dS.m}^{-1}$) were used to simulate various salinity regimes (Table 1). To reduce sodium toxicity and provide essential mineral for growth, a fertilizer-mixture based on calcium ammonium nitrate, single super phosphate and sulphate of potash was added to the irrigation medium in amounts appropriate to provide N:P:K ratio of 176:41:156. Mg^{++} was supplemented with MgSO_4 and micronutrients and Fe-EDTA each corresponding to half strength Hoagland solution were added at 100ml per 100 L of culture solution. Control culture solution was prepared in non-saline tap water with corresponding amounts of fertilizers and other amendments.

**Table 1. Analysis of different dilutions of sea water after chemical amendments.
(Data are the mean of 5 replicates).**

Irrigation medium	pH	EC (dS.m ⁻¹)	Na ⁺	K ⁺	Ca ⁺⁺ Mg ⁺⁺	SAR
Control	7.35	1.20	3.26	1.27	32.43	0.63
10% Sea Water + Amendments*	7.55	4.50	27.17	1.27	54.89	2.10
20% Sea Water + Amendments	7.45	9.50	32.82	3.19	69.86	6.04
30% Sea Water + Amendments	7.45	14.00	131.52	3.83	109.78	11.11
Sea Water (Arabian Sea)	7.50	40.00	328.80	8.00	162.17	36.51

*, abbreviated as SW+A.

A crop of guar (local strain sown in Lahya, Thal desert of Pakistan) was raised in July, 1985 at the experimental field of Botany Department, University of Karachi, by sowing seeds in 40cm diameter pots containing 20kg of coastal sandy soil and provided with a basal perforation to ensure drainage of surplus water. After 10 days of emergence thinning was done to keep single seedling of more or less equal vigour per pot. At this stage when seedlings measured 16.12±2.98cm in height and had 6 extra-cotyledonary leaves, pre-conditioning was practiced where seedlings were irrigated with 5% amended sea water and then the concentration was gradually increased to the level of salinity in which plants were grown upto maturity. In spite of the rain (25mm) during the month of August, the plants were regularly irrigated with 2.5 L of 10, 20 and 30% amended sea water with control plants receiving equivalent volume of control culture solution. Three replicates were kept for each treatment. The plants were harvested at maturity after 3 months when control and 10% sea water irrigated plants were 95-day old and 20 and 30% sea water treated plants were 87 and 80-day old, respectively, since salinity hastened the maturity. Data on various growth parameters and net reproductive effort was determined as the ratio of seed weight to the total plant biomass (Sarukhan, 1976). Since abscised parts were collected time to time from underneath the plants, the loss of unaccounted dry matter (if any) should be insignificant to affect the overall dry weight of the plant.

To follow the seed distribution pattern among the pods, number of seeds from a sizeable number of pods produced by treated and control plants were counted and their frequency diagrams were characterized with location and dispersion parameters (Fisher, 1948).

To follow mineral composition of the plant, a known portion of dried plant material was wet digested in nitric acid followed by perchloric acid. Na⁺, K⁺, Ca⁺⁺ and Mg⁺⁺ were determined by Jarrell Ash AA-782A atomic absorption spectrophotometer with three replicates for each observation.

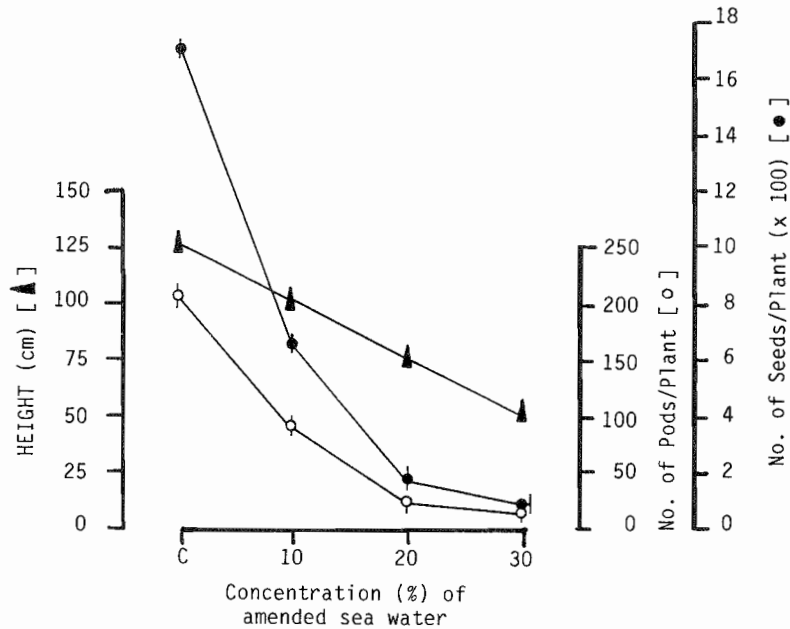


Fig. 1. Height and reproductive growth parameters of guar grown under various salinity regimes. Wherever standard error is not shown, it is covered by the point.

Results

(a) *Growth*: Plant growth in terms of height at maturity was maximum at control and declined progressively under salinity (Fig. 1). Linear relationship between EC_{iw} (X) and height (Y) was, $Y = 130.52 - 5.82 X$; $r = -0.9995$ ($p < 0.001$). Based on X on Y equation, calculated with data in form of relative height to the highest plant, a 50% reduction in height corresponded to EC_{iw} : 11.08 dS.m^{-1} .

Dry weights of various morphological components also indicated a significant decrease with salinity (Table 2). There was relatively sharp decrease in growth of stem, leaf, pods and seeds and least in the case of root. Consistent increase in root/shoot ratio was found with an enhancement of 296.39% over control in 30% sea water treatment. The relationship between growth of various structural components and salinity of irrigation water was linear in form of Y and X type equations:

$$\text{Root/plant (g.DW)} = 5.67 - 0.2277 EC_{iw} (\text{dS.m}^{-1}), r = -0.9845^{***}$$

$$\text{Stem/plant (g.DW)} = 41.26 - 3.16 EC_{iw} (\text{dS.m}^{-1}), r = -0.9091^{***}$$

$$\text{Leaves/plant (g.DW)} = 13.89 - 0.8194 EC_{iw} (\text{dS.m}^{-1}), r = -0.9148^{***}$$

Table 2. Biomass (g.DW) of various structural components of *yamopsis tetragonoloba* under saline water irrigation

Plant parts	Control	10% SW + A	20% SW + A	30% SW + A
Root	5.63±0.72 a	4.36±0.93 (-22.56) a	3.43±0.43 (-39.08) b	2.60±0.15 (-53.82) b
Stem	45.40±7.57 a	19.33±3.06 (-57.42) b	8.53±1.19 (-81.21) c	5.27±1.93 (-88.39) c
Leaf	14.97±4.11 a	7.97±0.92 (-46.76) b	4.93±0.75 (-67.07) c	3.75±0.85 (-74.95) c
Pod (without seeds)	24.73±3.32 a	14.33±0.17 (-42.05) b	4.60±1.86 (-81.39) c	3.07±1.31 (-87.58) c
Seeds	34.10±2.88 a	20.47±0.68 (-39.97) b	4.70±1.90 (-86.22) c	1.79±0.95 (-94.75) d
Total	124.83±5.69 a	66.46±4.88 (-46.76) b	26.20±3.00 (-78.93) c	16.49±2.92 (-86.79) d
Net Reproductive Effort (NRE)	27.32±3.91 a	30.80±4.09 (+12.74) a	17.49±4.68 (-34.33) c	10.86±2.36 (-60.25) c
Root/Shoot Ratio	0.0472	0.0702 (+48.72)	0.1506 (+219.07)	0.1871 (+296.39)

*, After Sarukhan (1976).

Mean Values of a given parameter followed by the same letter are not statistically significant at least at $P < 0.05$ as given by DMRT.

Figures in parenthesis denotes the percentage reduction (-) or promotion (+) over control.

$$\text{Pods-seeds/plant (g.DW)} = 24.03 - 1.6911 \text{ EC}_{\text{iw}}; \text{dSm}^{-1}, r = -0.9480^{***}$$

$$\text{Seeds/plant (g.DW)} = 31.25 - 2.3200 \text{ EC}_{\text{iw}} (\text{dS.m}^{-1}), r = 0.9692^{***}$$

$$\text{Total biomass/plant (g.DW)} = 118.53 - 8.22 \text{ EC}_{\text{iw}} (\text{dS.m}^{-1}), r = -0.9389$$

To predict 50% decrease in growth, X on Y type equations were calculated with data in form of relative yield (%) to the maximum control. By these equations 50% reduction in root, stem, leaves, pods, seeds and total biomass of the plant corresponded with EC_{iw} amounting to 9.40, 4.75, 4.85, 6.25, 5.76 and 5.80 dS.m^{-1} , respectively. Evidently, the root growth was relatively less inhibited than other plant parts.

The relationship between number of pods and seeds produced per plant (Y_1 and Y_2 , respectively) and salinity of irrigation water (X , EC_{iw}) was curvilinear (Fig. 1) as follows:

$$Y_1 = 255.07 - 42.45 X + 1.82 X^2; R^2 = 0.9916, F = 59.50^{***}$$

(t = 6.54) (t = 4.38)

$$Y_2 = 2058.79 - 354.71 X + 15.49 X^2; R^2 = 0.9820, F = 27.30^{***}$$

(t = 4.56) (t = 3.12)

(b) *Seed distribution among pods*: The average number of seeds per pod (around 7-8 seeds/pod) in treated as well as control plants remained unaffected. The distribution was distinctly leptokurtic in all cases. The variance increased in high salinity and distribution tended to be more negatively-skewed (Fig. 2).

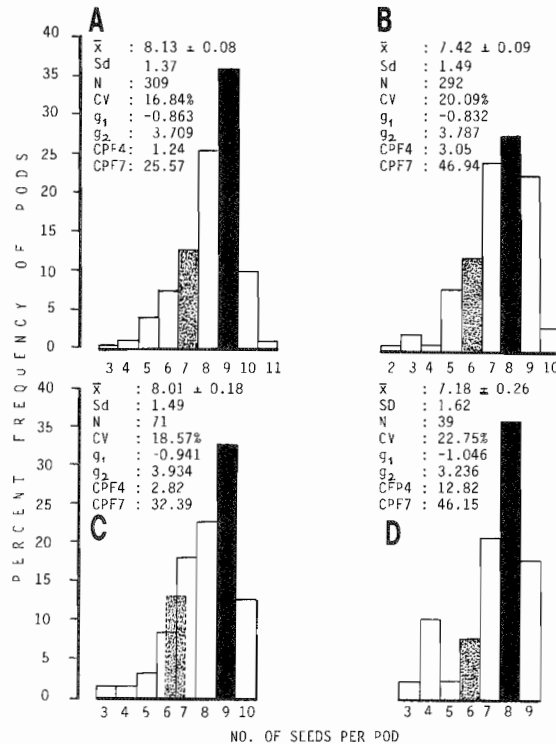


Fig. 2. Frequency distribution of seeds among pods of guar under salinity. A = Control; B = 10% SW + A; C = 20% SW + A; D = 30% SW + A; \bar{x} = mean; CV = Coefficient of variability; Sd = Standard deviation; g_1 = skewness; g_2 = kurtosis; CPF4 = Cumulative percent frequency up to class-4 seeds/pod; CPF7 = Cumulative percent frequency up to class-7 seeds/pods.

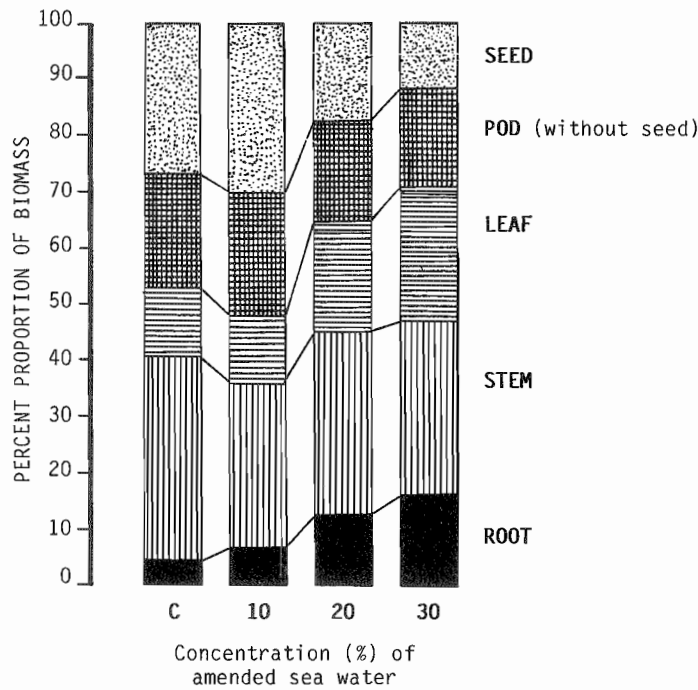


Fig. 3. Percentage allocation of total biomass among structural components of guar at maturity, when grown under various salinity regimes.

(c) *Biomass allocation*: The pattern of biomass distribution among various structural components at maturity indicated relative instability of proportion of dry matter allocated to reproductive parts under salinity (Fig. 3). Though salinity induced a tendency of earlier entrance in the reproductive phase, the crude reproductive effort, which increased at 10% sea water irrigation declined at higher salinity with the result that vegetative allocation increased proportionately. There was a trend of increase in leaf and root allocation at 20 and 30% sea water levels. The net reproductive effort, on the other hand, declined considerably at these levels of salinity (Table 2). Net reproductive effort which was $27.32 \pm 3.91\%$ in the control reduced to $17.94 \pm 4.68\%$ (reduction, c. 34%) and $10.86 \pm 2.36\%$ (reduction, c. 60%) at 20 and 30% sea water levels, respectively. At low salinity a promotion of c.4% over control in net reproductive effort was observed.

(d) *Mineral composition of the plant*: On whole basis, K^+ and Ca^{++} were the dominant cations in the control plants constituting c. 44.47 and 34.06% of the total cations, respectively (Fig. 4a). Na^+ , which was around 17% of the cations in control increased gradually up to 40.32% in 30% sea water treatment. The contribution of K^+ and Ca^{++} declined under salinity.

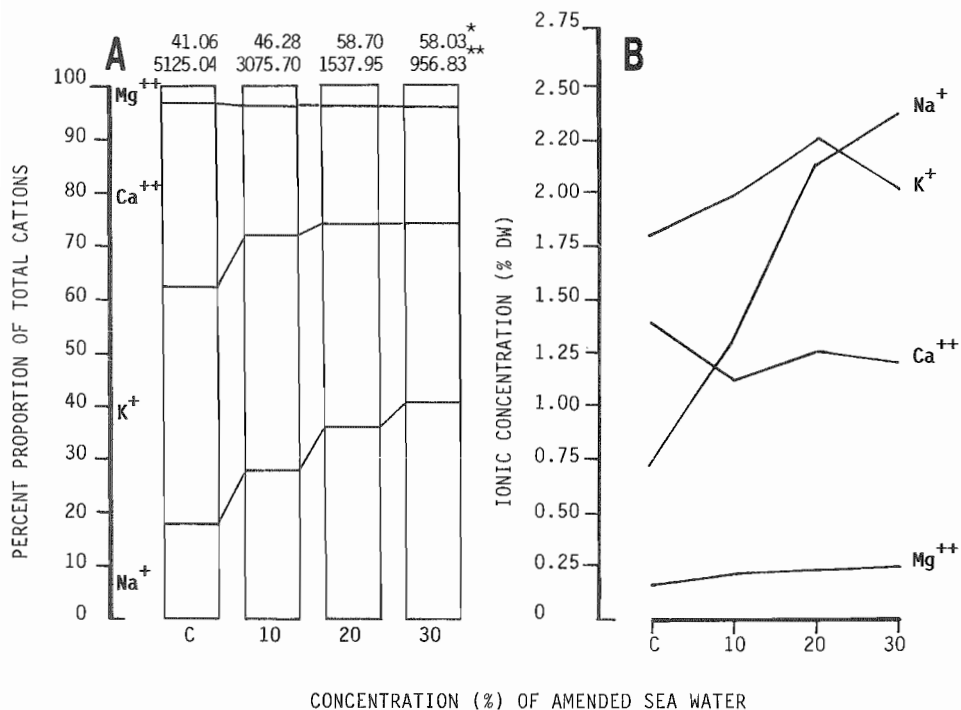


Fig. 4. Proportion of cations expressed on whole plant basis in guar as a function of the saline water irrigation (Fig. 4a) and concentration of cations expressed as a proportion of dry weight of the plant (Fig. 4b). *Total amount of cations (mg) per g DW of the plant. ** Total amount of cations (mg) per plant.

The concentration of cations, expressed on the basis of percentage proportion of the dry weight of the plant, indicated no change in absorption of Mg⁺⁺ but declined in absorption of Ca⁺⁺ with salinity (Fig. 4b). There was a sharp increase in absorption of Na⁺ which showed a promotion of c. 223.65% over control in 30% sea water treatment. There was also significant increase in K⁺ absorption up to 20% sea water treatment which thereafter declined. The absorption of Na⁺ and K⁺ was, however, almost equal at 20% sea water treatment. Concentration of Na⁺ in root, stem, leaf and fruit wall increased significantly with the increase of salts in the root zone (Table 3). K⁺ contents increased in leaf and fruit wall but decreased in root and stem. Similarly Ca⁺⁺ concentration decreased in leaf, stem and fruit wall which did not change in root. Mg⁺⁺ increased in stem, decreased in fruit wall and did not change in root and leaf. The concentration of cations in seeds produced under saline treatments was not significantly different from that of the control.

Table 3. Concentration (mg/g DW) of some cations in various morphological parts of *Cyamopsis tetragonoloba* grown under amended sea water irrigation.

Treatments	Root	Stem	Leaves	Fruit Wall	Seed
Sodium					
Control	14.83 ± 0.88 a	12.00 ± 0.58 a	4.00 ± 0.58 a	3.66 ± 0.33 a	3.66 ± 0.33 a
10% SW + A	24.00 ± 1.15 b	23.33 ± 0.66 b	17.33 ± 2.91 b	6.00 ± 1.15 b	3.33 ± 0.33 a
20% SW + A	24.33 ± 2.33 b	34.00 ± 1.53 c	27.33 ± 2.03 c	5.33 ± 0.88 b	4.00 ± 0.00 a
30% SW + A	24.66 ± 2.33 b	36.33 ± 0.33 c	28.00 ± 2.31 c	5.66 ± 0.33 b	4.33 ± 0.33 a
Potassium					
Control	8.33 ± 0.73 a	16.50 ± 1.04 a	17.83 ± 1.36 a	34.83 ± 0.72 a	10.33 ± 0.16 a
10% SW + A	6.00 ± 0.58 b	15.00 ± 0.58 a	23.33 ± 5.13 b	41.33 ± 1.86 b	11.33 ± 0.44 a
20% SW + A	4.83 ± 1.01 b	17.83 ± 1.83 a	33.50 ± 5.48 b	45.00 ± 3.51 b	10.83 ± 0.93 a
30% SW + A	4.83 ± 1.09 b	11.83 ± 1.17 b	29.50 ± 5.35 b	40.66 ± 1.20 b	11.00 ± 0.50 a
Calcium					
Control	8.66 ± 1.01 a	8.17 ± 1.66 a	51.33 ± 1.69 a	15.00 ± 1.53 a	5.50 ± 0.29 a
10% SW + A	7.50 ± 0.50 a	9.17 ± 0.67 a	30.66 ± 2.33 b	11.00 ± 0.50 b	7.17 ± 0.17 a
20% SW + A	7.50 ± 0.50 a	9.00 ± 0.50 a	29.00 ± 1.80 b	12.17 ± 0.33 b	6.83 ± 0.44 a
30% SW + A	10.16 ± 0.66 a	5.33 ± 0.16 b	28.83 ± 3.72 b	9.00 ± 0.76 c	5.83 ± 0.16 a
Magnesium					
Control	0.83 ± 0.17 a	0.66 ± 0.16 a	4.67 ± 0.44 a	2.16 ± 0.16 a	1.16 ± 0.16 a
10% SW + A	1.00 ± 0.00 a	1.33 ± 0.16 b	5.50 ± 0.29 a	2.67 ± 0.44 a	1.50 ± 0.00 a
20% SW + A	1.00 ± 0.00 a	1.67 ± 0.17 b	5.83 ± 0.17 a	1.67 ± 0.16 b	1.50 ± 0.00 a
30% SW + A	1.00 ± 0.00 a	1.67 ± 0.16 b	5.50 ± 0.29 a	1.83 ± 0.17 b	1.50 ± 0.00 a

Mean values in the column not followed by same letter are significantly different at $P < 0.05$ as given by Duncan Multiple Range Test.

(e) *Mineral distribution*: Comparison of the allocation patterns of ions among the structural components of the plant (Fig. 5) indicated the strategy of ion exclusion from the reproductive components, specifically the seeds. Under saline conditions larger parts of the ions allocated to reproductive parts was accumulated in fruit wall of the pods to an extent that the portion allotted to the seeds reduced substantially. Greater proportion of Na^+ was allocated to stem followed by leaves and roots. Translocation of K^+ to aerial parts was relatively rapid and larger proportion of it accumulated in the fruit wall. Allocation of K^+ to leaves increased significantly under 20 and 30% sea water treatments with a concomitant decrease in stem allocation. Ca^{++} and Mg^{++} were allocated in greater proportion to the leaves. Translocation of both of them to reproductive structures declined substantially with salinity. Both cations also exhibited some tendency of their accumulation in root which was more conspicuous in the case of Ca^{++} .

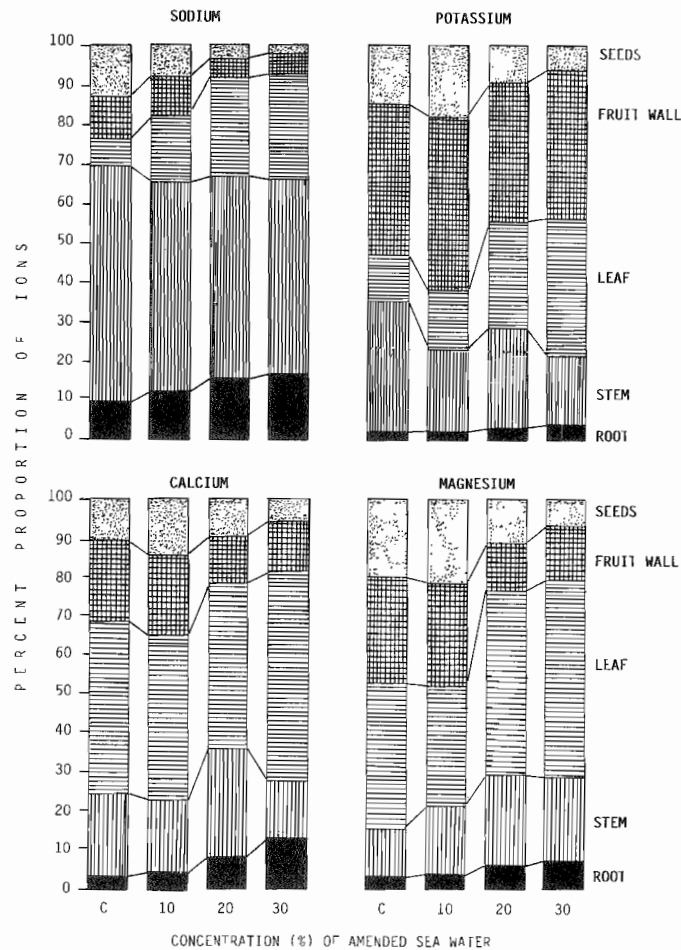


Fig. 5. Distribution pattern of ions among various structural components of guar grown under various salinity regimes.

Discussion

Although salt tolerance in guar at germination phase has been reported (Mehta & Desai, 1958; Yadava *et al.*, 1975), however, mere germination under unfavourable environment does not guarantee the successful and subsequent growth of the plant. In the present study all the parameters studied, exhibited a suppression of growth of guar under saline water irrigation. There was a stronger detrimental effect of salinity on shoot than root growth which is in contrast to Ungar (1964) and Okusanya (1980) who reported more inhibition of root than shoot growth under salinity. However, Mahmood & Malik (1987) reported relatively lesser inhibition of root than shoot in halophytic *Atriplex*

rhagodioides under salinity. Lesser inhibition of root growth may be due to chemical amendments added to bring maximum possible ionic balance in the irrigation water. Improvement in root growth on phosphate enrichment of saline nutrient medium has been reported in *Luffa aegyptica* (Okusanya & Ebong, 1984) and in *Lavetra arborea* (Okusanya & Fawole, 1985). Similarly, addition of Ca^{++} to saline sand culture promotes root growth even in the presence of 141 mm NaCl (Basset, 1980).

The homeostatic processes that maintain the normal distribution pattern of dry matter allocation among various plant parts seem to operate in guar only within a narrow range of salinity. Plasticity in allocation of biomass to reproduction in guar is in agreement with Hickman (1975) who reported reproductive plasticity in an annual *Polygonum cascadense* under adverse moisture regime and in *Atriplex triangularis* when grown in high salinity conditions (Khan, 1987). However, the effects of salinity on reproductive physiology are remarkably species-specific, even among the legumes grown under similar cultural conditions. Guar, in terms of early flowering and reduced reproductive yield resembles to *Leucaena leucocephala* (Ahmad, *et al.*, 1985) and *Indigofera oblongifolia* (Khan & Ahmad, unpublished) in contrast to *Sesbania sesban* in which salinity stimulated reproductive processes and increased the number of seeds as well as the total seed weight substantially (Ahmad *et al.*, 1984).

The threshold EC_{iw} corresponding to 50% reduction in growth of different parts were fairly consistent but low (except root) ranging from 4.75 to 6.25 dS.m^{-1} ($\bar{x} = 5.40 \pm 0.36$; $\text{CV} = 13.50\%$). This suggests that the given strain of guar is more susceptible to salinity than *Indigofera oblongifolia* where 50% reduction in growth under similar cultural conditions ranged from 10.83 to 13.83 dS.m^{-1} ($\bar{x} = 12.05 \pm 0.92 \text{ dS.m}^{-1}$) (Khan, 1987). Similar conclusion may also be drawn from the pattern of seed distribution among pods. Frazer (1977) suggested that in normal environment of a species, a character should be leptokurtic, symmetrical (non-skewed) and have low variance, and when conditions deviate from the norm, the variance should increase and some skewness might be detected. A leptokurtic distribution of seeds among guar pods, associated with increasing value of negative skewness and variance along salinity, indicates that salinities above c.10% sea water concentration constitute sub-optimal conditions for the plant with the result that toxic effects appear in form of relatively larger number of pods containing lesser number of seeds (≤ 7). Obviously, the given strain of guar, being susceptible to salinity, appears of little scope in problem soils. However, it may only be successfully cultivated with irrigation water of low salinity (less than 4 dS.m^{-1}) in sandy soils.

Mineral analysis of the plant exhibited a potassiophilic and calciphilic tendency. Absorption of sodium was though substantially enhanced under salinity, but the plant managed to absorb K^+ and Ca^{++} in appreciably high proportions. Absorption of K^+ also increased under low salinities and was almost equal to Na^+ absorption at 20% sea water irrigation. At 30% sea water K^+ absorption declined substantially. Na^+ level although

increased in root and shoot but was obviously lower than that in the saline irrigation medium indicating that plant attempted to check the entry of sodium in the root system. The amendments employed to ameliorate the concentration of K^+ , Ca^{++} and Mg^{++} in the irrigation medium could also have intensified the availability and uptake of K^+ and Ca^{++} . It may be mentioned that K^+-Na^+ exchange and selective uptake of K^+ depend upon the presence of Ca^{++} in the rooting medium (Epstein, 1972).

Mineral distribution presented mechanism of ion exclusion from the seeds by retaining the ions in the vegetative parts, like other salt tolerant legumes (Lauchli, 1984; Jacoby, 1974). It is evident by the sodium allocation pattern that as larger amount of sodium enters the root system, it is readily translocated to stem and retained there. On saturation in stem, it is rapidly translocated to leaves but is not allowed to enter the reproductive system. Somewhat similar sodium exclusion mechanism has also been shown to operate in *Leucaena leucocephala* (Ahmad *et al.*, 1985) and *Indigofera oblongifolia* (Khan, 1987). Allocation of Ca^{++} and Mg^{++} to reproductive parts was also significantly reduced under salinity, by retaining in vegetative parts, mostly in leaves. K^+ , however, showed greater mobility and almost equally accumulated in leaves and fruit wall. Guar, in respect to its greater foliar accumulation of Ca^{++} , however, resembles to plants such as *Zygophyllum simplex*, *Hammada recurva*, *Cressa cretica* and *Heliotropium curassavicum* which accumulate larger amounts of Ca^{++} in leaves (Ahmad & Zaheer, 1985).

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