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COMPETITIVE INTERFERENCE BY SOME INVADER SPECIES AGAINST KALLAR GRASS (*LEPTOCHLOA FUSCA*) UNDER DIFFERENT SALINITY AND WATERING REGIMES

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Abstract

Kallar grass [*Leptochloa fusca* (L.) Kunth] was grown in mono-cultures and in mixed-cultures with *Suaeda fruticosa* (L.) Forssk., *Cynodon dactylon* (L.) Pers., and *Sporobolus arabicus* Boiss., under different soil salinity and water conditions. The biomass yield data indicated that Kallar grass is a weak competitor against *S. fruticosa* at high salinity and against *C. dactylon* at low salinity, while its growth was not affected due to competition by *S. arabicus*. However, the yield of Kallar grass in mono-cultures (2 plants/pot) was significantly higher than that in corresponding mixed-cultures (2 plants Kallar grass + 2 plants of weed/pot). Although Kallar grass growth was low in its mono-cultures with 4 plants/pot compared to 2 plants/pot, it suffered more severe interference from weed species under certain conditions than from its own individuals. In general, at a particular salinity and watering treatment, nutrient concentrations in plant shoots of a species grown in mono- and mixed-cultures were similar. However, total uptake of nutrients (N,P,K,Ca and Na) by Kallar grass and competing species differed significantly and weed species removed proportionately higher amounts of nutrients in mixed-cultures. The significance of competitive interactions among species with regard to their coexistence and productivity in a common environment in saline areas is discussed.

Introduction

Kallar grass [*Leptochloa fusca* (L.) Kunth], being highly tolerant to salinity (Sandhu *et al.*, 1981) and sodicity (Aslam *et al.*, 1979), is extensively used as a primary colonizer for revegetation of salt-affected lands in Pakistan (Sandhu & Malik, 1975). The grass grows luxuriantly in saline soils without any fertilizer application even when irrigated with brackish underground water and can give 4-5 cuttings in summer yielding upto 40 tons biomass per hectare per year (Malik *et al.*, 1986). However, it is a common observation that after growing for a few years, Kallar grass fails to maintain its vigour and its growth is markedly reduced under field conditions, despite the fact that soil properties get improved. Rana & Parkash (1987) noted that Kallar grass occurs in low-lying alkali lands only, disappears gradually when alkali soils are reclaimed and provides a visible measure of the progress of soil amelioration. Our earlier studies indicated a successive colonization of Kallar grass field by other species during the amelioration process. Species like *Suaeda fruticosa* (L.) Forssk., *Cynodon dactylon* (L.) Pers., and *Sporobolus arabicus* Boiss., colonized and spread in dense patches in Kallar grass stands. The growth of Kallar grass in the weed patches was markedly reduced and it failed to persist with patch associated species. The soil factors in the weed patches and surrounding Kallar grass soils were comparable. Thus, the elimination of Kallar grass from the patches could not be attributed to soil conditions indicating interference from

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invader species (Mahmood *et al.*, 1989). Further, physical environment alone is not sufficient to explain distribution and zonation of species and the role of biological factors needs examination (Wilson & Keddy, 1985). Szczepanski (1977) suggested three possible mechanisms for plant interference which include competition for necessary growth factors, allelopathy, and possession of toxicant or repellant substances that prevent grazing. Systematic studies were undertaken to ascertain the role of soil conditions and interference in species invasion and decline of Kallar grass productivity. The results of field survey studies have been reported earlier (Mahmood *et al.*, 1989). This paper concerns competitive interference by these invader species against Kallar grass under different salinity and watering regimes. Saline soils are infertile and poor in nutrients. Competition for nutrients among plants is a major reason for reduction in yields, especially in soils of low nutrient status (Staniforth, 1957; Cook, 1985). Several reports show that N, P and K concentrations in plants changed in the presence of a competitor (Chambers & Holm, 1965; Hall, 1974; Kolar *et al.*, 1976). Therefore, the uptake of these nutrients by different species was also investigated.

Materials and Methods

Plant growth: Kallar grass was grown in mono-culture and mixed-cultures with different weeds in glazed pots, 26 cm in diameter and 28 cm deep. Two salinity levels and two watering regimes were combined in a factorial manner giving four treatment combinations (low salinity/low watering; low salinity/high watering; high salinity/low watering; and high salinity/high watering). The soils used in the experiment were collected from Kallar grass fields at Biosaline Research Station, Lahore, thoroughly mixed and analysed for physico-chemical properties (Table 1). The salinity levels were low [electrical

Table 1. Analysis of soils used in the experiment for studying competitive interactions between Kallar grass and weed species (Means of 6 replicates with standard errors)

Soil characteristic	Salinity level	
	Low	High
Textural class	Sandy clay loam	Clay loam
Water holding capacity, (% o.d. wt.)	29.5±0.52	30.60±1.13
pH	8.51±0.14	8.77±0.06
EC (dS/m)	6.12±0.18	16.10±0.12
Exchangeable Sodium Percentage (ESP)	33.47±1.02	60.49±4.12
Total nitrogen (%)	0.04	0.05
Mineral nitrogen (ppm)	16.80±0.81	15.71±2.17
Olsen P* (ppm)	9.57±0.40	20.35±0.83

*Available P extractable with 0.5 N $NaHCO_3$

conductivity (E.C.) = 6.1+0.18 dS/m] and high [(E.C.) = 16.1+0.12 dS/m]. For watering regimes the pots were irrigated twice a week so that a pot received water equivalent to 60% of soil water holding capacity weekly or fortnightly for high and low watering, respectively. Watering treatments were imposed after two weeks of transplanting. Each pot contained one species or two species in 1:1 proportion with overall density of 4 plants per pot. In addition, Kallar grass with density of 2 plants per pot was included to determine the effects of density per se.

Kallar grass and three weed species, *Cynodon dactylon, Sporobolus arabicus* and *Suaeda fruticosa* were grown in mono-cultures and mixed-cultures for 14 weeks. The plants of *S. fruticosa* were grown from seeds while the other species were grown from stubbles. Each treatment was replicated three times and the pots were arranged randomly. The plants were grown in the open in a net house. At the termination of experiment, above-ground biomass of each species was separately harvested by clipping at the soil surface. The material was dried at 70°C and weighed.

Design and analysis: The experimental design and analysis used was based upon that described by Fowler (1982) and del Moral *et al*., (1985). The growth of individual plants in mixture of two species was compared with the growth of individuals in mono-cultures at the same overall density. This design allows measuring the effects of competition amongst species despite the differences in absolute yields between different species.

From the yield of each species in each pot and the number of individuals in the pot, relative yield per plant (RYP) was calculated as under:

$$\text{RYP} = \frac{\text{Yield of species A in a mixture of species A\&B}}{\text{Yield of species A in a pure stand of species A}}$$

all values being per unit.

Relative yield per plant may be interpreted as the average performance of an individual in a mixture in comparison with the average performance of an individual of the same species in a pure stand of the same total density (Flower, 1982). If the growth of an individual is not affected by the identity of the neighbouring individuals, then RYP = 1.0; RYP of more than 1.0 means that individuals of species A suffer less competition from individuals of species B (inter-specific competition) than they do from individuals of their own species (intra-specific competition), and RYP of less than 1.0 implies that within species competition is less than that between species.

***Nutrient uptake*:** The shoot material of Kallar grass and different weeds was dried at 70°C to constant weight and ground (< 1mm), and analysed for concentrations of different nutrients. Three replicate determinations were made for each treatment. Nitrogen was determined by Micro-Kjeldahl method (Bremner, 1965) and K, Na and Ca by flame photometry (Richards, 1954). Phosphorus was determined spectrophotometrically (Jackson, 1958). From yield data and concentrations of different nutrients in plant shoots, amount of the nutrients taken up by different weeds and Kallar grass was calculated for different treatments.

Analysis of variance was used to compare the effects of different treatments and species cultures on yield of each species, nutrient concentrations and total nutrient uptake by different species using a factorial design (Gomez & Gomez, 1984).

Results

Plant Growth: In mono-cultures, Kallar grass gave optimum growth in high salinity/high watering. Increase in plant density decreased the dry weight per plant. However, the overall yield per pot was not affected in different salinity and water levels. Moreover, at high salinity level, high watering had favourable effect on the growth of Kallar grass (Fig.1).

In mixed-cultures with *S. fruticosa*, the growth of Kallar grass was drastically reduced at high salinity, whereas growth of *S. fruticosa* was higher in mixed-cultures than in mono-cultures when grown under high salinity. Relative yield values indicated up to 70% loss in Kallar grass growth due to *S. fruticosa* at high salinity. In low salinity/low watering treatment, biomass yield of Kallar grass was slightly higher in mixed-cultures compared to mono-cultures, while growth of *S. fruticosa* was similar both in mono- and mixed-cultures (Fig.1).

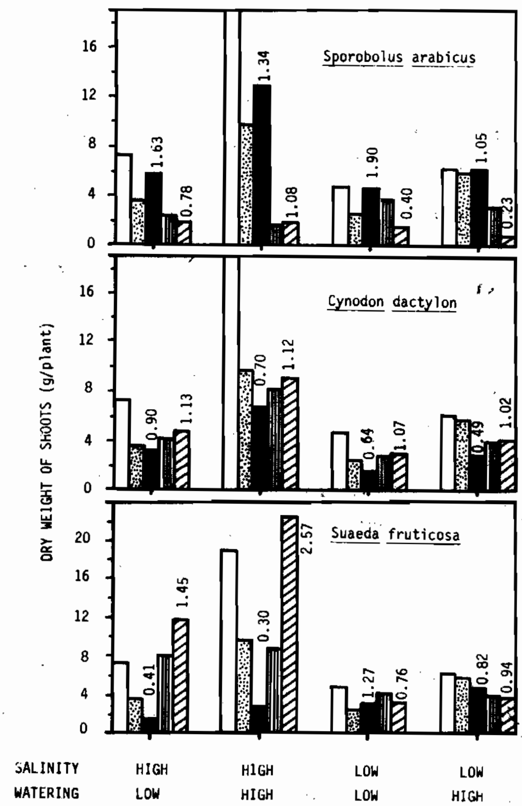

Fig.1. Shoot dry weights of *Leptochloa fusca* and weed species (*Suaeda, Cynodon, Sporobolus*) grown in mono- and mixed-species cultures [] *Leptochloa* mono-culture: 2 plants/pot [], 4 plants/pot ▨; *Leptochloa* mixed-culture ■; weed species mono-culture ▥; weed species mixed-culture under different salinity and watering treatments. Figures on the bars are relative yield. Values are means of 3 replicates, each represented by 4 plants.

L.S.D. (P = 0.05):

For species culture = 1.11, treatment = 0.67, treatment x species culture = 3.14, overall = 2.22.

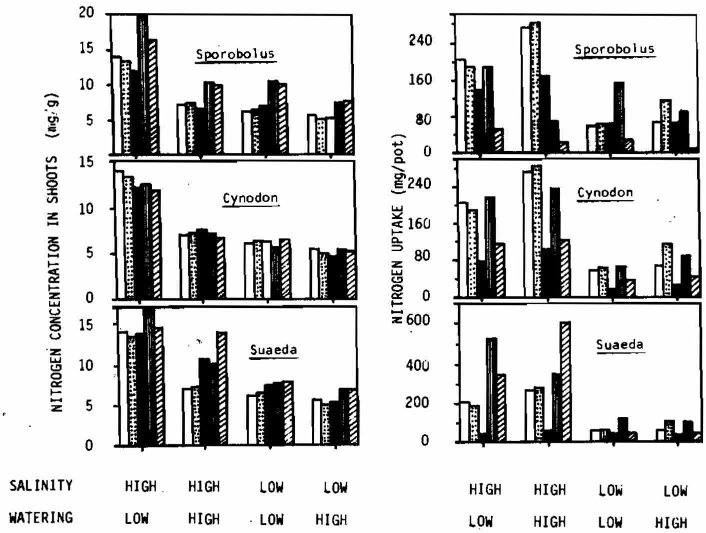

Fig.2. Nitrogen concentration in shoots and uptake by *Leptochloa fusca* and weed species (*Suaeda, Cynodon, Sporobolus*) grown in mono- and mixed-species cultures (*Leptochloa* mono-culture: 2 plants/pot [], 4 plants/pot ▦; *Leptochloa* mixed-culture ▮; weed species mono-culture ▮; weed species mixed-culture ▨) under different salinity and watering treatments. Values are means of 3 replicates.
L.S.D. (P = 0.05):
For treatment: N conc. = 0.61, N uptake. = 19.32; species culture: N conc. = 1.00, N uptake. = 32.04; treatment x species culture: N conc = 2.85, N uptake = 90.62; Overall: N conc = 2.02, N uptake = 64.08.

The presence of *C. dactylon* interfered with the growth of Kallar grass in almost all treatments, the effects being more pronounced at low salinity. The biomass yields of *C. dactylon* in mono-cultures and respective mixed-cultures were not very different. Kallar grass gave increased growth in mixed-cultures with *S. arabicus* while the growth of *Sporobolus* was adversely affected at low salinity in the presence of Kallar grass; its growth was not affected at high salinity (Fig.1).

Nutrient Uptake: For a given salinity and watering level, N concentration in Kallar grass was not very different when grown in competition with different species and in mono-cultures except that it was significantly higher in mixtures with *S. fruticosa* under high salinity/high watering. For competing species, N concentrations in *S. fruticosa, Cynodon dactylon* and *S. arabicus* were significantly higher in high salinity irrespective of watering treatment. Further, N concentrations in *Suaeda, Cynodon* and *Sporobolus* grown in mono- and mixed-cultures were almost similar (Fig.2).

Total N uptake by Kallar grass in mono-cultures was significantly higher at high salinity than that at low salinity. When grown in competition, N uptake by Kallar grass was reduced significantly in the presence of all competing species at high salinity in both watering treatments. At low salinity, *Cynodon dactylon* caused marked reduction in N uptake by Kallar grass, while *S. arabicus* had little effect. Large proportions of N uptake in mixed-cultures were at the part of competing species rather than Kallar grass (Fig.2).

In mono-cultures of Kallar grass, P concentrations in shoots of plants grown under high watering were significantly higher. P concentrations in Kallar grass slightly in-

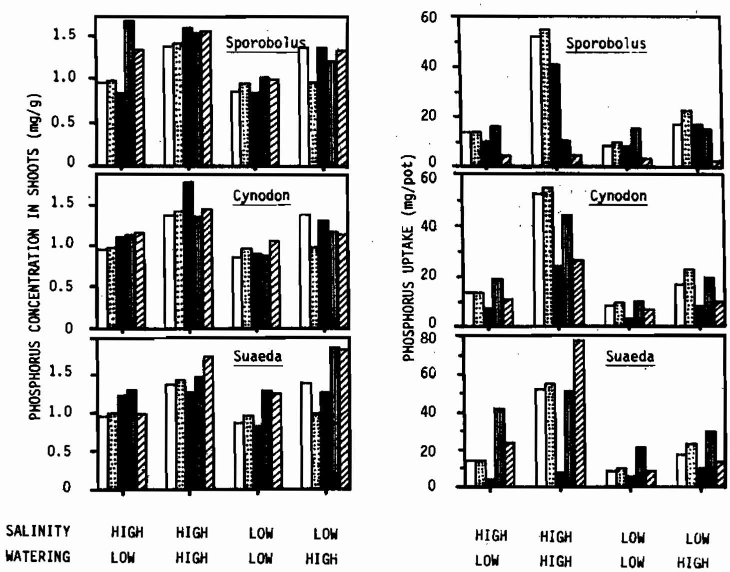

Fig.3. Phosphorus concentration in shoots and uptake by *Leptochloa fusca* and weed species (*Suaeda, Cynodon, Sporobolus*) grown in mono- and mixed-speices cultures (*Leptochloa* mono-culture: 2 plants/pot [], 4 plants/pot ▮; *Leptochloa* mixed-culture ▮; weed species mono-culture ▮; weed species mixed-culture ▮) under different salini ty and watering treatments. Values are means of 3 replciates.

L.S.D. (P = 0.05):

For treatment: P. conc. = 0.06, P uptake = 15.27; species culture: P conc. = 0.10, P uptake = 4.78, treatment x species culture: P conc. = 0.29, P uptake = 13.52; Overall: P conc. = 0.20, P uptake = 9.56.

creased or were little affected in the presence of competing species. For *C. dactylon* and *S. arabicus*, P concentrations in mono- and mixed-cultures were not different under a given treatment, while it increased significantly in *S. fruticosa* in the presence of Kallar grass at high salinity/high watering (Fig.3). Total P uptake by Kallar grass grown in competition with each species was reduced compared to that by its mono-cultures,. except when grown with *Sporobolus* at low salinity (Fig.3).

The concentrations of K in Kallar grass grown in mono-cultures and in competition with *S. fruticosa, S. arabicus* and *C. dactylon* were almost the same in different salinity and watering treatments, except that K concentrations were lower in plants grown under low salinity/high watering. *S. fruticosa* had higher K concentration when grown in mixture with Kallar grass compared to its mono-culture at low salinity. K concentrations in *Cynodon* and *Sporobolus* were higher in high salinity/low watering both in mixed- and mono-cultures. The reduction in K uptake by Kallar grass due to *S. fruticosa* and *C. dactylon* was very pronounced while in the presence of *S. arabicus* it was low in magnitude (Fig.4).

When grown in mixed-cultures with *S. fruticosa, S. arabicus* or *C. dactylon*, Ca concentrations in Kallar grass were similar to those in its mono-cultures. In mixed cultures, Ca uptake by Kallar grass was significantly reduced by *S. fruticosa* at high salinity, by *C. dactylon* in all treatments and by *S. arabicus* to a smaller extent only at high salinity level (Fig. 5).

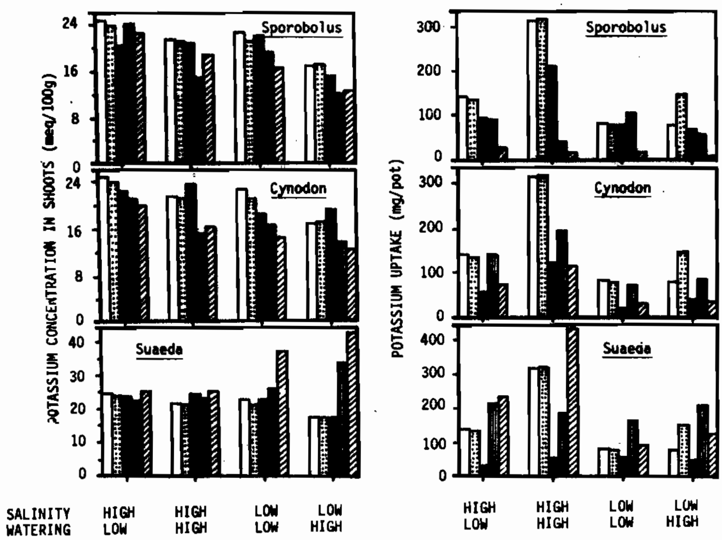

Fig.4. Potassium concentration in shoots and uptake by *Leptochloa fusca* and weed species (*Suaeda, Cynodon, Sporobolus*) grown in mono- and mixed-species cultures (*Leptochloa* mono-culture: 2 plants/pot [], 4 plants/pot ▦; *Leptochloa* mixed-culture ▮; weed species mono-culture ▮; weed species mixed-culture ▨) under differ ent salinity and watering treatments. Values are means of 3 replicates.
L.S.D. (P = 0.05):
For treatment: K conc. = 2.19, K uptake = 15.27; species culture: K conc. = 1.32, K uptake = 25.33; treatment x species culture, K conc. = 6.20, K uptake = 71.64; Overall: K conc. = 4.39, K uptake = 50.66.

Unlike other nutrients, Na concentrations in different species were highly variable depending on species and salinity treatment. All species had higher Na concentrations when grown under high salinity compared to low salinity. Na uptake by Kallar grass in mixed-cultures was significantly decreased by *Cynodon* in all treatments, by *Suaeda* or *Sporobolus* only at high salinity. *Suaeda* removed significantly higher amounts of Na from soil than did any other species under high salinity in particular (Fig.6).

Despite the fact that nutrient concentrations were not affected to a greater extent, variations in species efficiency to use resources in variable environment were very pronouned. In this respect, the weed species proved better in nutrient uptake. They often removed proportionately higher amounts of nutrients in mixed-cultures with Kallar grass relative to their corresponding mono-cultures.

Discussion

The biomass yield responses of different species indicated that Kallar grass is a weak competitor against *S. fruticosa* at high salinity and against *C. dactylon* at low salinity (Fig.1). Changes in soil environment, salinity in particular, may alter the competitive ability of different species. Salinity was the main factor responsible for characteristic distribution of *Festuca pseudovina* and *Puccinellia limosa* in two distinct ecological niches (Oertli & Muller, 1985); the latter species was suppressed due to competition at low salinity whereas it grew well in mixtures with the former at high salinity. Likewise,

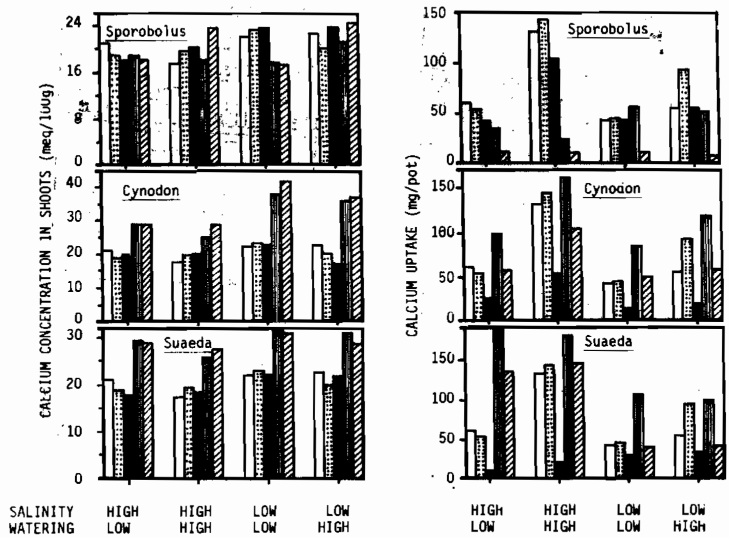

Fig.5. Calcium concentration in shoots and uptake by *Leptochloa fusca* and weed species (*Suaeda, Cynodon, Sporobolus*) grown in mono- and mixed-species cultures (*Leptochloa* mono-culture: 2 plants/pot [], 4 plants/pot ▦; *Leptochloa* mixed-culture ▮; weed spe cies mono-culture ▮; weed species mixed-culture ▨) under different salinity and watering treatments. Values are means of 3 repli cates.

L.S.D (P = 0.05):

For treatment: Ca conc. = 1.32, Ca uptake = 8.90; speices cul ture: Ca conc. = 2.19, Ca uptake = 14.75; treatment x species culture: Ca conc. = 6.20, Ca uptake = 41.73; Overall: Ca conc. = 4.38, Ca uptake = 29.50.

S. fruticosa and *C. dactylon* seem to have adapted to specific niches in relation to salinity which is also reflected in their dominance over Kallar grass in mixed-cultures depending on salinity of their common habitat. In the present studies, soil salinity treatments were not high enough to eliminate Kallar grass because the species is highly tolerant to salinity (Sandhu *et al.*, 1981) and well adapted to severely degraded and highly alkaline soil conditions (Rana & Parkash, 1987).

Although it is very difficult to separate the relative effects of different components of interference (competition and allelopathy), the growth responses of different species in mono- and mixed-cultures suggested competition to be an important component. Competitive displacement is known to play important role in distribution of plant species. Competition between *Heterotheca latifolia* and *Erigeron canadensis* resulted in significant reduction in growth and consequent replacement of the latter under a variety of environmental conditions (Tremmel & Peterson, 1983). Competition for nutrients among plants is a major reason for reduction in yields, especially in soils of low nutrient status (Staniforth, 1957; Cook, 1985). The competitive outcome was clearly manifested in terms of biomass yields, but without significant changes in nutrient concentrations in Kallar grass, an observation similar to that reported for other grasses (Allen, 1982). However, similar concentrations of nutrients do not necessarily indicate a lack of competition for nutrients. In a soil of low fertility, competition for a nutrient could result in reduced growth without changing nutrient concentrations. The uptake and use of

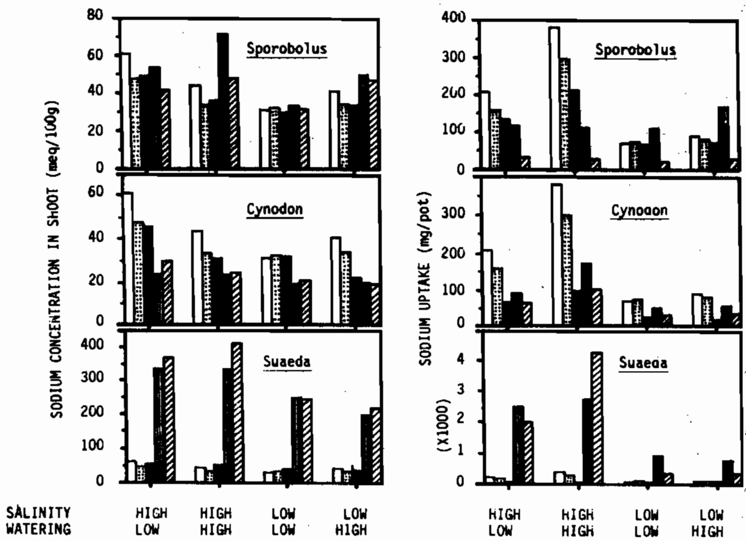

Fig.6. Sodium concentration in shoots and uptake by *Leptochloa fusca* and weed species (*Suaeda, Cynodon, Sporobolus*) grown in mono- and mixed-species cultures (*Leptochloa* mono-culture: 2 plants/pot [], 4 plants/pot ▮; *Leptochloa* mixed-culture ▮; weed species mono-culture ▮; weed species mixed-culture ▮) under different salinity and watering treatments. Values are means of 3 replicates.
L.S.D. (P = 0.05):
For treatment: Na conc. = 6.32, Na uptake = 121.13; speices culture: Na conc. = 10.49, Na uptake = 200.88; treatment x species culture: Na conc. = 29.66, Na uptake = 568.16; Overall: Na conc. = 20.97, Na uptake = 401.75.

nutrients by Kallar grass and competing species was influenced by many different factors. Consequently, the growth of Kallar grass was not suppressed to the same extent by different weed species, and by a particular species under different soil conditions. This suggests that the species differ in their efficiency for nutrient uptake and use under different salinity and water regimes. Hence, the species could exploit the nutrient resources differently under certain conditions even if they were not limiting, and this trend was related to specific niches.

The differences between different weed species and Kallar grass in their efficiency in exploiting soil nutrients under different environmental conditions were clearly shown by their total uptake of nutrients. Uptake of P by different species was relatively higher under high watering than low watering level, particularly at high salinity (Fig.3). Soil moisture is important in aiding plant uptake of limiting as well as relatively immobile nutrients such as P (Thorup, 1969; Jackman & Mouat, 1972). Increase in Na and decrease in K and Ca concentrations due to increasing salinity are well known for many plant species. However, such responses are not consistent for all species. In the present studies, Ca concentrations in *Cynodon dactylon* decreased at high salinity in contrast to all the other species, while K concentrations were not affected. Mahmood & Malik (1987) noted that concentrations of K and Ca in *Atriplex rhagodioides* were not consistently decreased and their uptake was maintained over a range of salinities. It is interesting to note that *S. fruticosa* accumulated high amounts of Na even at low salinity. Halophytes are capable of substantial ion uptake even at low ionic concentrations in the soil suggesting that internal plant factors, rather than soil salt concentrations, control the uptake of ions by halophytes (Osmond *et al.*, 1980).

Apart from soil salinity and watering rates, uptake of N, P, K, Ca and Na by Kallar grass was reduced in the presence of competing species to varying degrees (Figs.2-6). Such decreases in nutrient uptake due to competition are common. Shamsi & Ahmad (1984) reported up to 56% relative-to-control decrease in N, P and K uptake by wheat due to competition from weeds. In the present studies, therefore, it seems plausible to elucidate the outcome of competition in relation to nutrient uptake efficiency of different species under specific niches. In this regard, the weed species proved superior to Kallar grass under certain conditions depending on soil salinity in particular. *S. fruticosa* is well adapted to highly saline conditions (Rutter & Sheikh, 1962; Sheikh & Mahmood, 1986) and *C. dactylon* to low salinity (Malik *et al.*, 1984; Rana & Parkash, 1987). These species strongly compete with Kallar grass that may lead to exclusion of the grass from patches dominated by invader species in field conditions (Mahmood *et al.*, 1989). On the other hand, *Sporobolus arabicus*, although not a strong competitor, was able to persist and interfere with Kallar grass growth. From the foregoing, it is evident that the weed species invade and establish in patches more hospitable for them and replace Kallar grass gradually. In the present studies, competition has been identified as an important factor influencing distribution of species in patches. Previously, Wilson & Keddy (1985) have pointed out the significance of biological interactions to plant distribution in addition to physical environment. Another possible mechanism of interference against Kallar grass by invader species could be their allelopathic effects, which need investigation.

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