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COMPETITIVE SUPERIORITY OF *KOCHIA INDICA* OVER *LEPTOCHLOA FUSCA* (KALLAR GRASS) UNDER VARYING LEVELS OF SOIL MOISTURE AND SALINITY

KHALID MAHMOOD

Nuclear Institute for Agriculture and Biology (NIAB), P.O.Box 128, Faisalabad, Pakistan.

Abstract

Kallar grass [*Leptochloa fusca* (L.) Kunth] and *Kochia indica* Wight were grown in mono-cultures and mixed-cultures under different soil salinity and water conditions. *K. indica* suppressed growth of kallar grass in all salinity and watering treatments; the reduction in biomass yield of the latter species was more pronounced in low watering treatment at both salinity levels. In contrast, *K. indica* gave increased yield when intercropped with kallar grass as compared to that in mono-cultures suggesting its competitive superiority. Nutrient (N,P,K, Ca and Na) concentrations in shoots of a species grown in mono- and mixed-cultures under a particular treatment were similar. However, the total uptake of nutrients differed significantly and *K. indica* removed proportionately higher amounts of nutrients when grown in mixed-cultures compared to corresponding mono-cultures. The significance of competition by *K. indica* is discussed with regard to its invasion and spread in kallar grass stands.

Introduction

Kallar grass [*Leptochloa fusca* (L.) Kunth] has been recommended and extensively used as a primary colonizer for revegetation of saline lands (Sandhu & Malik, 1975; Malik *et al.*, 1986). Kallar grass is highly tolerant to salinity (Sandhu *et al.*, 1981) and sodicity (Aslam *et al.*, 1979); it grows well on saline-sodic and waterlogged soils without any fertilizer even when irrigated with brackish underground water (Malik *et al.*, 1986). However, the species fails to maintain its vigour despite the fact that soil properties get improved in the process. Our field studies (Mahmood *et al.*, 1989, 1994) revealed that many species, including *Kochia indica* Wight, spread in dense patches in kallar grass stands eliminating the latter. The failure of kallar grass to persist in patch-associated species could not be attributed to the soil factors that were comparable in patches and surrounding kallar grass soils, thus indicating the presence of some interference mechanism (Mahmood *et al.*, 1989). Competition for necessary growth factors and addition of toxic substances to the environment (allelopathy) can play a major role in plant growth and species distribution (Szczepanski, 1977; Rice, 1984). Systematic studies were conducted to ascertain the significance of plant interactions in species invasion and decline of kallar grass productivity in the field after few years of its growth. This paper reports competitive interference by *Kochia indica* against kallar grass.

Materials and Methods

Plant growth: Kallar grass and *Kochia indica* were grown in mono- and mixed-cultures in glazed pots, 26 cm in diam. and 28 cm deep. Two salinity levels and two watering regimes were combined in a factorial manner giving 4 treatment combinations (low salinity-low watering; low salinity-high watering; high salinity-low watering; and high salinity-high watering). The soils used 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 conductivity (E.C.) of soil extract = 6.1±0.18 dS/m and high (E.C. = 16.1±0.12 dS/m). whereas for watering regimes the pots were irrigated with tap water 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. The plants of *K. indica* were grown from seed and those of kallar grass from stubbles (root-stocks) and transplanted in the pots. The plants were allowed to establish after transplanting for two weeks and then watering treatments were imposed. Each pot contained one species or two species in 1:1 proportion with overall density of 4 individual plants per pot. In addition, kallar grass with density of 2 plants per pot was included to determine the effects of plant density *per se*. Each treatment was replicated three times and the pots were arranged randomly. The plants were grown in the open in a net house and protected from rain. After 12 weeks' growth, the 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 followed was based upon that described by Fowler (1982) and del Moral *et al.* (1985), and used in our earlier studies (Mahmood *et al.*, 1993). 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:

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

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 (Fowler, 1982). If the growth of an individual is not affected by the presence 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 *Kochia* was dried at 70 °C to constant weight, ground (< 1mm) and analysed for concentrations of different nutrients following wet digestion. Three replicate determinations were made for each treatment.

Table 1. Analysis of soils used in the experiment for studying competition between kallar grass and *Kochia indica* (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	30.6±1.13
E C (dS/m)	6.12±0.18	16.1±0.12
pH	8.51±0.14	8.77±0.06
Exchangeable Sodium Percentage (ESP)	33.4±1.02	60.5±4.12
Total nitrogen (%)	0.04	0.05
Mineral nitrogen (mg/kg)	16.8±0.81	15.7±2.17
Olsen P* (mg/kg)	9.57±0.40	20.3±0.83

*Available P extractable with 0.5 *N* $NaHCO_3$

Nitrogen was determined by Micro-Kjeldahl method. K, Na and Ca were determined by flame photometry, and phosphorus was determined spectrophotometrically. From yield data and concentrations of different nutrients in plant shoots, amount of the nutrients taken up by *K. indica* and kallar grass was calculated for different treatments.

Statistical analysis: 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 the highest biomass yield in high salinity/high watering treatment. Increase in plant density generally resulted in reduced dry weight per plant. However, the overall yield per pot was not affected for different salinity and watering treatments. Further, irrespective of salinity treatment, high watering had favourable effect on the growth of kallar grass (Fig. 1).

In mixed-cultures, *Kochia indica* suppressed growth of kallar grass in all salinity and watering treatments. However, the reduction in yield of kallar grass in the presence of *K. indica* was more pronounced in low watering treatment at both salinity levels. On the other hand, *K. indica* gave increased yield when intercropped with kallar grass as compared to that in mono-cultures. The relative yield values of 0.32 to 0.77 for kallar grass clearly indicate that the species is a weak competitor against *K. indica* which had relative yield values more than 1 in all treatments (Fig. 1). However, the intensity of competition varied with soil salinity and water regimes.

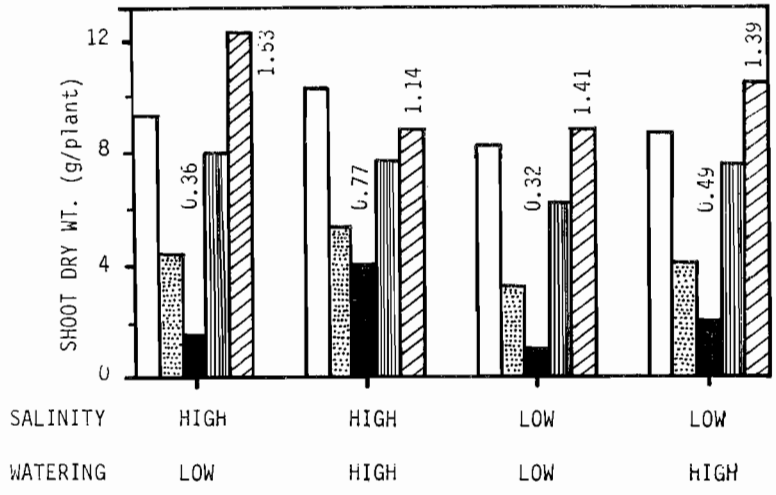

Fig.1. Shoot dry weights of *Leptochloa fusca* and *Kochia indica* grown in mono- and mixed- species cultures (*Leptochloa* mono-culture: 2 plants/pot [], 4 plants/pot [:]; *Leptochloa* mixed-culture ▮; *Kochia indica* mono-culture [|]; *Kochia* mixed-culture, ▨) under different salinity and watering regimes. Figures on the bars are relative yield. Values are means of 3 replicates, each represented by average of 4 plants.
L.S.D. ($P = 0.05$):
For species cultures = 1.15; treatments = 1.03; treatment x species culture = not significant; overall = 3.08.

Nutrient uptake: Kallar grass and *Kochia indica* showed wide variations in their ability to extract and use soil nutrients under different soil conditions. In general, at a particular salinity and watering treatment, nutrient concentrations in shoots of a species grown in mono- and mixed-cultures were similar. However, total uptake of nutrients (N, P, K, Ca and Na) by both species differed significantly depending on species culture and salinity/watering treatments. The concentrations of N and P in kallar grass grown in mono- and mixed-cultures were relatively higher in high salinity. When growing in competition with *K. indica*, kallar grass had higher N concentration in low watering than in high watering. However, N concentration in kallar grass did not change significantly due to competition from *K. indica*, except at low salinity/low watering. Similarly, P concentration in kallar grass was not affected in the presence of *K. indica* (Fig. 2). *K. indica* shoots had relatively higher N concentration when grown at high salinity, and watering rate or presence of kallar grass had little effect on it. The concentrations of P in *Kochia* in mono- and mixed-cultures were similar under a given treatment (Fig. 2).

Although N and P concentrations in plants were almost similar, total uptake of these nutrients by the two species was markedly different. The presence of *K. indica* caused significant reduction in N and P uptake by kallar grass under all salinity and watering treatments. On the other hand, N and P uptake by *K. indica* was markedly lower in mixed-cultures with kallar grass compared to its respective mono-cultures. However, considering the uptake by individual plants, large proportions of N and P

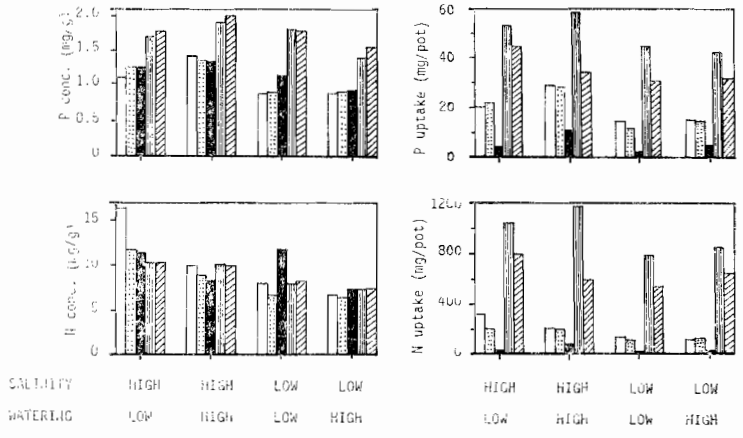

Fig. 2. Nitrogen and phosphorus concentrations in shoots and uptake by *Leptochloa fusca* and *Kochia indica* grown in mono- and mixed-species cultures (*Leptochloa* mono- culture: 2 plants/pot [], 4 plants/pot [▒]; *Leptochloa* mixed-culture ▒; *Kochia indica* mono-culture []; *Kochia* mixed-culture, ▨) under different salinity and watering regimes. Values are means of 3 replicates.

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

For species cultures: N conc. = 1.13; N uptake = 77.6

P conc. = 0.12; P uptake = 4.25

treatments: N conc. = 1.01; N uptake = 69.4

P conc. = 0.11; P uptake = 3.80

Treatment x species: N conc. = 3.20; N uptake = 219 culture

P conc. = n.s.; P uptake = n.s.

Overall: N conc. = 2.26; N uptake = 155

P conc. = 0.24; P uptake = 8.50

uptake were at the part of *Kochia indica* rather than kallar grass (Fig. 2).

The concentrations of K, Ca and Na in kallar grass shoots were not affected either by the presence of *K. indica* or by salinity and watering levels. In contract, *K. indica* had slightly higher K concentrations when grown in the presence of kallar grass in all treatments while Ca and Na concentrations were little affected except for high salinity/high watering where these were low in mixed-cultures (Fig. 3).

The total uptake of K, Ca and Na by kallar grass decreased significantly due to competition from *K. indica* in all salinity/watering treatments. *Kochia* removed significantly higher amounts of K, Ca and Na when grown in mixed-cultures with kallar grass under different treatments with the only exception that K and Ca uptake by the latter species was higher when grown in mono-cultures than mixed-culture under low salinity/high watering treatment (Fig. 3). Despite the fact that nutrient concentrations were not affected to a great extent, species' efficiency to use resources differed markedly. In this respect, *K. indica* proved better because it often removed proportionately higher amounts of nutrients in mixed-cultures relative to the corresponding mono-cultures.

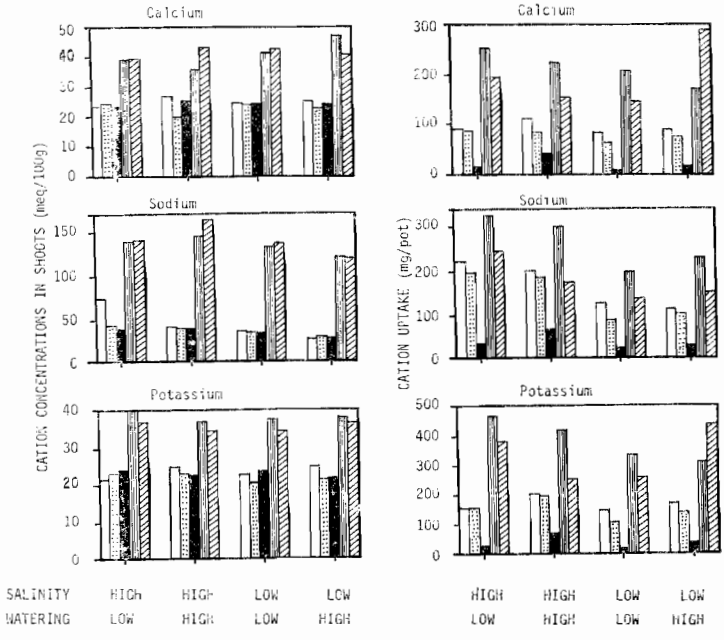

Fig. 3. Cation (K, Na and Ca) concentrations in shoots and uptake by *Leptochloa fusca* and *Kochia indica* grown in mono- and mixed-species cultures (*Leptochloa* mono-culture: 2 plants/pot [], 4 plants/pot [▒]; *Leptochloa* mixed-culture ▒; *Kochia indica* mono-culture [▒]; *Kochia* mixed-culture, [▒]) under different salinity and watering regimes. Values are means of 3 replicates.

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

For species cultures: K conc. = 2.03; K uptake = 97.9
Na conc. = 6.17; Na uptake = 22.8
Ca conc. = 3.06; Ca uptake = 21.6

treatments: K conc. = n.s.; K uptake = 30.9
Na conc. = 5.52; Na uptake = 30.9
Ca conc. = n.s.; Ca uptake = 19.3

Treatment x species: K conc. = n.s.; K uptake = 97.9
culture Na conc. = 17.4; Na uptake = 64.5
Ca conc. = n.s.; Ca uptake = n.s.

Overall: K conc. = 4.07; K uptake = 69.2
Na conc. = 12.3; Na uptake = 45.6
Ca conc. = 6.11; Ca uptake = 43.2

Discussion

In addition to soil factors and inherited preferences of a species to particular habitat conditions, biological interactions among plants are also important in their distribution and coexistence in a common environment (Wilson & Keddy, 1985). Earlier field survey studies (Mahmood *et al.*, 1989) showed that soil properties in *Kochia indica* patches and surrounding kallar grass were comparable. Thus, the elimination of kallar grass from *K. indica* patches could not be attributed to soil factors, indicating possibility of some interference mechanism. The results regarding biomass (Fig. 1) indicated that kallar grass is a weak competitor against *K. indica*; the intensity of competition varied with soil salinity and moisture level.

Changes in soil environment are known to alter competitive ability of different species (Tremmel & Peterson, 1983; Oertli & Muller, 1985). The intensity of competition against kallar grass from species differing in relative salt tolerance is known to vary with soil salinity level; species having higher tolerance are superior competitor at high salinity and those lower in tolerance at low salinity regimes (Mahmood *et al.*, 1993). Commonly, a species growing within or close to the optimum of its ecological amplitude is presumably more successful with regard to biological interactions with its neighbours. *K. indica* suppressed kallar grass both at low and high salinity levels with low watering. *Kochia* is well adapted to arid regions while kallar grass prefers low-lying places prone to water stagnation (Rana & Parkash, 1987), and is relatively more salt tolerant than kallar grass (Mahmood *et al.*, 1996). Kallar grass performed better in mixed-cultures with *K. indica* under high salinity/high watering condition. Watering treatment might have influenced the competitive ability of the former species directly, or indirectly by modifying salinity stress.

Competition for nutrients among plants is a major reason for reduction in yield especially in soils of low nutrient status (Staniforth, 1957; Cook, 1985). Although the competitive outcome was clearly manifested in terms of biomass yields, competition did not cause significant changes in nutrient concentrations in kallar grass. Similar observations have been reported for other species (Allen, 1982; Ellis *et al.*, 1985), and also for kallar grass when grown in the presence of *Suaeda fruticosa, Sporobolus arabicus* and *Cynodon dactylon* (Mahmood *et al.*, 1993). On the contrary, N, P and K concentrations in plants changed in the presence of a competitor (Hall, 1974; Kolar *et al.*, 1976). However, similar concentrations of nutrients do not necessarily indicate a lack of competition for nutrients (Allen, 1982), thus competition for a nutrient could result in reduced growth without changing nutrient concentrations. The efficiency of *K. indica* and kallar grass to exploit soil nutrients was clearly manifested in terms of their total uptake of nutrients (Figs. 2 & 3), the former proved superior in this regard.

K. indica is a superior competitor compared to kallar grass under varied soil conditions. Therefore, competition seems an important factor involved in its invasion and spread in kallar grass stands observed in the field (Mahmood *et al.*, 1989). However, competition is not the only reason and thus other possible mechanisms also need to be investigated.

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