Pak.J.Bot., 31(1): 137-149, 1999.

ALLELOPATHIC POTENTIAL OF WEED SPECIES INVADING KALLAR GRASS (*LEPTOCHLOA FUSCA* (L.) KUNTH) IN SALINE AGRICULTURAL LAND

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Abstract

Cynodon dactylon (L.) Pers., *Desmostachya bipinnata* (L.) Stapf, *Kochia indica* Wight, *Polypogon monspeliensis* (L.) Desf., *Sporobolus arabicus* Boiss., and *Suaeda fruticosa* (L.) Forssk. established in well-defined patches in saline fields planted with Kallar grass (*Leptochloa fusca* (L.) Kunth). Water extracts, shoot material of different species decomposing in soil and leachates from soils amended with shoot materials inhibited seed germination and/or growth of Kallar grass to varying degrees. Each species showed allelopathic potential against Kallar grass in one or more tests. Six allelochemicals viz., benzoic, ferulic, caffeic, p-OH-benzoic, vanillic and syringic acids were identified in water and/or hydrolysis extracts of different species. Four of these compounds (present in all species) inhibited seed germination and seedling growth of Kallar grass. Allelopathic influence of invading species and autotoxicity are important factors causing elimination of Kallar grass from weed patches and its decreased productivity in older stands.

Introduction

Kallar grass (*Leptochloa fusca* (L.) Kunth) is extensively grown for utilization and improvement of saline wastelands in Pakistan. The grass is highly tolerant to soil salinity, sodicity, pH and waterlogging, and grows luxuriantly in saline soils without any fertilizer application yielding up to 40 tons biomass per hectare per year (Malik *et al.*, 1986). However, after growing for a few years, Kallar grass fails to maintain vigour in the field and its growth is markedly reduced despite improvement of soil conditions (Mahmood *et al.*, 1989; 1994). As a result of soil improvement, many weed species were observed to invade and spread naturally in Kallar grass stands. These invader species appeared in dense patches with clear boundaries and Kallar grass failed to persist in the weed patches. Since the soil properties in the weed patches and surrounding Kallar grass were similar, the elimination of the grass from patches was not attributable to soil factors.

Biological interactions among plants are also important in species existence, and their possible mechanisms are competition for necessary growth factors, allelopathy and possession of toxicants that prevent grazing (Szczepanski, 1977). Allelopathy and autotoxicity play an important role in vegetation composition and patterning as well as in invasion and replacement of susceptible species (Muller, 1966; Rice, 1984).

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Earlier studies (Mahmood *et al.*, 1989) showed that elimination from weed patches and decreased productivity of Kallar grass were not attributable merely to soil conditions which suggested the presence of some interference mechanism. Studies were, therefore, conducted to ascertain the role of plant interference: competition and allelopathy in species invasion and decline of Kallar grass productivity. The present paper describes the allelopathic effects of invading weed species against Kallar grass.

Materials and Methods

Plant materials and soil used in the experiments were collected from fields at Biosaline Research Station near Lahore, Pakistan. Aerial parts of 6 weed species viz., *Cynodon dactylon, Desmostachya bipinnata, Kochia indica, Polypogon monspeliensis, Sporobolus arabicus, Suaeda fruticosa* and Kallar grass were collected separately from vigorously growing plants, air dried, ground and passed through 1mm sieve before use.

Effect of aqueous extracts: Aqueous extracts were prepared by immersing 10 g air dried shoot material of each species in 100 ml distilled water at 40°C for 1 h followed by homogenizing and removing particulate material by filtration/centrifugation. The volume of the filtrate was made to 100 ml with water. Experimental dilutions of 2.5% and 5% (w/v, shoot/water) were made and pH was adjusted to approximately 6.5 using NaOH or HCl.

Twenty seeds of Kallar grass were sown in Petri dishes containing sand saturated with 20 ml each of distilled water (control), 2.5% or 5% extracts of the different species with 4 replicate dishes per treatment. Germination percentage (plumule emergence) of seeds was recorded at 30±1°C (in light/dark, 14/10 h) over a period of 10 days.

To determine the effects on seedling growth, the extract (5% w/v) was prepared using 0.5 strength Hoagland nutrient solution. Kallar grass seeds were germinated in sand in plastic pots. After 4 weeks, the seedlings were thinned to 4 per pot and cut at uniform height. Extracts of different species were added to the pots, 4 per treatment and 0.5 strength Hoagland solution to the pots for control. Subsequently, the pots were watered with extracts or Hoagland solution alternated with water every week. As the pots were closed, amounts just enough to saturate the sand were added to avoid anaerobic conditions in root zone. Seedlings were allowed to grow for additional five weeks at 25 °C and 14 h photoperiod with 40 K lux light intensity and harvested. Shoot and root portions were separated, dried at 70 °C and weighed.

Effect of decomposing plant material: The soil collected from the field was crushed, passed through a sieve and thoroughly mixed with sand in the ratio 2:1 (soil: sand). Shoot material of each of the weed species and Kallar grass was mixed in soil @ 1% and 2%, and allowed to decompose at room temperature for 2 and 6 weeks. During this period the soil was kept moist at field capacity and thoroughly mixed twice a week. Available soil nitrogen (KCl extractable) and phosphorus ($NaHCO_3$ extractable) were determined by steam distillation and spectrophotometer methods, respectively. Fifty g portions of these soils were taken in Petri dishes, saturated with water and 20 seeds of Kallar grass were sown in each dish, 4 dishes per treatment. The seeds were allowed to germinate at 30±1°C.

In plant growth experiments, pots lined with polyethylene were filled with 750 g of soils having 1% and 2% of shoot material of different species, decomposed for 2 and 6 weeks. Control soil was supplemented with 1% and 2% farm manure (garden compost consisting of mainly decomposed leaf litter) to adjust carbon. Three stem cuttings of similar size (ca. 5 cm), having only one basal node, of Kallar grass were planted in each pot, 4 pots for each treatment. Roots and shoots initiating from the node develop into young plant; the original stem cutting dries out and is, therefore, not included in growth estimates. Plants were grown in the open in a net house and were irrigated as needed. The plants were harvested after 8 weeks and dry weights of roots and shoots were recorded.

In a similar additional experiment, 2% shoot material of each of 7 plant species was added in sand and allowed to decompose for 2 weeks. Three stem cuttings of Kallar grass were planted in each of 4 replicate pots for each treatment. Thereafter, test and control pots were irrigated with 0.5 strength Hoagland solution alternated with water to maintain nutrient supply. Root and shoot dry weights were recorded after 6 weeks.

Effect of soil leachates on plant growth: Shoot material of different plant species was added to soil @ 2% and allowed to decompose for 8 weeks. Leachate was collected by flooding the soil with equal amount of 0.5 strength Hoagland nutrient solution. Soil was stirred, allowed to stand and leachate was decanted. Subsequent leaching was repeated in the same manner for the same soils. The leachate was stored in dark polyethylene containers at 5 °C. Seeds of Kallar grass were germinated in sand, thinned to 4 seedlings per pot and watered with leachates; control pots received 0.5 strength Hoagland solution. The plants were grown for 5 weeks at 25 °C and 14 h photoperiod under 40 K lux light intensity and harvested.

Isolation and identification of phytotoxins: Phenolic acids from Kallar grass and 6 invading species were separately extracted by soaking in hot water (50°C) for 1 h and by hydrolysis with 2*N* NaOH (Lodhi, 1975). The individual phenolic compounds in water and hydrolysis extracts of each species were identified with the authentic chemicals by co-chromatography following Kuwatsuka & Shindo (1973) on a Hitachi 163 Gas Chromatograph equipped with a flame ionization detector and stainless steel column (1m x 3mm inner diam.), packed with chromosorb W (60-80 mesh) coated with 1.5% silicon SE 30. Nitrogen was used as carrier gas at the flow rate 30 ml/min. The temperatures of injector and detector were 280 and 300°C, respectively. The column temperature was programmed from 100 to 250°C at 5°C/min. The unknown compounds in the samples were identified by comparing their relative retention time with that of known standard compounds.

Biological activity of phytotoxins: The phytotoxic activity of four allelochemicals viz., caffeic, p-OH-benzoic, ferulic, and benzoic acids (present in all weed species) against Kallar grass was investigated. Each compound was separately added to Hoagland nutrient solution at a concentration of $1x10^{-4}$ M. Twenty seeds of Kallar grass were sown on filter paper moistened with 5ml of respective solution in Petri plates in 5 replicates and seed germination was noted over a two-week period. For effects on seedling growth, Kallar grass seeds were sown in 100 ml glass beakers filled with sand which

was soaked with 0.5 strength Hoagland solution. Following germination, 5 seedlings of similar size were left per beaker after thinning and the appropriate treatment solutions (25ml) were added to the beakers, five per treatment. Thereafter, the seedlings were supplied with distilled water and treatment solutions alternately as needed. The seedlings were grown for 4 weeks in growth chamber as described earlier and harvested.

Results

Effect of water extracts: Germination of Kallar grass seeds was inhibited to varying degrees depending on weed species and concentration of extract used (Table 1). Water extracts of *Suaeda fruticosa* and *Kochia indica* were highly inhibitory whereas *Cynodon dactylon* extract did not affect seed germination of Kallar grass. *Polypogon monspeliensis* and *Sporobolus arabicus* extracts reduced germination percentage of Kallar grass seeds at low concentration, while 5% extract of Kallar grass itself also reduced its seed germination. *Desmostachya bipinnata* had no significant effect on seed germination of Kallar grass (Table 1).

The growth of Kallar grass roots was significantly lower in extracts of Kallar grass and all weed species except *Cynodon dactylon* as compared with that in control (Table 1). Extracts of *Suaeda fruticosa* and *Kochia indica* were strongly inhibitory to Kallar grass followed by those of *Polypogon monspeliensis, Desmostachya bipinnata, Sporobolus arabicus*, and Kallar grass itself. Kallar grass shoot growth was inhibited to varying extent by extracts of almost all species tested. Dry weights of shoots of Kallar

Table 1. Effect of water extracts of different plant species on seed germination and growth of Kallar grass. Values are means of 4 replicates, each represented by an average of 4 plants. The values for germination are average of 4 replicates each with 20 seeds.

Treatment/ species	Germination (%)		Dry weight (mg/plant)		
	2.5* %	5* %	Root	Shoot	Root+Shoot
Control	46c**	46de	19.35d	57.55c	76.90d
Kallar grass	41bc	21ab	12.80bc	49.98bc	62.78bcd
Cynodon	46c	52e	16.73cd	53.93bc	70.66cd
Desmostachya	40bc	36cd	10.30b	41.55bc	51.85b
Kochia	35abc	25bc	3.25a	6.93a	10.18a
Polypogon	31ab	45de	9.90b	38.43b	48.33b
Sporobolus	28ab	40de	11.13a	46.45bc	37.58bc
Suaeda	21a	8a	2.40a	8.03b	10.43a

*Seed germination was tested at two extract concentrations.

**Means followed by same letters in a column are not significantly different at $P = 0.05$ according to Duncan's multiple range test.

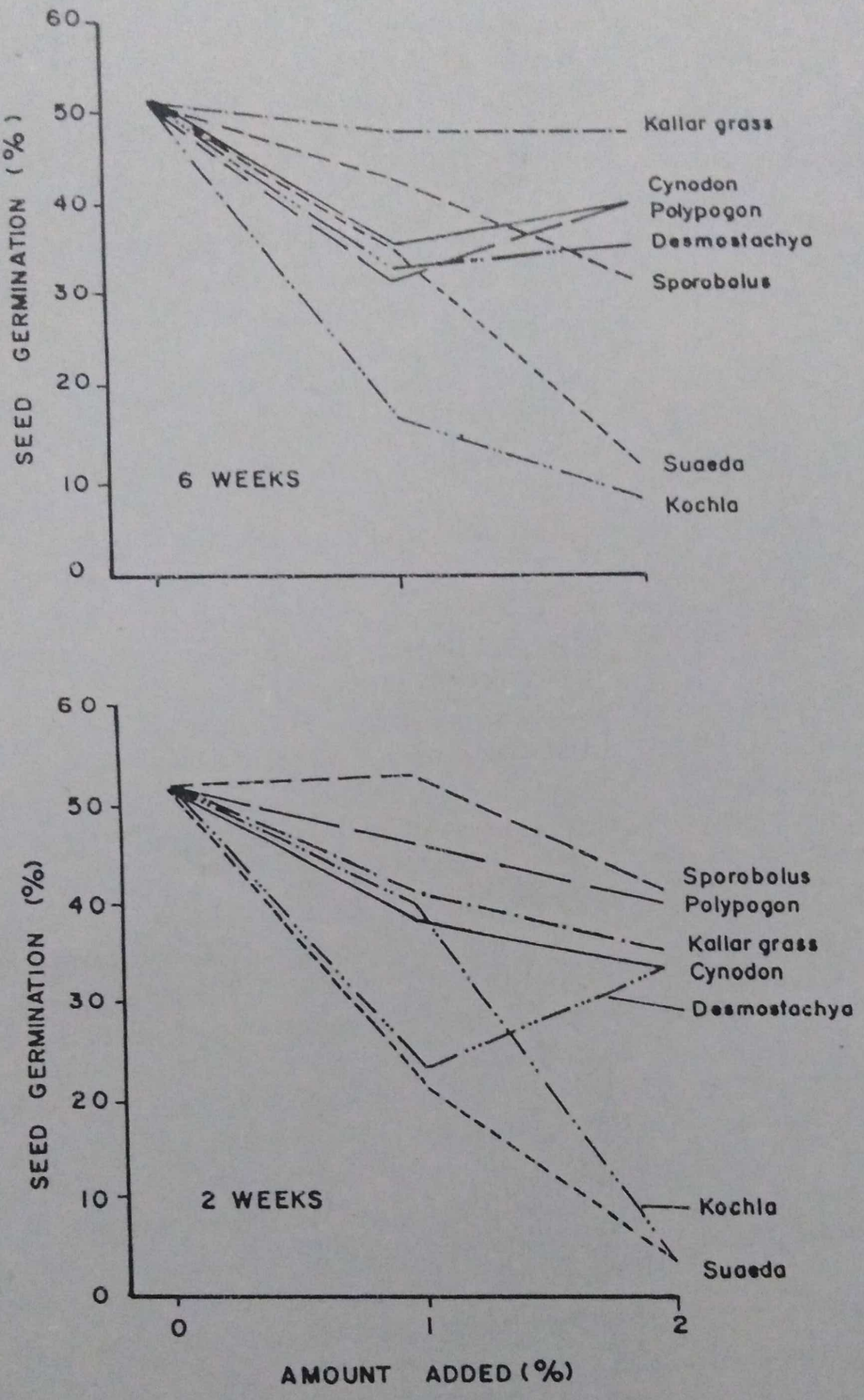

Fig. 1. Effect of addition of shoot material of different species in soil on seed germination of Kallar grass. Values shown are the means of four replicates each having 20 seeds. For comparison of values L.S.D. (P = 0.05) = 15.6.

grass grown in extracts of *Suaeda fruticosa, Kochia indica* and *Polypogon monspeliensis* were significantly lower than in control. Similarly, whole plant dry weight of Kallar grass grown in control was significantly higher than that of the plants grown in extracts of weed species except *Cynodon dactylon* and Kallar grass itself (Table 1).

Effect of addition of shoot material in soil: The effects of decomposing material in soil on seed germination of Kallar grass differed greatly with species, amount of material added and time allowed for decomposition (Fig. 1). After decomposition for 2 weeks, all species inhibited Kallar grass seed germination, *Kochia indica* and *Suaeda fruticosa* being highly toxic while *Sporobolus arabicus* was least inhibitory. In soil having 1% *Desmostachya bipinnata*, germination percentage of Kallar grass seeds was markedly low and it slightly increased in soil with 2% addition of shoot material of *Desmostachya bipinnata*. Seed germination was inhibited in soils having shoot material of all species, except Kallar grass, when it was allowed to decompose for 6 weeks. *Kochia indica* and *Suaeda fruticosa* were highly inhibitory and their toxicity increased with increasing amount of material added, while for other species 1% or 2% addition of material reduced seed germination of Kallar grass to almost same extent. On the whole, inhibitory effects increased with increasing amount of material added and decreased with the time allowed for decomposition (Fig. 1).

The growth of Kallar grass was affected differently depending on type and amount of material added in soil and time given for its decomposition (Table 2). Addition of Kallar grass itself, *Desmostachya bipinnata, Polypogon monspeliensis* and *Cynodon dactylon* inhibited the growth of Kallar grass shoots. In contrast, addition of 1% *Sporobolus arabicus, Kochia indica* and *Suaeda fruticosa* showed stimulation in growth which decreased when 1% material was allowed to decompose for 6 weeks. Further, shoot growth of Kallar grass in soils having 2% *Sporobolus arabicus, Kochia indica* and *Suaeda fruticosa*, decomposed for 6 weeks, was lower than that in control. Addition of farm manure also slightly reduced shoot growth of Kallar grass (Table 2).

Root growth of Kallar grass was reduced in soil having 1% or 2% plant material of a species decomposed for 2 or 6 weeks, except that 1% *Sporobolus arabicus* had little effect. It may be noted that the amount of material added, and time for decomposition also had significantly different effects on Kallar grass shoot or root growth (Table 2).

The amounts of available nitrogen and phosphorus in soil (Fig. 2) had little effect on the growth of both root and shoot of Kallar grass. Significant correlation ($r = 0.607$, $p = 0.05$) between available nitrogen and shoot dry weight was observed. Nevertheless, in many of the individual treatments, shoot dry weight was higher (Table 2) despite the fact that available nitrogen in respective soil was lower (Fig. 2).

Effect of addition of plant material in sand: When Kallar grass was grown in sand having 2% shoot material of different species and watered with 0.5 strength Hoagland solution, growth of Kallar grass was significantly reduced (Table 3). Root dry weights of Kallar grass plants grown in sand amended with 2% material of either species were significantly lower than that in control, while shoot dry weights were also lower except in *Sporobolus arabicus* and *Polypogon monspeliensis* amendments. The whole Kallar grass plant growth also showed similar trend and was significantly inhibited by all species tested excluding *Sporobolus arabicus* and *Polypogon monspeliensis* (Table 3).

Table 2. Effect of addition of shoot material of different plant species in soil on growth of Kallar grass. Values are means of 4 replicates, each average of four plants.

Species	Material added (%)	Decomposing time 2 weeks	6 weeks	Mean
		Shoot Dry weight (mg/plant)		
Nil (Control)		0.76	0.76	0.76
Farm manure	1	0.54	0.54	0.54
	2	0.61	0.61	0.61
Kallar grass	1	0.19	0.17	0.18
	2	0.22	0.13	0.17
Cynodon	1	0.64	0.39	0.51
	2	0.93	0.30	0.61
Desmostachya	1	0.41	0.15	0.28
	2	0.47	0.26	0.36
Kochia	1	1.54	1.01	1.27
	2	1.10	0.54	0.82
Polypogon	1	0.15	0.27	0.21
	2	0.19	0.25	0.22
Sporobolus	1	0.86	0.89	0.87
	2	0.98	0.57	0.77
Suaeda	1	1.28	0.94	1.11
	2	0.59	0.59	0.59
Mean		0.674	0.492	
LSD ($P = 0.05$)		Decomposing time = 0.05	Material = 0.16	
			Overall = 0.22	
		Root dry weight (mg/plant)		
Nil (Control)		0.52	0.52	0.52
Farm manure	1	0.30	0.30	0.30
	2	0.32	0.32	0.32
Kallar grass	1	0.15	0.12	0.13
	2	0.17	0.12	0.14
Cynodon	1	0.46	0.27	0.36
	2	0.55	0.26	0.40
Desmostachya	1	0.34	0.13	0.23
	2	0.33	0.23	0.28
Kochia	1	0.42	0.49	0.45
	2	0.48	0.25	0.36
Polypogon	1	0.16	0.15	0.15
	2	0.13	0.15	0.14
Sporobolus	1	0.59	0.56	0.58
	2	0.49	0.40	0.44
Suaeda	1	0.50	0.38	0.44
	2	0.25	0.25	0.25
Mean		0.362	0.288	
LSD ($P = 0.05$)		Decomposing time = 0.03		Material = 0.08
			Overall = 0.12	

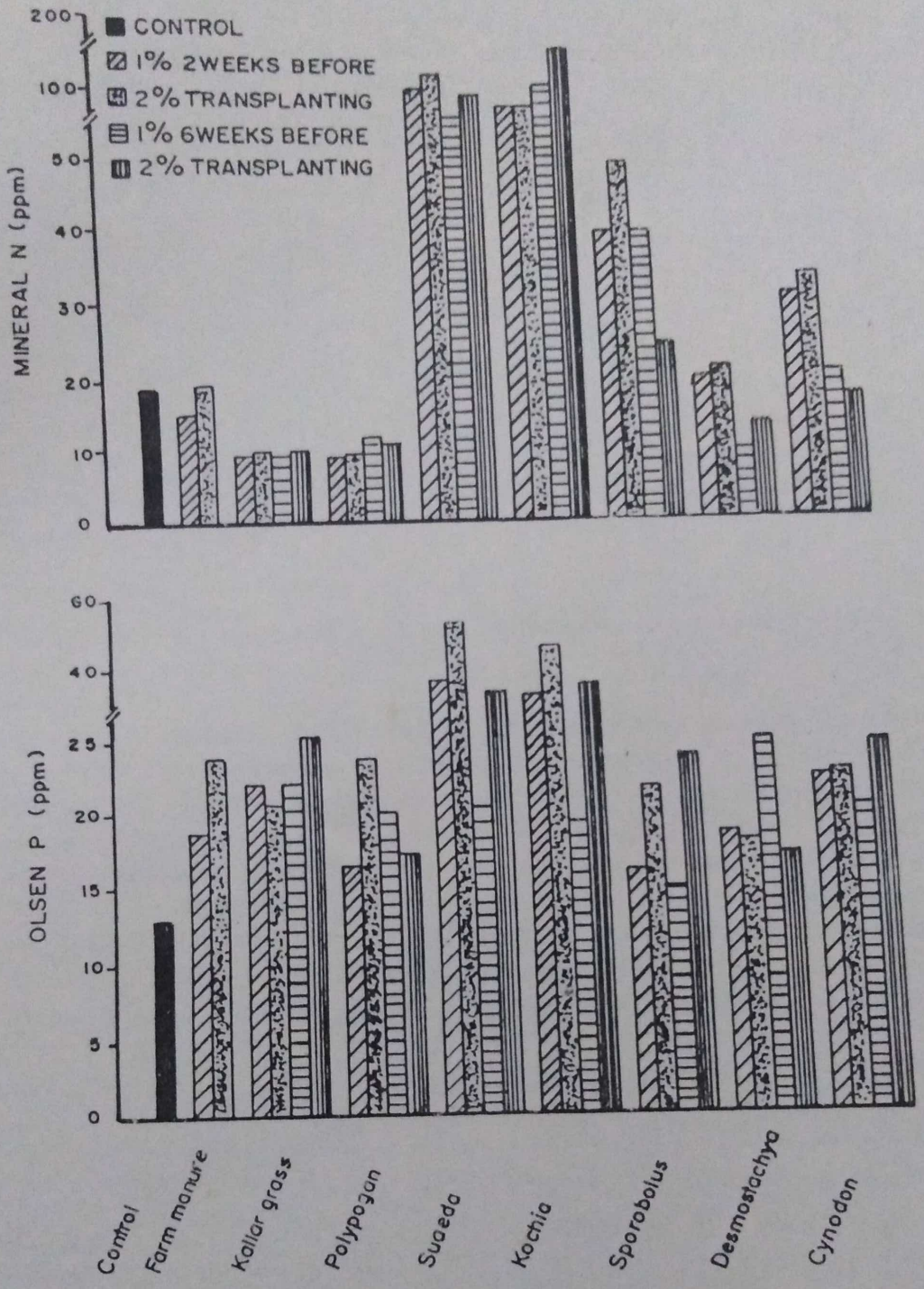

Fig.2. Status of available nitrogen and phosphorus in soils at the time of Kallar grass planting. The determinations were done after allowing 1 or 2% shoot material of each species separately to decompose in soil for 2 or 6 weeks at room temperature. Values are means of three replicates. Coefficients of correlation between available N and P in soil and biomass yield of Kallar grass (Table 2):

Root dry weight vs. P = 0.078 n.s.

Root dry weight vs. N = 0.253 n.s.

Shoot dry weight vs. P = 0.295 n.s.

Shoot dry weight vs. N = 0.607*

n.s. = not significant

* significant at $P = 0.05$

Table 3. Effect of shoot material (2%) of different plant species decomposing in sand on growth of Kallar grass irrigated with 0.5 strength Hoagland solution. Values are means of 4 replicates, each represented by average of 3 plants.

Material Added	Dry weight (mg/plant) Root	Shoot	Root + Shoot
Control	77.93c*	549.7b	627.6b
Farm manure	69.95c	586.0b	655.9b
Kallar grass	39.80a	292.7a	332.0a
Cynodon	37.03a	355.0a	392.0a
Desmostachya	37.93a	332.7a	370.6a
Kochia	35.10a	249.2a	284.3a
Polypogon	54.70a	494.7b	549.4b
Sporobolus	55.70b	552.0b	607.7b
Suaeda	27.80a	264.0a	291.8a

*Means followed by the same letters in a column are not significantly different at $P = 0.05$ according to Duncan's multiple range test.

Effect of soil leachates: Leachates collected from soils having decomposing shoot material of different species were invariably inhibitory to growth of Kallar grass seedlings (Table 4). Dry weights of roots, shoots, and whole plants of Kallar grass grown in soil leachates of all weed species were significantly lower than those of plants grown in leachate collected from control soil. Leachate from soil having Kallar grass

Table 4. Effect of leachates collected from decomposing shoot material of different species in soil on Kallar grass growth. Values are means of 4 replicates, each represented by average of 4 plants.

Material Added	Dry weight (mg/plant) Root	Shoot	Root + Shoot
Control	17.48c*	48.25c	65.73d
Kallar grass	8.10c	27.43b	35.53c
Cynodon	3.78ab	13.75a	17.53ab
Desmostachya	4.70ab	15.35a	20.05ab
Kochia	3.50b	17.85a	21.35b
Polypogon	5.33b	17.75a	23.08ab
Sporobolus	5.33b	17.75a	23.08a
Suaeda	3.18a	10.20a	13.38a

*Means followed by the same letters in a column are not significantly different at $P = 0.05$ according to Duncan's multiple range test.

Table 5. Allelochemicals identified in different plant species showing phytotoxic activity against Kallar grass.

Plant species	Benzoic acid	Ferulic acid	Caffeic acid	p-OH-benz-oic acid	Vanillic acid	Syringic acid
			Hydrolysis extracts			
Cynodon	+	+	+	-	-	-
Desmostachya	-	+	+	-	-	-
Kallar grass	-	+	+	-	-	-
Kochia	-	+	+	+	+	-
Polypogon	+	+	+	+	-	-
Sporobolus	+	+	+	+	+	-
Suaeda	+	+	+	-	-	-
			Water extracts			
Cynodon	+	+	-	+	+	+
Desmostachya	+	+	+	+	-	+
Kochia	+	+	+	+	+	-
Polypogon	+	+	-	+	+	+
Sporobolus	+	+	+	+	-	+
Suaeda	-	+	+	+	-	+
Kallar grass	-	+	-	-	-	+

The sign (+) indicates presence and (-) absence of the compounds.

Qurecetin and chlorogenic acid also were identified in *Kochia indica* by paper chromatography.

also reduced growth of Kallar grass seedlings but inhibition was relatively lower compared with that caused by weed species. All species, including Kallar grass itself, showed strong allelopathic potential against Kallar grass (Table 4).

***Identification and biological activity of phytotoxins*:** In hydrolysis extracts, ferulic and caffeic acids were identified from all the 7 species while benzoic acid was present in 4 and p-OH-benzoic acid in 2 species. In water extracts, benzoic, p-OH-benzoic, ferulic and syringic acids were common in most of the weed species while vanillic acid was identified in 3 species. It may be noted that most of the weed species had 5 identified allelochemicals compared to 3 in Kallar grass (Table 5). Other phenolic compounds were also isolated in each species which were not identified.

The germination percentage and rates (as expressed by germination index) were suppressed significantly by different allelochemicals. Similarly, seedling growth was suppressed to varying degrees by these phytotoxins, caffeic and ferulic acids being highly toxic. Further, the toxicity was more pronounced against shoot growth than root growth (Table 6).

Table 6. Effect of different allelochemicals on seed germination and seedling growth of Kallar grass. Values are means of 5 replicates.

Treatment*	Germination (%)#	Germination index	Dry weight (mg) Root	Shoot
Control	35.0a$	9.60a	32.8a	65.2a
Caffeic acid	23.3b	5.35bc	29.8a	48.4bc
p-OH-benzoic acid	21.6b	5.65bc	28.0a	59.6ab
Ferulic acid	22.3b	6.75b	28.8a	47.2c
Benzoic acid	13.3b	4.05c	34.6a	61.6a

*Half strength Hoagland nutrient solution (control) having $1x10^{-4}$ M of respective allelochemical.

#Germinability of Kallar grass seeds is low.

$Values sharing the same letters in a column are not significantly different at $P = 0.05$ according to Duncan's multiple range test.

Discussion

In natural plant communities, there is a possibility of interference among plant species for scarcity of physical factors of the environment and plants may compete for the deficient factors. Our field observations (Mahmood *et al.*, 1989; 1994) showed that failure of Kallar grass to persist with weeds was not related to mere physical factors. Plants might interfere through certain biochemical means which would often lead to success of some species and failure of others. Water extracts of all invader species, except *Cynodon dactylon*, reduced the germination of Kallar grass seeds while the growth of seedlings of the species was retarded by all weeds (Table 1), indicating the allelopathic potential of weed species against Kallar grass. The leachates from plant residues of many species are known to decrease growth and eliminate associated species (Chung & Miller, 1995b; Miller, 1996). The addition of shoot material of weed species into soil resulted in decreased seed germination and growth of Kallar grass to varying degrees depending on species, amounts added, and duration of decomposition (Fig. 1, Table 2). These data further augmented the presence of allelopathic mechanism leading to invasion and elimination of Kallar grass by invader species. Expression of allelopathy through incorporated fresh or decomposing residues is reported (Inderjit & Dakshini, 1995). Allelopathic inhibition is a well documented phenomenon (Einhellig, 1996; Miller, 1996) and is known to result in failure and replacement of susceptible species in common habitat by many species (Chung & Miller, 1995b; Muller, 1966; Rice, 1984).

Low crop yields in the presence of wheat straw residues were generally due to nitrogen immobilization but addition of nitrogen did not reduce the phytotoxicity of wheat straw mixed in soil (Kimber, 1973). This supports the present observation that reduction in growth of Kallar grass by decomposing weed material was not attributable

to immobilization of nutrients. Dry weights of roots and shoots of Kallar grass were poorly correlated with amounts of available nitrogen and phosphorus in soil, and in many instances Kallar grass growth was significantly lower in amended soils having better nutrient availability compared to that in control (Fig. 2, Table 2). Further, the growth of Kallar grass was strongly inhibited in the presence of weed materials even when nutrient supplies were maintained (Table 3). Kallar grass is known to grow well on soils low in nutrients and responds poorly to fertilizer applications (Malik *et al.*, 1986). Newman & Rovira (1975) reported that reduction in growth of *Hypochoeris radicata, Lolium perenne* and *Trifolium repens* in their own or one another's leachates was due to allelopathic effects rather than due to deficiency of nutrients like N, P, K.

Phenolic acids and their derivatives are among the most important allelopathic compounds and, being generally water soluble, can be leached from living and decaying plant tissue (Thompson, 1985). The phenolic compounds identified from different weed species and Kallar grass (Table 5) are known to be allelopathic (Rice, 1984; Thompson, 1985) and they significantly inhibited germination and growth of Kallar grass (Table 6). Although no effort was made to quantitate the phenolics, their presence in water and hydrolysis extracts clearly established the allelopathic potential of different species. Small quantities of toxins may be responsible for massive reduction in plant growth and in absorption of water and minerals and, therefore, strongly influence micro-habitat (Muller, 1966). The phytotoxins (phenolics) can target one or more physiological systems to retard growth. Therefore, because of their synergistic effects, a mixture of allelochemicals can be more detrimental than one at the same concentration (Einhellig, 1996).

In addition to interference from invader species, autoinhibition seems to be an important factor responsible for low productivity of Kallar grass in its older stands. The standing crop biomass of Kallar grass was significantly lower in 30-months old fields (85 ± 4.1 g/0.25 m^2) compared with that in 15-months old fields (229 ± 24.2 g/0.25 m^2) (Mahmood *et al.*, 1989). Many crop plants produce phytotoxic substances and crop residues may lower the productivity of subsequent crops of the same kind or of different crops (Chung & Miller, 1995a; Rice, 1984; Thompson, 1985). Reduction in productivity during long-term growth of many range species is well documented (Qureshi & Hussain, 1980).

The results presented here support the hypothesis that allelopathy is operative in spread of weeds and decline in productivity of Kallar grass after a few years of its growth. The allelopathic mechanism involves phytotoxicity of invader species resulting in complete suppression of Kallar grass in and around patches of weed species, while autotoxicity of the grass further reduces its growth. The present study does not, however, prove allelopathy to be the only factor but warrants the significant influence of allelopathy in species coexistence and productivity in saline environments, where soil conditions have been often considered the only determining factors.

Acknowledgments

We are thankful to Mr. Noor Ahmad and Mr. Rafiq Asi for their help in experimental work and gas chromatography, respectively, and Mr. Ghulam Rasul Tahir for statistical analysis of the data.

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(Received for publication on 2 July 1997)