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EFFECT OF SALINE WATER IRRIGATION ON GROWTH, ION CONTENT AND FORAGE YIELD OF HALOPHYTIC GRASSES GROWN ON SALINE BLACK SOIL

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SUMMARY

In a pot study, two halophytic grasses, *Eragrostis* species and *Aeluropus lagopoides* were grown using saline water of EC 10, 20, 30 and 40 dS m^{-1}. There was good establishment, growth and forage production up to EC 40 dS m^{-1}. Ion partitioning in shoots and roots of both the grasses indicated that the roots act as potential sinks for toxic ions like Na^+ and Cl^-. Total Na^+ content was found less in the shoot than in the root, in both the grasses irrespective of salinity and age of the plant. Cl^- was found much higher in the root than in the shoot. The rate of flux of Na^+ and Cl^- to the whole plant was found to increase with salinity. *Aeluropus lagopoides* was found to possess high tissue tolerance and better forage quality traits *i.e.*, protein, proline, fibre, ash and sugar contents, compared to *Eragrostis* species. *Aeluropus lagopoides*, because of its ability to withstand high salinity, better forage quality, ion partitioning and fast growing nature, forms an ideal forage grass for saline agriculture on saline black soil of Gujarat region.

Key words: ***Aeluropus lagopoides, Eragrostis*, halophytes, ion uptake, saline black soils, saline agriculture.**

INTRODUCTION

The agricultural use of saline water or soils is an important approach in the management of saline wastelands and saline water. The problem of soil salinity is severe in the coastal area and also in the irrigation commands of Gujarat state. Prevalence of highly saline ground water and high water table aggravate salinity hazards in most part of the Bhal area of the Gujarat state. Salt affected black soils, due to their inherent physico-chemical characteristics like poor hydraulic conductivity, low infiltration rate, high clay content (>50%) and narrow workable moisture range are difficult to manage even at low salinity. Highly salinized black soils with high saline ground water are well distributed in Bhal area of Gujarat and the coastal belt, possess only some native and hardy species and *by and large* remain barren and uncultivated. Identification of economically important halophytes and salt tolerant plants and also the feasibility of using saline water for irrigation would form an important management strategy for bringing saline black soils under production. Though, studies on evolving technology for domesticating an economic halophyte, *Salvadora persica* (Gururaja Rao *et al.* 2003, 2004, Gulzar and Khan 2003, Gulzar *et al.* 2005) and some salt tolerant forage grasses (Gururaja Rao *et al.* 2001) have been studied, information on growth and forage production of halophytic forage grasses under saline water irrigation when grown on saline black soils is scanty. In the present paper, we report growth, salt uptake and biomass yield of two halophytic grasses grown on saline black soil under saline water irrigation and the feasibility of their introduction in biosaline agricultural programmes.

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MATERIALS AND METHODS

Halophytic grasses, *Eragrostis* species and *Aeluropus lagopoides* were collected from the Bhal area (Dholera coast) in Ahmedabad district and raised in the nursery at CSSRI, RRS Farm located at Samni village, Bharuch district (21^o 51' N latitude and 72^o 53' to 72^o 54' E longitude). The climate is characterized as semi-arid with hot and dry pre-monsoon summer months (May to June) followed by monsoon period (June to September). The subsequent short period of October to November received uncertain and infrequent showers followed by fair, dry and mild winter (December to February). The mean air temperatures are about 41 ^{o}C during April-May and minimum, 11-15 ^{o}C noticed during December-January. Bulk of the rainfall is received during July to September months and the mean annual rainfall is about 650 mm. Study was conducted in pots of 10 kg capacity filled with finely powdered black soil (surface soil collected from Samni farm) mixed with farmyard manure (FYM) in 3:1 ratio. Physico-chemical characteristics of the soil indicate that the soils are saline in the sub-surface layers (ECe, 10.5 - 11.4 dS m^{-1}) while the upper profile showed higher ESP (10.0 to 11.3).

The rooted slips of the halophyte grass species, *Aeluropus lagopoides* and *Eragrostis* sp. collected from the nursery were planted in plastic pots (2 slips pot^{-1}). Treatments comprised four levels of salinity of irrigation water (EC 10, 20, 30 and 40 dS m^{-1}) replicated four times in completely randomized design. The pots were irrigated with best available water of EC 0.9 dS m^{-1} for about one week till the grasses showed proper sprouting and establishment. Thereafter, the pots were irrigated with saline water (1 l pot^{-1} mainly comprising NaCl) of EC 10, 20, 30 and 40 dS m^{-1}. Irrigations were repeated five times during the entire plant growth (45 days). The plants were allowed to grow in open. Periodic soil samples were collected prior to each saline water irrigation and analyzed for salinity status.

Plant height and number of tillers were measured at 3 days interval (starting at 3 days after sprouting) till the initiation of flowering (36-40 days) and growth increment was recorded. The plants were harvested and separated into root and shoot, oven dried at 80° C for 72 h. The oven-dried samples were extracted in 100 mol m^{-3} acetic acid in water bath at 90° C for 2 h. The samples were cooled and made up to known volume and sodium content measured on Systronics Mediflame Flame Photometer. Chloride content of the samples was measured titrimetrically using silver nitrate (Richards 1954). The rate of ion transport (flux) from root to shoot and to whole plant was calculated using the formula, Js= (MS_2-MS_1) ln $(WR_2-WR_1) / (t_2-t_1) (WR_2-WR_1)$ where, Js is the rate of transport (flux), MS_1 and MS_2 are the amounts of ion in the shoot/ whole plant and WR_1 and WR_2 are the fresh weights of the roots at the harvest times t_1 and t_2 (Pitman 1975). Forage quality parameters, *viz.* sugars (Highkin and Frankel 1962), protein (Lowry *et al.* 1951), crude fibre and ash (Kanwar and Chopra 1967) and osmoregulatory substance proline (Bates *et al.* 1973) were estimated in the mature leaves. Forage biomass was also recorded at the end of experiment. The data were analysed statistically.

RESULTS AND DISCUSSION

Soil salinity build-up

Irrigation with saline water over a period of time increased the soil salinity under saline water irrigations of 10, 20, 30 and 40 dS m^{-1}. The saline water irrigation was given till the grasses showed flower initiation (about 6-7 weeks). The salinity build up (Table 1) indicated highest salinity of 30.5 dS m^{-1} under *Eragrostis* spp. and 31 dS m^{-1} under *Aeluropus lagopoides* when irrigated with 40 dS m^{-1} saline water. There was a significant difference in salinity build up under different treatments indicating the salt build up in the pots.

Growth

Data on plant height and tiller production indicated that *Aeluropus lagopoides* produced higher number of tillers and showed better growth at all salinity treatments when compared to *Eragrostis* indicating its higher salt tolerance. While plant height decreased with increase in salinity in *Eragrostis*, *Aeluropus* showed increased growth with salinity. Though there was an increase in tillers with salinity in both the species, their further growth got slowed down with increase in salinity, particularly in *Eragrostis*. A decrease was recorded in growth with an increase in the level of saline water over a period of 36

Table 1. Salinity build-up in soil (ECe) after saline water irrigations (dS m^{-1})

ECe,	*Eragrostis* sp.					*Aeluropus lagopoides*				
dS m^{-1}	I_1	I_2	I_3	I_4	I_5	I_1	I_2	I_3	I_4	I_5
10	9.55	8.92	10.72	13.75	14.05	10.12	8.75	10.87	11.25	11.82
20	15.27	16.57	16.62	17.25	17.42	14.42	15.47	17.65	19.50	20.32
30	15.85	17.13	20.25	23.52	23.65	14.82	18.25	19.95	20.25	22.15
40	18.95	20.95	25.0	29.04	30.54	15.92	27.53	28.25	29.51	31.01
C.D $_{0.05}$	1.92	2.23	1.81	3.09	2.85	2.28	2.21	1.77	2.34	2.07

(I_1-I_5 represent number of saline water irrigations)

days (flower initiation stage) particularly in *Eragrostis*. However, the difference between 10 and 20 dS m^{-1} saline water treatments over a period of time is almost similar in *Aeluropus lagopoides* while *Eragrostis*. showed only little variation (Figs. 1a and 1b). At highest salinity, it was clearly seen that though the buds producing new tillers were emerged, the high salt content of the shoot system affected their further growth. However, these grasses responded well to the saline irrigation even at 30 dS m^{-1} of irrigation water.

Eragrostis sp. showed higher fresh and dry plant biomass when compared to *Aeluropus lagopoides* (Table 2). Among the treatments, *Eragrostis* species did not show much variation in the fresh and dry shoot biomass where as *Aeluropus lagopoides* showed distinguishing variation in these parameters indicating the higher tolerance of *Eragrostis sp.* The root biomass was, however found to be more at higher salinity in both the grasses, indicating that the roots of these grasses showed more tolerance than shoots. This is also clearly evident from the shoot/root biomass ratios of both the grasses.

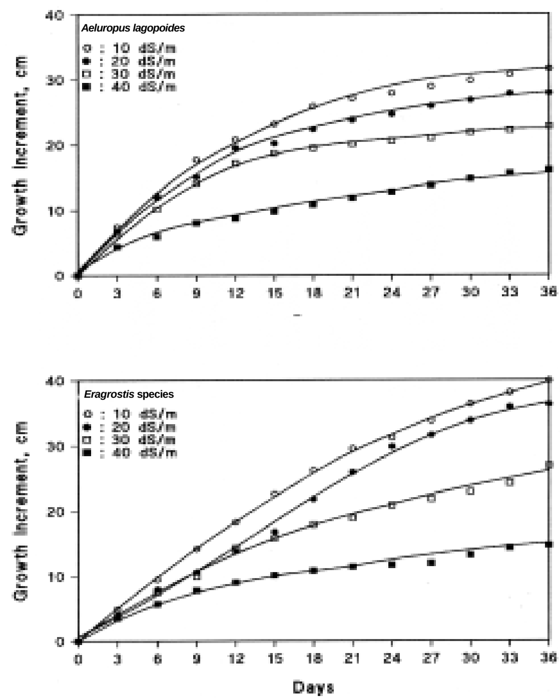

Fig. 1. Growth (height) of halophytic grasses as influenced by saline water irrigation

Table 2. Plant biomass (g/plant) of halophytic grasses irrigated with saline water

ECe,	*Eragrostis* sp.				*Aeluropus lagopoides*			
dS m^{-1}	Shoot		Root		Shoot		Root	
	fw	dw	fw	dw	fw	dw	fw	dw
10	21.39	10.93	11.23	5.21	13.95	7.42	5.27	2.64
20	19.75	9.83	11.74	5.33	11.41	6.94	7.10	3.60
30	18.31	9.17	13.37	6.42	10.69	6.36	8.64	4.33
40	17.04	8.47	17.38	8.99	8.67	4.87	9.06	4.84
C.D $_{0.05}$	1.00	0.94	2.09	1.11	0.87	1.20	1.98	1.21

The increase in salinity resulted in decrease in shoot biomass indicating an inverse relation between salinity and biomass production as has also been reported earlier (Qureshi *et al.* 1982, Gururaja Rao *et al.* 2001).

Ionic content

The leaf and stem ions, *i.e.* Na^+ and Cl^- increased with the increase in salinity. The shoot (leaf and stem) sodium content after two irrigations increased from 2000 µmoles (ECiw, 10 dS m^{-1}) to 5900 µmoles (ECiw, 40 dS m^{-1}) in leaf of *Eragrostis* sp. and 3500 µmoles to 6100 µmoles in *Aeluropus lagopoides*. In stem the Na^+ and Cl^- contents were higher when compared to the leaves indicating stem as a potential sink. Among the grasses, Na^+ and Cl^- contents were found to be more in *Aeluropus lagopoides* than *Eragrostis* sp. (Fig. 2). Ion partitioning (Na^+ and Cl^-) in shoot and roots of two grasses indicated that roots do act as sinks for this toxic ions when plants attain maturity. However, every relative transaction of these ions, particularly that of Na is more in *Eragrostis* sp. whereas they are evenly distributed in *Aeluropus lagopoides.* The total Na^+ uptake showed a decreasing trend with increase in salinity of irrigation water in both the grasses, which is due to increase in biomass resulting in the dilution of ions *per se*. Among the grasses, *Aeluropus lagopoides* showed higher uptake than that of *Eragrostis* sp. though the increase was only marginal (Tables 3, 4). The total Na^+ content is less in shoot than in the root in both the grasses irrespective of salinity and age of the plant. Chloride uptake, however, is relatively more in root than in shoot. The rate of flux of Na^+ and Cl^- to the whole plant increased with salinity and age of the plant. The studies clearly indicate that *Aeluropus* has the ability to extract more salt than *Eragrostis*, thus indicating its higher salt tolerance.

Table 3. Uptake and flux of Na^+ and Cl^- ions in *Aeluropus lagopoides* under saline water irrigation

Salinity ($dS\ m^{-1}$)	Uptake (g)				Flux ($\mu g\ g^{-1}\ day^{-1}$)			
	Shoot		Root		To whole plant		To shoot	
	Na^+	Cl^-	Na^+	Cl^-	Na^+	Cl^-	Na^+	Cl^-
	1st week							
10	4.20	4.85	5.82	5.13				
20	3.92	4.60	5.20	4.93				
30	3.61	4.05	4.85	4.14				
40	3.40	3.70	3.85	3.96				
	2nd week				**Between 1st and 2nd week**			
10	5.15	4.74	6.40	4.68	8.78	1.88	2.42	3.62
20	4.95	4.44	6.00	4.53	9.92	13.84	3.03	4.81
30	4.45	4.10	5.28	3.96	12.62	14.09	3.84	4.99
40	3.62	3.78	4.62	3.65	13.12	26.32	4.12	8.92
	3rd week				**Between 2nd and 3rd week**			
10	5.60	5.66	6.78	5.25	13.42	16.24	3.62	5.14
20	5.05	5.05	6.18	4.94	17.32	20.33	5.14	6.24
30	4.62	4.60	5.85	4.60	18.92	28.75	5.92	8.36
40	4.28	4.20	4.90	4.28	24.32	32.48	7.96	10.62
	4th week				**Between 3rd and 4th week**			
10	6.05	6.20	6.90	6.18	19.70	26.78	6.32	8.32
20	5.25	5.00	6.23	5.54	26.30	32.14	8.44	10.64
30	5.05	5.05	5.63	4.84	28.15	39.36	9.63	14.20
40	4.60	4.60	5.00	4.12	30.10	42.74	10.40	16.32

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Table 4. Uptake and flux of Na^+ and Cl^- ions in *Eragrostis* under saline water irrigation

Salinity ($dS\ m^{-1}$)	Uptake (g)				Flux ($\mu g\ g^{-1}\ day^{-1}$)			
	Shoot		Root		To whole plant		To shoot	
	Na^+	Cl^-	Na^+	Cl^-	Na^+	Cl^-	Na^+	Cl^-
	1st week							
10	3.91	4.37	5.42	5.14				
20	3.64	4.12	4.86	4.58				
30	3.42	3.90	4.39	4.32				
40	3.08	3.76	4.14	4.24				
	2nd week				**Between 1st and 2nd week**			
10	4.78	4.36	5.96	4.35	7.90	9.92	2.18	3.42
20	4.32	4.04	5.78	4.14	8.62	10.42	3.62	3.75
30	4.02	3.92	4.14	3.62	9.36	12.62	3.92	4.62
40	3.64	3.51	4.04	3.44	10.42	18.80	4.14	5.96
	3rd week				**Between 2nd and 3rd week**			
10	4.92	4.88	5.84	4.98	10.39	12.82	3.14	4.36
20	4.81	4.64	5.72	4.86	13.86	16.01	3.36	5.62
30	4.32	4.38	4.92	4.64	15.14	22.41	3.92	6.98
40	4.02	4.14	4.44	4.32	19.52	24.62	4.79	9.39
	4th week				**Between 3rd and 4th week**			
10	5.64	5.84	6.10	5.14	15.76	19.72	3.79	4.72
20	4.92	4.92	5.72	5.02	16.80	25.60	5.16	6.72
30	4.84	4.63	5.32	4.84	18.44	26.81	6.13	8.42
40	4.12	4.24	4.79	4.36	26.12	28.42	7.14	8.92

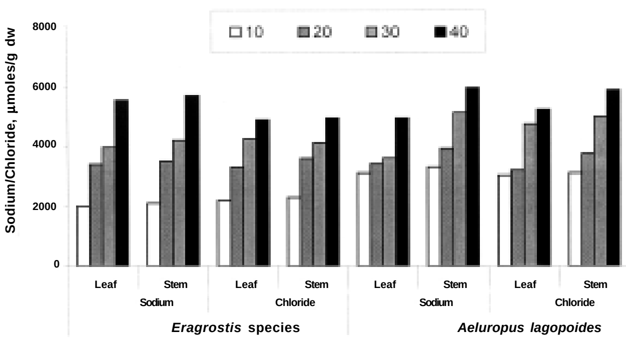

Fig. 2. Tissue ion content of halophytic grasses after two saline water irrigations

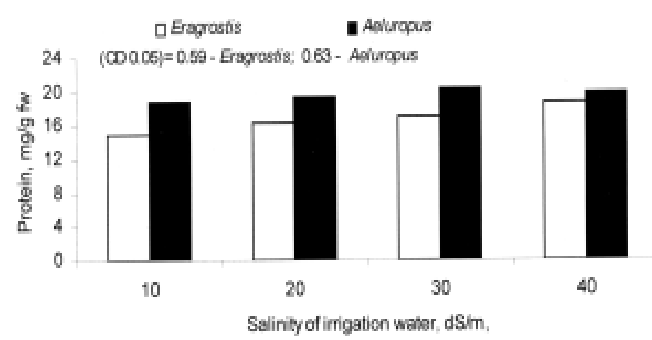

Fig. 3. Protein content of forage grasses under saline water irrigation

Protein

Leaf protein content was found to be more in *Aeluropus lagopoides* than *Eragrostis sp*. at all salinity treatments (Fig. 3). With increase in salinity, a decrease in protein content was noticed in both the grass species. There is a significant variation among the treatments in protein contents. There was an increase in protein with increase in salinity indicating the efficiency of nitrogen metabolism in these grasses.

Sugars

Sugar content of the shoot was higher in *Aeluropus lagopoides* than *Eragrostis* sp. (Fig. 4). The sugar content was found to increase in shoots with increase in salinity of irrigation water upto 30 dS m^{-1}. However, under 40 dS m^{-1} saline water irrigation, both the grasses showed lesser sugars as compared to 30 dS m^{-1}. Significant variations in sugars were noticed between 10 dS m^{-1} and other treatments in both the grasses.

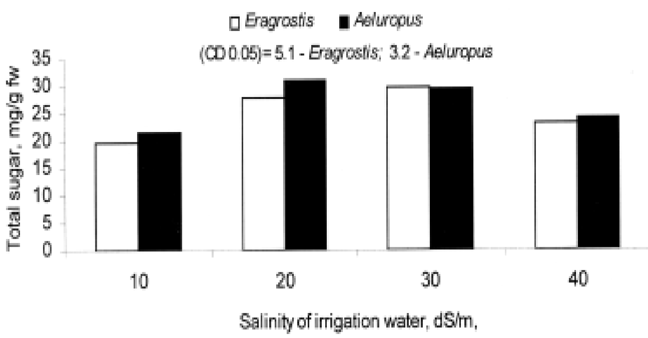

Fig. 4. Total sugar content of forage grasses under saline water irrigation

Proline

Proline content also followed the trend of the protein in that it increased from 10 dS m^{-1} to 40 dS m^{-1} in both grasses (Fig. 5). Higher proline as noticed at higher salinities coupled with higher tissue Na^+ constitute the osmoregulating substances which favours water uptake from saline medium, thereby enabling the plants to maintain its physiological activity. Higher amounts of proline noticed in these grasses help in turgor regulation and thus the physiological activity of these grasses.

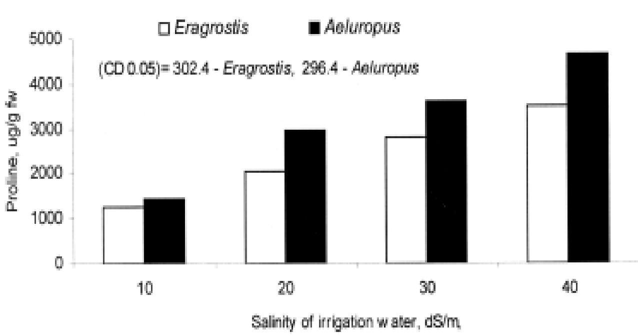

Fig. 5. Proline content of forage grasses under saline water irrigation

Crude fiber and ash

Crude fiber and ash contents (Figs. 6 & 7) of the halophytic grasses (shoots) indicated that *Aeluropus lagopoides* showed higher fiber and ash content when compared to *Eragrostis*. However, the differences between fiber content was not so more as that of the ash content between the two species.

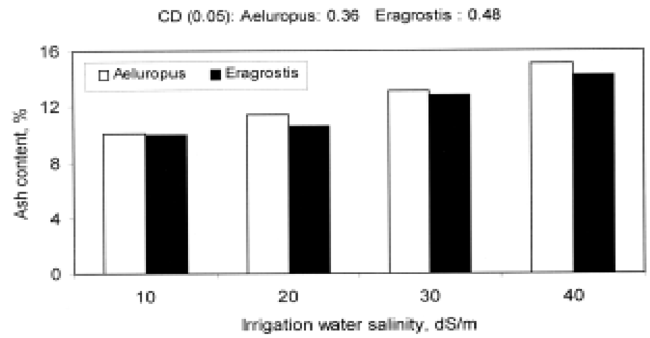

Fig. 6. Effect of saline water irrigation on ash content of halophytic grasses

Increase in these forage quality traits with increase in salinity of irrigation water was noticed in both the species indicating their higher production at higher salinity levels. Crude fibre is a mixture of cellulose, hemicellulose and lignin gives strength and its higher content indicates higher photosynthate production and further its conversion. Higher ash content of *Aeluropus lagopoides* can be ascribed to higher mineral uptake as reported in other grasses (Ashok Kumar and Abrol 1986). The study

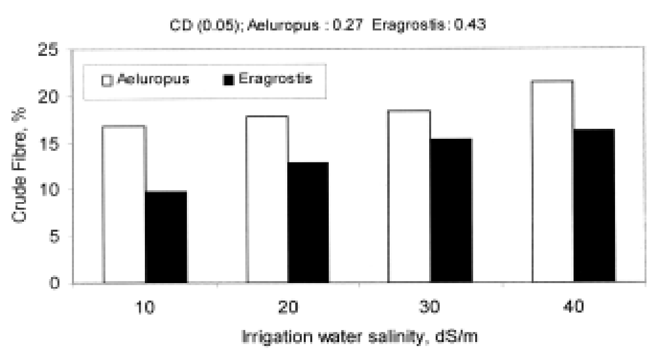

Fig. 7. Effect of saline water irrigation on crude fibre content (%) of halophytic grasses

thus indicated that *Aeluropus lagopoides*, in view of its better ion uptake and partitioning, forage quality traits and higher salt tolerance was found an ideal forage species for saline agriculture on saline black soils.

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