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Effect of sodicity and salinity on seedling growth of two early successional agroforestry tree species

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Abstract: The growth responses of *Dalbergia sissoo* Roxb. and *Acacia nilotica* (Linn.) Willd. ex. Del. seedlings were compared on different levels of soil sodicity and salinity. The growth and dry weight of one-year old seedlings decreased as the level of sodicity and salinity increased in both species. However, the suppression in growth caused by sodicity and salinity was relatively greater in *D. sissoo* than in *A. nilotica. A. nilotica* showed wider response breadth compared with *D. sissoo* on both the gradients. Further, the response breadths were comparatively higher under sodicity levels than under salinity levels. Root : shoot ratio and root weight ratio in both the species increased on increasing the levels of sodicity and salinity, whereas relative growth rate and net assimilation rate indicated a reverse trend.

Resumen: Las respuestas de crecimiento de plántulas de *Dalbergia sissoo* Roxb. y *Acacia nilotica* (Linn.) Willd. ex. Del. fueron comparadas bajo condiciones diferentes de sodicidad y salinidad. El crecimiento y el peso seco de las plántulas de un año de edad disminuyeron en ambas especies conforme aumentó el nivel de sodicidad y de salinidad. Sin embargo, la supresión del crecimiento causado por la sodicidad y la salinidad fue relativamente mayor en *D. sissoo* que en *A. nilotica. A. nilotica* mostró una mayor amplitud de respuesta en comparación con *D. sissoo* a lo largo de ambos gradientes. Además, las amplitudes de respuesta fueron comparativamente mayores bajo niveles de sodicidad que bajo niveles de salinidad. Los cocientes raíz:vástago y raíz:peso en ambas especies aumentaron conforme se incrementaron los niveles de sodicidad y salinidad, mientras que la tasa relativa de crecimiento y la tasa neta de asimilación indicaron la existencia de una tendencia contraria.

Resumo: As respostas de crescimento das plântulas da *Dalbergia sisso* Roxb e *Acacia nilotica* (linn.) Willd. Ex. Del. foram comparadas para diferentes níveis de teor de sódio e salinidade. O crescimento e o peso seco das plântulas com um ano de idade de ambas as espécies decresceu à medida que o teor de sódio e salinidade aumentou. Contudo, a supressão no crescimento causada pelo teor de sódio e salinidade foi relativamente mais elevado na *D. sissoo* do que na *A. nilotica.* Esta última mostrou uma resposta mais ampla quando comparada com a *D. sissoo* em ambos os gradientes. Foi também encontrado que a amplitude das respostas foi comparativamente mais elevada para os níveis em teor de sódio do que para os níveis de salinidade. O ratio raiz: rebentos e peso da raiz cresceu com o aumento dos níveis de sódio e salinidade em ambas as espécies enquanto as taxas

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de acréscimo do crescimento relativo e assimilação líquida evidenciaram uma tendência contrária.

Key words: *Acacia nilotica, Dalbergia sissoo,* response breadth, salinity, seedling growth, sodicity, successional species, quality index.

Introduction

In India about 8.1 m ha land is affected by varying degree of salinity and sodicity (Singh 1992). These lands are lying barren in different parts of the country owing to high pH, presence of excessive sodium on the exchange complex and hardpan of calcium carbonate at variable depths. Importance of tree planting for the reclamation of salt-affected lands is recognized by Morris & Thomson (1983) and Schofield (1990). However, the levels of sodicity and salinity vary from site to site and the salt tolerance also varies greatly among the plant species (Tinus 1984; Toth 1981; Tomar & Yadav 1980). Plantation of trees on such soils without considering their level of tolerance to sodicity and salinity has suffered with heavy mortality (Singh *et al.* 1991, 1992). Therefore, the selection of species for different sites should be made according to sodicity and salinity levels. In the present study relative tolerance of *Dalbergia sissoo* Roxb. and *Acacia nilotica* (Linn.) Willd. ex. Del. has been compared on different levels of sodicity and salinity at early stages of their growth.

D. sissoo and *A. nilotica* are indigenous multipurpose tree species and are widely planted under various agroforestry systems (Tewari 1994). Both the species are early successional (Champion & Seth 1968; Puri 1960; Troup 1921) and can grow in nutrient poor soils. In present case, these species were selected because of their potential salt tolerance nature (Grewal & Abrol 1986; Yadav & Singh 1970).

Materials and methods

The experiments were conducted at Main Experiment Station of Forestry Department, N.D. University of Agriculture & Technology, Kumarganj, Faizabad, in the net house with overhead polythene sheet to protect the direct impact of rain water. The seeds of *D. sissoo* were collected in the month of January and of *A. nilotica* in June 2001. These seeds were sown in nursery beds during the first week of July. One month old seedlings were transplanted into polythene bags (30 x 45 cm) containing sandy loam soils with different levels of sodicity and salinity.

The nursery soil was treated with $NaHCO_3$ at different rates to create various sodicity levels (i.e., ESP 20, 40, 60 and 80) following Bains & Fireman (1964). The treated soils were covered with polythene sheets for fifteen days to reduce evaporation and to obtain the soil equilibrium. Throughout this period the moisture content in soil was maintained at saturation percentage of soil. Various salinity levels (i.e., ECe 5.0, 7.5, 10.0, 12.5 and 15.0 dS m^{-1}) were maintained by mixing NaCl in the nursery soil at different rates as per the method of Jackson (1967). To maintain a particular ECe level in soil, salt solution was prepared by dissolving calculated amount of the NaCl in water and added to soil at field capacity level. The field capacity was determined on the basis of saturation percent of the soil. The sodicity and salinity levels as mentioned above were fixed in the soil at the start of the experiments. Untreated nursery soil was considered as control, which had ESP 9.7 and ECe 0.38 dS m^{-1}. Based on the high mortality of seedlings at increasing levels of salinity and sodicity as well as for the destructive sampling for dry weight estimation, a total of 40 bags of each species in each of the three replications were placed under each treatment in a randomized block design. The bags were moistened regularly by adding uniform volume of deionized water to keep the soil at field capacity. Seedlings were measured for different growth parameters at the interval of 3 months upto one year. Dry weight was estimated after harvesting three seedlings from each of the above treatments for each species. At each harvest roots were washed thoroughly in running water and finally with distilled water, separated into root, stem and leaves and oven dried (80° C, 48 h).

Data recorded for all the growth characters were subjected to statistical analysis to test the level of significance (Snedecor & Cochran 1967). Relative growth rate (RGR), leaf weight ratio (LWR), net assimilation rate (NAR) and root weight ratio (RWR) were determined according to Evans (1972). Quotient of sturdiness (SQ) was calculated following Thompson (1985). To quantify the morphological quality of seedlings, the quality index (QI) was calculated following Dickson *et al.* (1960) formula: QI = TW/(H/D) + (SW/RW), where, TW is the total seedling dry weight (g), H is the seedling height (cm), D is the collar diameter (mm), SW is the shoot dry weight (g), and RW is the root dry weight (g) of seedling.

Measure of response breadth was calculated using Levins's (1968) niche breadth metric:

$$B = \frac{1}{\left[\sum_{i=1}^{s} P_i^2\right] S}$$

where, Pi is the proportion of seedling height growth, collar diameter or seedling dry weight response in state i, and S is the total number of states (treatments). The resulting measure B is a scale from 0 to 1 with 1 being the widest breadth. The degree of similarity between the two species was calculated as in Schoener (1970):

$$PSij = 1 - 1/2 \sum_{H=1}^{S} \{Pih - Pjh\}$$

where, PSij is the degree of similarity between species i and j and Ph is the proportion of response of a species, i or j, in state h. These values also range from 0 to 1 with 1 being maximum similarity.

Results

Effect of sodicity on seedling growth

The differences in all the growth parameters for both species were significant between treatments (P<0.01) indicating significant

Table 1. Performance of seedlings of *D. sissoo* and *A. nilotica* after one year growth at different sodicity levels (ESP = Exchangeable sodium percentage).

Treatment	Survival (%)	Height (cm)	Collar diameter (mm)	Leaf dry weight (g)	Shoot dry weight (g)	Root dry weight (g)	Total dry weight (g)	Quality index
				Dalbergia sissoo				
Control	90.0	132.7	11.8	12.9	42.3	23.5	65.8	5.15
ESP 20	84.1	79.5	10.7	8.6	24.4	17.5	41.9	4.88
ESP 40	69.0	39.7	7.9	2.9	10.9	8.2	19.0	3.02
ESP 60	40.2	28.5	5.0	1.8	5.0	4.0	9.0	1.29
ESP 80	6.2	18.2	3.0	1.2	3.1	2.8	5.9	0.80
CD (5%)	8.48**	9.54**	1.20**	1.47**	4.78**	2.33**	8.05**	0.25**
				Acacia nilotica				
Control	92.8	156.3	14.9	6.9	39.4	6.4	45.8	2.67
ESP 20	86.7	135.0	13.7	5.8	31.7	6.00	37.7	2.48
ESP 40	73.4	103.4	11.8	3.9	26.4	5.2	31.6	2.29
ESP 60	43.8	75.4	10.5	3.6	18.3	4.2	22.5	1.84
ESP 80	8.0	60.0	8.6	2.8	11.7	3.2	14.9	1.35
CD(5%)	7.28**	7.56**	1.36**	0.38**	3.91**	0.49**	8.74**	0.39**

** Significant at P<0.01

influence of sodicity levels on the growth (Table 1). However, the CD (5%) values indicated non-significant differences between control and sodicity level at ESP 20 in seedling survival and collar diameter in both the species and root dry weight, total dry weight and QI in *A. nilotica.* Total seedling dry weight and QI in *A. nilotica* even indicated a non-significant difference in their values between ESP 20 and 40 suggesting a greater tolerance by *A. nilotica* than *D. sissoo* under sodic conditions.

In both species, seedling survival decreased with increasing sodicity (Table 1). However, the survival at all the levels of sodicity was higher in *A. nilotica* than in *D. sissoo*. The height growth and dry weight of seedlings also decreased as the level of sodicity increased in both species (Fig. 1). Consequently, similar response patterns (as shown by the proportions of height growth and total dry weight at different sodicity levels) were observed for the two species. *A. nilotica* seedlings attained comparatively greater height growth than *D. sissoo*. However, seedling dry weight was greater in *D. sissoo* than in *A. nilotica* up to ESP 20, but thereafter *A. nilotica* seedlings obtained greater dry weight. Quality index of seedlings decreased with increasing sodicity levels. However, *D. sissoo* indicated greater QI than *A. nilotica* up to ESP 40, whilst at ESP 60 and 80 *A. nilotica* seedlings showed greater QI. The suppression in growth caused by increasing sodicity levels was relatively greater in *D. sissoo* than in *A. nilotica*. This is also reflected by the relatively wider response breadths for *A. nilotica* than for *D.sissoo* (Table 2). However, the response breadths in terms of survival were almost similar for both the species. Values of the degree of similarity indicated that the two species at their early stages of growth had similar responses on sodicity gradient. However, the similarity was greater for survival than for other growth parameters.

On increasing the sodicity level, LWR, RWR, root : shoot ratio and total height per unit dry weight of stem increased in both the species (Table 3). On the other hand, the values of RGR, NAR and SQ decreased with increasing soil sodicity, thereby indicating a similar pattern observed for height, collar diameter and total seedling dry weight.

Effect of salinity on seedling growth

Seedling survival decreased with increasing level of salinity and decrease was more pronounced in *D. sissoo* seedlings as compared to *A. nilotica.* Difference ($P<0.01$) between the treatments was significant (Table 4). Both height and dry weight of one year old seedlings also decreased with increasing salinity levels (Fig. 2). Values for relative performance indicate that the suppression caused by salinity was lower for *A. nilotica* than for *D. sissoo* seedlings. Under control conditions which supported maximum height growth, *A. nilotica* seedlings were approximately 18% taller than the *D. sissoo* seedlings. In contrast, the total seedling dry weight was higher in *D. sissoo* seedlings than in *A. nilotica* under control condition. However, it decreased more rapidly in *D. sissoo* than in *A. nilotica* under higher salinity levels. This is reflected in the relatively wider response breadths obtained for *A. nilotica* seedlings than for *D. sissoo* seedlings (Table 2). The suppression caused by highest salinity level (ECe 15 dS m^{-1}) on seedling QI was about 96% in *D. sissoo* and 68% in *A. nilotica* when compared with the control. Further, about 50% suppression in seedling QI was observed at ECe 5.0 dS m^{-1} in *D. sissoo* and at ECe 7.5 dS m^{-1} in *A. nilotica.* The trends in shoot dry weight of one

Table 2. Growth responses of *D. sissoo* and *A. nilotica* seedlings on sodicity and salinity gradients.

Parameters	Sodicity levels			Salinity levels		
	Response breadth		Degree of Similarity	Response breadth		Degree of Similarity
	D.sissoo	*A.nilotica*		*D.sissoo*	*A.nilotica*	
Survival	0.755	0.787	0.984	0.497	0.586	0.871
Height	0.671	0.896	0.841	0.432	0.712	0.730
Collar diameter	0.840	0.966	0.888	0.606	0.801	0.869
Leaf dry weight	0.602	0.904	0.768	0.305	0.669	0.655
Shoot dry weight	0.579	0.877	0.778	0.341	0.694	0.663
Root dry weight	0.662	0.947	0.763	0.403	0.833	0.689
Total dry weight	0.612	0.970	0.787	0.353	0.718	0.653
Quality index	0.740	0.956	0.822	0.485	0.850	0.748

Table 3. Effect of sodicity levels on different growth indices in *D. sissoo* and *A. nilotica.*

Treatment	LWR	RGR ($g\ g^{-1}d^{-1}$)	NAR ($g\ g^{-1}d^{-1}$)	Root: Shoot	RWR	SQ ($cm\ mm^{-1}$)	Total height: Stem dry weight ($cm\ g^{-1}$)
			Dalbergia sissoo				
Control	0.194	0.011	0.207	0.56	0.35	11.2	4.51
ESP 20	0.200	0.009	0.128	0.72	0.41	6.7	4.42
ESP 40	0.156	0.008	0.068	0.76	0.43	5.0	5.02
ESP 60	0.201	0.006	0.046	0.80	0.44	5.7	8.90
ESP 80	0.204	0.006	0.040	0.89	0.47	6.3	9.90
			Acacia nilotica				
Control	0.151	0.009	0.196	0.16	0.14	10.5	4.81
ESP 20	0.154	0.008	0.139	0.19	0.16	9.8	5.25
ESP 40	0.123	0.006	0.059	0.20	0.17	8.8	4.88
ESP 60	0.160	0.005	0.047	0.23	0.19	7.2	5.35
ESP 80	0.187	0.004	0.045	0.27	0.21	7.0	7.05

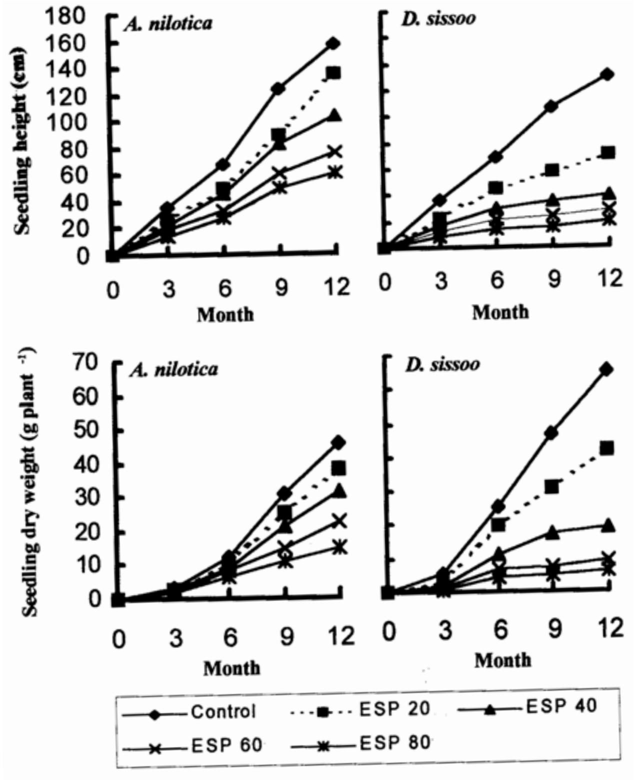

Fig. 1. Seedling height growth and total dry weight at different sodicity levels for *Acacia nilotica* and *Dalbergia sissoo* during a one year study period.

year old seedlings of both species were similar to the trends in total seedling dry weight. Values of the proportional similarities between *D. sissoo* and *A. nilotica* on the salinity gradient showed resemblance more in their survival and collar diameter than other parameters.

The values of RGR and NAR decreased with increasing salinity levels in both the species (Table 5). On the other hand, RWR and root: shoot ratio increased from lower to higher salinity levels in both the species. This increase was particularly greater in *A. nilotica* than in *D. sissoo.*

Discussion

This attempt to elucidate the response of two early successional species indicated considerable decline in survival and various growth parameters with increasing sodicity and salinity levels. The values for survival, collar diameter and QI of seedling did not show significant variation upto 20 ESP level in *D.*

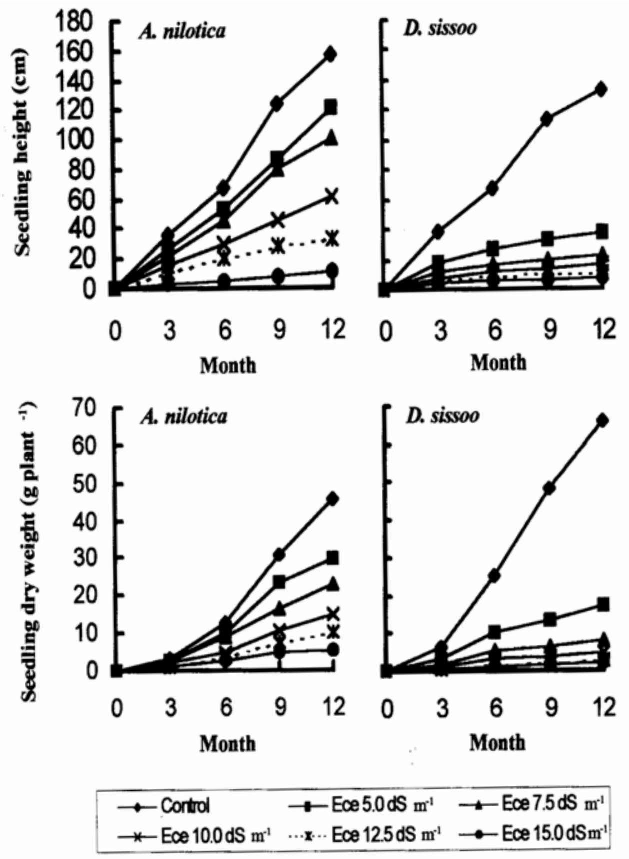

Fig. 2. Seedling height growth and total dry weight at different salinity levels for *Acacia nilotica* and *Dalbergia sissoo* during a one year study period.

sissoo and 40 ESP level in *A. nilotica*, thus indicating higher tolerance of *A. nilotica* seedlings than those of *D. sissoo* seedlings to sodicity levels. This may be due to the difference in their root behaviour and hardiness of these species to such adverse soil environment (Singh 1994). About 74% reduction in total dry weight and 50% reduction in QI of the seedlings at ECe 5.0 dS m^{-1} from control treatment in *D. sissoo* revealed poor tolerance of this species to salinity. On the other hand, *A. nilotica* seedlings indicated only 25% reduction in QI at ECe 5.0 dS m^{-1} level from the control treatment. Thus, *A. nilotica* is more tolerant to salinity as compared to *D. sissoo.* Yadav & Singh (1970), while studying the performance of different species in salt-affected usar soils, have observed variability in the tolerance of *D. sissoo* and *A. nilotica* seedlings. Our results are also in conformity with the earlier findings of Singh &

Table 4. Performance of seedlings of *D. sissoo* and *A. nilotica* after one year growth at different salinity levels. (ECe = Electrical conductivity of saturation extract).

Treatments	Survival (%)	Height (cm)	Collar diameter (mm)	Leaf dry weight (g)	Shoot dry weight (g)	Root dry weight (g)	Total dry weight (g)	Quality index
				Dalbergia sissoo				
Control	80.0	132.7	11.8	12.9	42.3	23.5	65.8	5.15
ECe 5.0 dS m^{-1}	41.0	37.4	7.1	2.1	9.5	7.4	16.9	2.58
ECe 7.5 dS m^{-1}	24.8	23.0	4.6	1.4	4.2	3.5	7.7	1.26
ECe 10.0 dS m^{-1}	14.2	16.0	2.6	0.9	2.5	2.2	4.7	0.64
ECe 12.5 dS m^{-1}	6.0	10.8	1.1	0.3	1.4	1.3	2.7	0.26
ECe 15.0 dS m^{-1}	2.0	7.5	1.0	0.2	1.1	1.0	2.1	0.25
CD (5%)	13.88**	6.40**	0.64**	1.41**	4.22**	3.08**	7.11**	0.24**
				Acacia nilotica				
Control	92.8	156.3	14.9	6.9	39.4	6.4	45.8	2.67
ECe 5.0 dS m^{-1}	63.5	120.2	12.3	4.5	25.0	4.8	29.8	1.99
ECe 7.5 dS m^{-1}	49.4	99.4	8.7	2.7	18.8	3.9	22.7	1.40
ECe 10.0 dS m^{-1}	14.0	61.3	7.0	2.0	12.1	3.0	15.1	1.14
ECe 12.5 dS m^{-1}	9.6	32.5	5.3	1.3	8.0	2.3	10.3	1.06
ECe 15.0 dS m^{-1}	3.6	10.7	2.2	0.8	4.0	1.5	5.5	0.86
CD (5%)	9.58**	6.65**	0.79**	0.31**	5.65**	0.39**	5.52**	0.37**

** Significant at P<0.01

Table 5. Effect of salinity levels on different growth indices in *D. sissoo* and *A. nilotica*.

Treatments	LWR	RGR ($g\ g^{-1} d^{-1}$)	NAR ($g\ g^{-1} d^{-1}$)	Root: shoot	RWR	SQ ($cm\ mm^{-1}$)	Total height: Stem dry weight ($cm\ g^{-1}$)
			Dalbergia sissoo				
Control	0.194	0.011	0.207	0.56	0.35	11.2	4.51
ECe 5.0 dS m^{-1}	0.123	0.008	0.110	0.78	0.43	5.3	5.05
ECe 7.5 dS m^{-1}	0.176	0.007	0.082	0.84	0.44	5.0	8.21
ECe 10.0 dS m^{-1}	0.181	0.006	0.072	0.88	0.46	6.2	10.00
ECe 12.5 dS m^{-1}	0.113	0.006	0.054	0.93	0.48	9.8	9.82
ECe 15.0 dS m^{-1}	0.121	0.005	0.038	0.99	0.48	7.5	9.37
			Acacia nilotica				
Control	0.151	0.009	0.196	0.16	0.14	10.5	4.81
ECe 5.0 dS m^{-1}	0.150	0.008	0.169	0.19	0.16	9.8	5.50
ECe 7.5 dS m^{-1}	0.120	0.008	0.125	0.21	0.17	11.4	6.17
ECe 10.0 dS m^{-1}	0.136	0.006	0.088	0.25	0.20	8.8	6.05
ECe 12.5 dS m^{-1}	0.124	0.005	0.060	0.29	0.22	6.1	4.85
ECe 15.0 dS m^{-1}	0.145	0.005	0.049	0.38	0.27	4.9	3.34

Yadav (1985) and Singh *et al.* (1988, 1991) who observed better growth in *A. nilotica* than in *D. sissoo* under saline soils. The differences in the salinity tolerance in these two species may be due to different rate of salt transport to the shoots adversely affecting the leaf growth reducing the photosynthetic efficiency of the plants. The reduction in leaf dry weight in the present study was higher in *D. sissoo* than in *A. nilotica* under all the salinity levels. Singh & Yadav (1985) have reported that *D. sissoo* shows fairly good growth response up to ECe 4.2 dS m^{-1} and ESP 15.2 in the early stages of its growth under an alluvial silty clay loam soil. Sharma *et al.* (1998), while working on the performance of tree species at nursery stage under clay soil have observed that *D. sissoo* can grow better upto ECe 3.5 dS m^{-1}. In the present study, however, the growth of *D. sissoo* was better still at a little higher ESP (20) and ECe (5 dS m^{-1}) levels. This variation can be attributed to difference in soil texture (Singh *et al.* 1990).

Previous observations indicated that early successional species are capable of occupying a greater habitat range (Parrish & Bazzaz 1982) thus showing a broader responses on environmental gradients. However, the seedlings of *D. sissoo* and *A. nilotica* indicated lower response breadth on salinity and sodicity gradients than even under other environmental gradients studied by us (Tewari *et al.* unpublished).

Further, between the gradients of salinity and sodicity the response breadth was comparatively higher under sodicity. As such *A. nilotica* exhibited greater response breadths than *D. sissoo* under both the gradients. Thus, although *D. sissoo* can tolerate sodicity upto ESP 20, it is tolerant to salinity only upto ECe 5 dS m^{-1}. On the other hand, *A. nilotica* tolerates higher level of sodicity (ESP 40) than *D. sissoo* and can also tolerate salinity upto ECe 7.5 dS m^{-1}.

Investigation on allocation of dry matter to plant parts indicate that the patterns were consistent with the findings of Monk (1966) and Abrahamson & Gadgil (1973) in that root : shoot ratio and RWR in *D. sissoo* and *A. nilotica* had an inverse relation with the RGR and NAR. Root: shoot ratio and RWR in both the species increased on increasing the levels of salinity and sodicity, while RGR and NAR indicated just the reverse trend. The high root : shoot ratios in these species at sodicity and salinity levels appear to be an adaptive strategy to increase the ratio of water absorbing to water transpiring organs (Bernstein 1975). The higher proportion of dry weight in root of *D. sissoo* at all the levels of sodicity and salinity, indicates greater susceptibility of dry weight allocation to the shoot in *D. sissoo* to sodicity and salinity than in *A. nilotica.* Between the two gradients, root : shoot ratio in both the species was greater at salinity than at sodicity levels. Harper (1977) has pointed out that root growth is dependent on shoot growth and root: shoot ratios change with environmental treatment. The decrease in RGR on increasing sodicity and salinity levels was evidently due to decline in NAR. Comparatively higher NAR in *A. nilotica* under stress conditions may be regarded as the characteristic feature for higher sodicity and salinity tolerance as compared to *D. sissoo*. The total seedling height per unit stem dry weight was, in general, higher in *D. sissoo* as compared to *A. nilotica.* It appears that in *D. sissoo* the pattern of dry weight allocation to the stem is more vurnerable to sodicity and salinity, compared to *A. nilotica.*

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