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The Response of Fodderibeet to Salinity: an Analysis of Physiological and Morphological Aspects of Growth

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Abstract
Greenhouse studies on fodderbeet cultivars *Beta vulgaris* (cvs. Majoral, Monored, and Polygroeningia) and of *Beta mariti* (Seabeet) showed significant differences for Relative Growth Rate (RGR) among themselves while no significant differen were observed for salinity treatments until the first harvest. Plants had adapted themselves to salinity after six weeks treatment and showed significant differences in RGR and Net Assimilation Rate (NAR) during the whole period of grow Leaf thickness did not change significantly with salinity. *B. vulgaris* cv. Majoral and *B. maritima* were found to be be adapted 150 mM NaCl concentration in soil solution than cv. Monored and Polygroeningia under greenhouse conditio

Introduction
The potential of saline land for the growth of salt tolerant plants is an established fact (Malcolm, 1989). Kallar grass *(Leptochloa fusca)* and Atriplex can be successfully grown on otherwise unproductive land (Aslam *et al.*, 1991). The animal feed deficit during winter (November to February) range from 25 to 40 per cent (Akram, 1986). Therefore, non-conventional salt tolerant fodder plants may be tried to make up the fodder requirement of cattle and the objective of utilization of salt affected soil be achieved as well.
Fodderbeet is reported to be a highly salt tolerant crop at the vegetative stage (Rozema *et al.*, 1992). NaCl (295-1180 Kg ha^{-1}) is required for a significant increase in tops and root yield of fodderbeet (Goh and Magat, 1989). It is grown in the coastal areas in many European countries like U.K., Netherlands, France, Germany, Spain, Austria and Sweden etc. (Magat and Goh, 1988). A few reports on successful cropping are available from Russia and New Zealand (Popovic and Stikie, 1986; Magat and Goh, 1988). Sugar yield of sugarbeet is also reported to be improved by the application of NaCl (Stephen *et al.*, 1980; Pescini and McCrone, 1980). The sugar content of fodderbeet is low compared to sugarbeet (Quin *et al.*, 1980), which favours raising fodderbeet as a fodder crop under saline conditions. Successful cultivation of the fodderbeet during the winter period may help to solve the problem of farmers in salt affected areas for successful utilization of non-arable land. Cultivation practice in some areas would also be helpful for other salt tolerant crops during the summer season.
Results of a geeenhouse study conducted on the growth and physiological response of three cultivars of fodderbeet *(Beta vulgaris)* compared with its ancestor the seabeet *(B. maritima)* to increased soil salinity are reported in this publication.

Materials and Methods
Seeds of three fodderbeet *(B. vulgaris)* cultivars Majoral, Monored and Polygroeningia and of seabeet (*B. maritima*: the primary ancestor collected from the Atlantic Coast Brittany) were germinated in sand moistened with disti water. Seedling emerged were counted for record percent germination. After two weeks of germination, seedling in each pot was transplanted containing 3 garden soil (characteristics given in Table 1). On the wh 16 replicates were maintained per treatment. Two levels (O i.e. control and 150 mM NaCl) were applied a one week of establishment of the seedlings in pots. The solution was added on alternate days in increments of mM NaCl, twice on the top of soil and the third time to dish placed at the bottom of pot in order to maintai uniform salt concentration throughout the soil profile. plants were raised in the greenhouse with an aver temperature of 24°C during the day, 22°C during night, relative humidity 75 per cent and light inten 250μE m^{-2} S^{-1} provided by HPI/T lamps (Philips). An in harvest was taken before the addition of salt. Two s harvests were taken after two and six weeks of application of the salt treatment, respectively. experiment was designed according to a comp randomized block. At each harvest the following parame were assessed: dry matter yield, leaf area, using a leaf meter (Li 3100 Li-Corp. Inc. Lincoln, Nebraska USA well as by measurement of length and width of the blade manually, leaf thickness (Dial pipe guage (0.0 m.m) No. 2046-08-Mitutoyo Japan), total water pote of the shoot (Pressure Bomb), osmotic potential of expressed from the leaves (Vapour pressure osmom 5100 Wescor Inc. USA) and net photosynthesis (Parki leaf chamber ADC-LCA 3 system, The Analy Development Company Ltd, Hoddesdon, Herts, recorded at the time of each harvest. Correlation of area worked out by leaf area meter and measureme length and width was calculated. Relative Growth R LAR, SLA and SLW were calculated according to (1982). Results were statistically analyzed using AN described by Sokal and Rohlf (1981).

able 1: Physico-chemical analysis of garden soil (source: Potgrond mengselm, Aalsmeer)

ysical analysis	
oisture percentage	64.0
r cent organic matter	70.0
ol. weight perlite granule	207.0
re vol	88.3
ol. % water by PF 1.5	54.8
ol. % air by PF 1.5	33.5
emical analysis	
ganic matter	72.0
CO_3	2.5
H_2O	6.2
dS/m	1.4
ion (mM/l extract)	
	0.7
$_4$	3.2
$_4$	0.8
$_3$	2.2
tion (mM/l extract)	
$_4$	3.1
	2.9
	1.8
	0.8
al Nitrogen	5.3

sults

eds of all cultivars gave approximately 100 per cent mination under normal conditions within seven days. *B. ritima* showed a delayed germination of about four days. e leaves of seedlings of *B. maritima* were comparatively k green in colour. Mean relative growth rate (RGR, mg day $^{-1}$) of cultivars Majoral, Monored and Polygroeningia ot was higher than that of *B. maritima* during the first vest (Fig la). At a later stage all cultivars showed a uced size of stem and leaves directly emerging from it, ereas *B. maritima* developed a branched stem which ame elongated (maximum length 4 cm). The RGR did show any significant difference for the salinity tment upto the second week of salt added to the pots, there were significant differences between the cultivars RGR. The cultivar Polygroeningia showed the highest R, while *B. maritima* gave the lowest value (Fig. 1a). ence of NaCl (150 mM) in the growth medium had no ct on RGR upto two weeks (Fig. 1a). After 6 weeks, R significantly decreased compared to first harvest (Fig. . Presence of 150 mM NaCl had a significant positive ct on RGR in all the cultivars at the time of second vest except for *B. maritima* where a significant decrease s noted in the presence of 150 mM NaCl as compared to trol. Net assimilation rate (NAR, g m^{-2} day^{-1}) in *B. ritima* and cv. Polygroeningia was higher than in cvs. oral and Monored (Fig. 2a). NAR increased in all the ivars except cv. Polygroeningia. NAR was positively uenced by the salinity treatments for almost all the ivars except *B. maritima* by the presence of 150 mM NaCl upto the sixth week (Fig. 2b). Leaf area ratio (LAR m^{2} g^{-1}) was not significantly different for the salinity treatments in monored upto 2 weeks. The LAR of cvs. Majoral and Monored was significantly diferent from cv. Polygroeningia. A significant low LAR in *B. maritima* had been recorded under 150 mM NaCl. Leaf area ratio significantly increased at the time of second harvest compared to the first harvest (Table 2). Leaf weight ratio

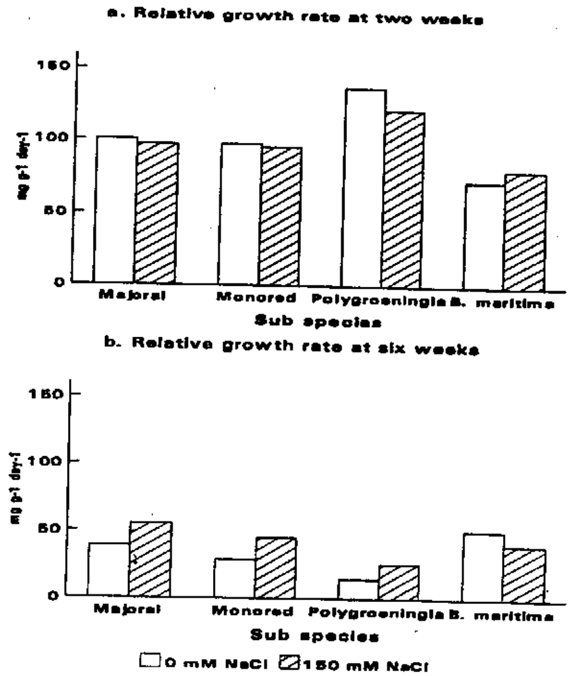

Fig. 1: Relative growth rate of different cultivars of *B. vulgaris* and *B. maritima*

significantly increased at the time of second harvest compared to the first harvest (Table 2). Leaf weight ratio (LWR g g^{-1}) was almost equal in all cultivars even in the presence of increased salinity upto 2 week. Later LWR decreased and a significant low LWR had been recorded at six week. Significantly positive correlations (R2 = 0.96) were recorded in measuring leaf area by leaf area meter and by the product of leaf length and breadth. An increase in LAR at 6 week time may be associated with a decrease in

LWR in all the cultivars except in *B. maritima.* Specific leaf area (SLA, $m^{2} g^{-1}$) decreased in the presence of salinity in cvs. Majoral and Monored (Table 2), which is associated with an increase in the specific leaf weight (SLW, $g m^{-1}$) in the same cultivar and with the treatment (Table 2). Specific Leaf Area significantly increased with the age of the plant but there were no significant differences among the cultivars and treatment except for cv. Monored, at two weeks period (Table 2). Specific Leaf Weight was significantly decreased after 6 weeks of treatment in all the cultivars (Table 2).

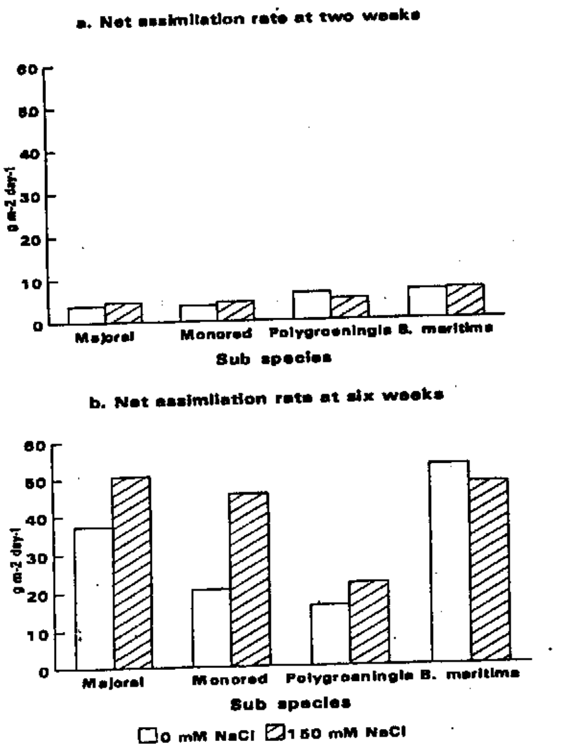

Fig. 2: Net assimilation rate of different cultivars of *B. vulgaris* and *B. maritima.*

The rate of net photosynthesis ($\mu M\ CO_2\ m^{-2}\ s^{-1}$) was not significantly affected by increased salinity in cvs. Majoral, Monored and *B. maritima.* Net photosynthesis decreased in cv.Polygroeningia (Fig. 3). The total water potential of the shoot did not significantly change in the presence of salinity (150 mM NaCl) in all the cultivars except *B. martima* where it increased (Table 2). The osmotic potential of leaf sap decreased significantly with increased salinity. NaCl did not affect the leaf thickness in almost all the cultivars except *B. maritima* (Fig 4).

A marked reduction was noticed in the dry weight of root and leaf in comparison with the control treatment after two weeks in all cultivars except for *B. maritima* (Table 3). Leaf dry weight in cv. Majoral showed an increase of 56 per cent over the control treatment after 4 weeks of first harvest, but there was still 1. 3 per cent reduction in root dry weight. *B. maritima* gained 57.3 per cent leaf dry weight and 50.6 per cent root dry weight over control after two weeks of treatment. A 55.7 per cent increase of whole plant dry weight compared to the control treatment was recorded (Table 3). Leaf area was reduced after two weeks of salt treatment in all the cultivars except B. *maritima* (Table 3). The number of leaves increased significantly in the cultivar Majoral and in seabeet after six weeks (Table 4), while the leaf area decreased (Table 3).

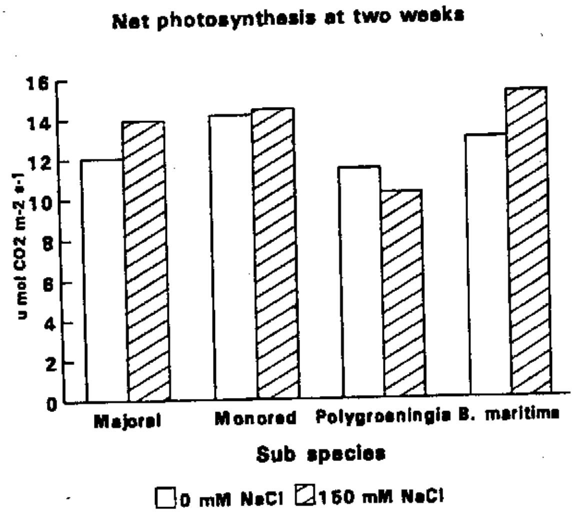

Fig. 3: Net photosynthesis of different cultivvvars of *B. vulgaris* and *B. maritima*

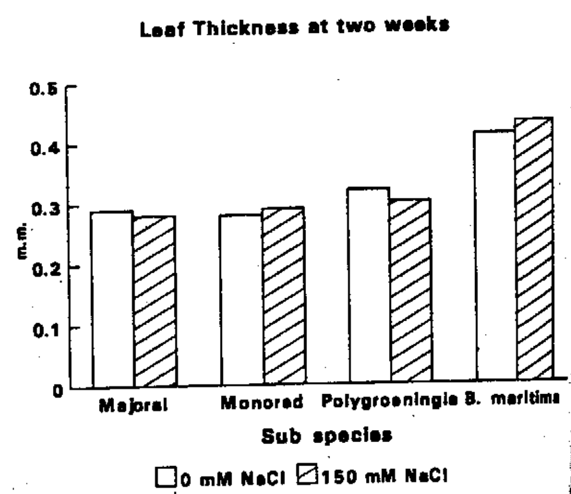

Fig. 4: Leaf thickness of different cultivars of *B. vulgaris* and *B. maritima*

Table 2: Effect of increased salinity (150 mM NaCl in soil moisture)on growth parameters of fodderbeet and seabeet after two (I) and four (II) weeks of treatment.

		Cultivar			
		Majoral	Monored	Polygroeningia	*B. maritima*
LAR m2 g-1					
0	I	0.025±0.003	0.027±0.004	0.016±0.001	0.015±0.002
	II	0.83±0.07	0.95±0.11	0.62±0.07	1.33±0.21
150	I	0.021±0.005	0.019±0.001	0.019±0.002	0.016±0.001
	II	0.84±0.01	0.68±0.14	0.75±0.09	0.94±0.11
LWR					
0	I	0.739±0.039	0.754±0.015	0.669±0.043	0.764±0.019
	II	0.47±0.01	0.43±0.06	0.38±0.08	0.74±0.11
150	I	0.735±0.048	0.782±0.027	0.734±0.037	0.772±0.012
	II	0.60±0.14	0.45±0.13	0.39±0.04	0.63±0.20
SLA m2 g-1					
0	I	0.035±0.006	0.035±0.005	0.023±0.001	0.020±0.003
	II	1.85±0.15	2.19±0.47	1.63±0.07	1.76±0.14
150	I	0.033±0.003	0.024±0.001	0.25±0.002	0.020±0.001
	II	1.46±0.27	1.50±0.20	1.94±0.05	1.49±0.13
SLW g m-2					
0	I	30.54±3.99	30.31±4.56	42.77±1.92	53.15±7.95
	II	0.56±0.03	0.46±0.11	0.62±0.04	0.61±0.12
150	I	35.66±3.16	42.27±1.47	40..37±3.25	49.48±3.19
	II	0.69±0.05	0.68±0.08	0.54±0.12	0.73±0.05
W.Pot-Bars					
0	I	9.16±2.10	6.67±1.04	11.37±1.81	13.66±2.71
150	I	11.50±3.10	9.67±1.60	10.16±1.65	19.50±2.00
O.Pot-Bars					
0	I	9.71±0.42	10.38±3.00	8.33±2.41	17.55±3.72
150	I	14.42±1.87	12.87±1.74	12.63±2.46	23.13±3.11

Table 3: Per cent increase (+) or decrease (-) in the growth of fodderbeet cultivated at increased salinity (150 mM NaCl in soil moisture after two (I) and four (II) weeks of the salinity treatment.

Cultivar	Harvest	Fresh weight (g)			Dry weight (g)			Leaf area (m^2)
		leaf	root	plant	leaf	root	plant	
Majoral	I	-14.67	-11.77	-13.96	-23.28	-3.44	-18.18	-3.44
	II	+23.31	-26.36	+4.08	+56.05	-1.31	+24.45	-24.54
Monored	I	-18.50	-23.87	-25.95	-11.40	-23.83	-14.64	-19.73
	II	+40.13	+30.19	+35.73	-62.19	+1.19	+26.55	+8.15
Polygroe-ningia	I	-21.77	-25.19	-22.52	-35.55	-50.91	-40.74	-15.08
	II	+7.83	-17.70	-3.47	-9.19	-13.45	-11.83	+7.09
B. maritima	I	+22.02	+8.08	+19.35	+57.31	+50.57	+55.71	+13.84
	II	+1.86	+56.29	+11.58	+1.69	+49.51	+12.62	-1.85

Table 4: Per cent increase(+) or decrease (-) in number of leaves in the presence of 150 mM NaCl after two (harvest I) and four (harvest II) week of the salt treatment.

Cultivar	Harvest I			Harvest II		
	0mM	150mM	%±	0 mM	150 mM	%±
Majoral	12.12	11.57	-4.54	13.75	15.75	+14.54
Monored	12.87	12.25	- 4.82	14.00	12.25	-12.50
Polygroeningia	10.25	11.87	+15.80	11.75	12.25	+4.25
B maritima	21.87	23.28	+ 6.45	37.75	42.25	+11.92

Discussion

A significantly higher RGR was observed for fodderbeet cultivars in comparison to *B. maritima*. The RGR for cvs. Majoral and Monored was not affected by 150 mM NaCl upto two weeks. The values of RGR were within the range of herbaceous plants mentioned by Poorter (1989). RGR decreased significantly during the period of last six weeks. The NAR increased for cvs. Majoral and Monored in the presence of 150 mM NaCl during the growth of the fodderbeet plants. The NAR significantly increased over four weeks. Leaf area increased significantly during this period. The leaf area ratio (LAR) was correlated to the increase in leaf area of plant (Lambers *et al.*, 1989). The NAR increased for cvs. Majoral and Monored in the presence of 150 mM NaCl during the growth, while LAR decreased. The rate of photosynthesis was enhanced with increased salinity in *B. martima.* Increase in SLW was followed by a decrease in SLA. It resulted in a significant increase of the leaf thickness. There was no significant change in the total water potential of the shoot (pressure bomb) under saline conditions. The osmotic potential was significantly affected under 150 mM NaCl. In the present study there was 57 per cent increase in leaf dry weight and 51 per cent in root dry weight of *B. maritima* with increased salinity (150 mM NaCl). On the whole there was a 55.7 per cent increase in dry weight compared to control treatment (Table 3). In the cultivar Majoral, a 23 per cent reduction in dry weight of leaf and a 3 per cent reduction in root dry weight was observed under the saline conditions (Table 3). The total leaf area per plant differed significantly between the cultivars (Table 3). A significant difference in the number of leaves per plant may be the basic reason (Table 4). *B. maritima* had the highest average number of leaves, but the total leaf area per plant was less compared to rest of the cultivars due to a smaller leaf area of the individual leaf. The average number of leaves in cv. Majoral was lower than *B. maritima* but bigger leaf size has considerably added to the dry weight of the shoot.

Age of the fodderbeet plants may have caused an interaction between cultivars and the salinity treatment. Fodderbeet plants possibly used up most of the energy available for ion pumps involved in compartmentation and secretion and repair of cellular damage caused by the saline conditions (Penning de Vries, 1975; Schwarz and Gale, 1981) to overcome the effect of salinity. Also the hormonal and physical (i.e. turgor potential) factors controlling cell wall loosening and cell expansion (Cleland, 1986) may have adjusted during the growth period of the fodderbeet plants. The amount translocated to root under saline conditions was relatively low during the first two weeks, later (after four weeks) a considerable amount of photosynthates accumulated in the root system. This adaptation may be related to increase in leaf area (*B. maritima,* + 13.84%) (Table 3). Cultivars appear to differ significantly for LAR and LWR. The difference may be related to a significantly negative effect of salinity treatment on SLA (Table 2) in all cultivars except Polygroeningia. SLW was significantl increased in the presence of salinity in all the cultivar except Polygroeningia (Table 2). The increase in SLW an simultaneous reduction in SLA relate to the increase of lea thickness.

Comparatively better growth rate of fodderbeet cultivar other than *B. maritima* may be related to the delaye germination and perennial nature of *B. maritima*. *Bet maritima* is an halophytic ancestor growing in the coast areas, while the cultivars are its domesticated breeds. Th wild *B. maritima* has a rosette structure, a greater numbe of leaves and comparatively narrow leaves.

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