GROWTH RESPONSE AND CATION INTERACTION IN *HIPPOPHAE RHAMNOIDES* L.

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Abstract

The interaction between sodium and calcium, magnesium and calcium and the combined effect of sodium, magnesium and calcium was observed on the growth and ion uptake of *Hippophae rhamnoides* L. The results demonstrated that an addition of sodium with calcium, (set a, Na 2.5 + Ca 5 mM) showed prominent increase in fresh weight of roots and shoots. The dry weight (average) of roots decreased and that of shoots increased but the percent dry weight of both roots and shoots decreased following an increase in percent water content. An addition of magnesium with calcium, (set b, Mg 2.5 + Ca 5 mM) showed an increase in fresh and dry weight (average and percentage of root and shoot), while percent water content decreased. The addition of sodium and magnesium with calcium, (set c, Na 2.5 + Mg 2.5 + Ca 5 mM) showed an increase in fresh and dry weight (average) of roots and shoots, while percentage dry weight of roots decreased and that of shoots increased and the percentage water content of roots increased and that of shoots decreased. The treatments of sets a, b and c increased the uptake of all ions studied. However, a difference in ion uptake within treatments occurred. It appears that the presence of calcium mitigates the adverse effects of sodium and magnesium by preventing their uptake and enhances the uptake of potassium.

Introduction

Hippophae rhamnoides L. is a species of the Eleagnaceae family that grows both inland and in coastal dune habitats. In maritime climates, owing to the proximity to the seashore, it frequently comes across high concentrations of dissolved salts. Gorham [6] has mentioned the effect salt spray has on increasing the concentrations of sodium, magnesium and chloride in dune soils at Blakeney point, Norfolk, in the U.K.. Similar findings have been reported by Willis and Yemm [15] for dune soils at Braunton Burrows, U.K.. In a soil analysis of Gibraltar point, Lincolnshire, U.K., the authors (unpublished data) found high calcium, magnesium and sodium concentrations of soils in which *H. rhamnoides* grew.

Keywords: Growth; *Hippophae rhamnoides*; Interaction; Ion uptake

An understanding of the interaction of salts which possess either antagonistic or synergistic effects is vital. In soil solutions, particularly in saline or stressed soils, this sort of interaction between ions does occur. For instance in saline soils, competitive inhibition of potassium uptake occurs and in serpentine soils magnesium inhibits calcium uptake [13]. Calcium on the other hand enhances potassium uptake [5] and sodium/calcium interaction is well documented [3, 9, 10].

In a previous report, the effect of NaCl on culture solutions was reported [14] and that of $MgCl_2$ has also been presented (in press). Owing to the importance of the interaction of salts under field conditions, the present attempt has been made to emphasize the interaction of Ca, Mg and Na and the growth response of *H. rhamnoides* to these cations in combined solutions.

Materials and Methods

Culture experiments were performed at 25±1°C temperature and at 1076.25 lux light intensity. The photoperiod was adjusted to 16 h a day.

The culture experimentation procedure was the same as that mentioned earlier by Tirmizi *et al.* [14]. The interaction of sodium and magnesium with high calcium concentrations was observed. There were three sets of treatments (Ca + Na, Ca+ Mg and Ca + Na + Mg; the sign a, b and c, respectively, are assigned to these sets in further discussions) and a control. High calcium concentrations of 5 mM were uniformly maintained in all three sets of treatments except the control (Long Asbton's nutrient solution in full strength). In the first set, (a), sodium concentration was increased to 2.5 mM and magnesium was kept normal (24 ppm), while in the second set, (b), magnesium was raised to 2.5 mM and sodium was kept normal (20 ppm) and in the third set, (c) both sodium and magnesium were increased to 2.5 mM. Calcium chloride hexahydrate, magnesium chloride hexahydrate and sodium chloride salts were applied to increase the calcium, magnesium and sodium concentrations of the nutrient solution. There were five replicates of each treatment consisting of five plants in each. Four-week-old seedlings were used and were harvested twelve weeks after the commencement of the experiment.

After harvesting, roots and shoots were rinsed under tap water for 30 seconds to remove salts from the outer surface of the plant and the wet seedlings were immediately dried with tissue paper in order to protect seedlings from contamination and depletion of salts. The following analyses were carried out: (a) fresh and dry weight of root and shoot; (b) root and shoot lengths; and (c) root : shoot ratios (length and dry weight). For weight, seedlings were dried in an oven at 80°C.

The chemical analyses for inorganic cations were carried out following the acid digestion method using an atomic absorption spectrophotometer [1]. Statistical analysis of variance was carried out following Bishop [2].

Results and Discussion

Fresh and Dry Weight

The mean fresh weight of the roots and shoots increased in all treatments of set (a) (Ca 5 mM + Na 2.5 mM), set (b) (Ca 5 mM + Mg 2.5 mM) and set (c) (Ca 5 mM + Na 2.5 mM + Mg 2.5 mM) compared to the control. However, the increment in mean fresh weight of the root was remarkably higher in the combined treatment of set (c) and that of the shoot was higher in the treatment of set (a) than in the other treatments (Table 1).

The mean dry weight of the shoots also increased in all treatments of sets (a), (b) and (c) compared to the control. The dry weight of the roots decreased in the treatment of set (a) and increased in other treatments of sets (b) and (c) compared to the control.

On the contrary, the percentage dry weight of the roots increased in the treatment of set (a) and decreased in other treatments (sets b and c) compared to the control. The percentage dry weight of the shoots increased remarkably in the treatments of sets (b) and (c) and decreased in set (a) compared to the control (Table 1).

In a previous report, Tirmizi *et al.* [14] reported an increase in dry matter production of roots and shoots of *H. rhamnoides* on salinization with NaCl. However, according to the present experimental results, the ameliorative role of calcium did not prominently affect roots in set (a) (Ca + Na), since the percentage dry matter of roots decreased. Nevertheless, the ameliorative role of calcium is prominent in other treatments (Ca + Mg and Ca + Mg + Na, sets (b) and (c)). The ameliorative role of calcium has been reported by many workers, for instance Kent and Läuchli [8] and recently Nawaz *et al.* [12], who mentioned that $CaCl_2$ partly overcame the inhibitory effects of NaCl salinity in NalAB-78 cotton variety.

Percent Water Content

The percentage water content of the roots increased noticeably in the treatment of set (a) and slightly in the treatment of set (c), conversely it decreased in the treatment of set (b) compared to the control. The percentage water content of the shoots decreased remarkably in the treatment of sets (b) and (c) and increased prominently in treatment (a) compared to the control. The increase and decrease in percentage water content is similar to that reported by Tirmizi *et al.* [14] who made an analogy that water balance is inversely correlated with either an increase or decrease in dry matter. This is probably due to the maintenance of turgor pressure potential as reported by Tirmizi *et al.* [14] on the effect of NaCl salinity in *H. rhamnoides*.

Nevertheless, the inconsistent results associated with an increase in water content in set (a) (Ca + Na) and a reduction in sets (b) and (c) (Ca + Mg and Ca + Mg + Na) obscure and make it more difficult to comment on the ameliorative effect of calcium on sodium and the mitigating effect of calcium also seems to be less prominent in the other two sets owing to the more adverse effects of magnesium, since, as reports suggest, on salinization a sort of dehydration in cells occurs [11].

Root-Shoot Length and Ratios

The length of the roots decreased in the treatments of sets (a) and (b) and increased in the treatment of set (c) compared to the control. The length of the shoots decreased insignificantly in the treatment of set (b) and increased in the treatments of sets (a) and (c) and root to shoot ratios increased (Table 1).

Table 1. Fresh weight, dry weight, water content, root and shoot length and their ratios±SD at combined treatments. (Mean values of five plants from each treatment).

Concentrations	F.W. in g.		D.W. in g.				W.C.				Root length in cm.	Shoot length in cm.	Root to shoot length ratio	Root to shoot ratio DW
	Root	Shoot	Root	Shoot	%DWR	%DWS	Root	Shoot	%DWR	%DWS				
Control	a 0.102 ±0.013	a 0.202 ±0.012	a 0.018 ±0.001	a 0.026 ±0.004	17.65	12.87	0.08	0.18	82.35	87.13	a 10 ±4.64	d 12.8 ±4.02	1:1.28	1:1.45
(a)	b 0.12 ±0.016	b 0.54 ±0.019	b 0.014 ±0.002	b 0.042 ±0.003	11.66	7.78	0.106	0.498	88.34	92.22	ab 7.5 ±1.84	a 13 ±1.56	1:1.74	1:3.0
(b)	ab 0.104 ±0.014	ac 0.22 ±0.009	c 0.023 ±0.003	cb 0.04 ±0.002	22.12	18.18	0.08	0.18	78	81.82	ab 6.6 ±2.75	a 11.3 ±3.83	1:1.72	1:1.74
(c)	cd 0.149 ±0.001	d 0.264 ±0.012	dc 0.024 ±0.002	d 0.057 ±0.005	16.1	21.59	0.13	0.217	83.9	78.41	ac 12.5 ±3.24	a 14.5 ±2.07	1:1.16	1:2.38

Smaller letters show insignificant variation while different letters show significant differences between treatments.

Table 2. Mean values of cation content in g.100 dm^3 of plant material ±DS

Concentrations	Control			(a)			(b)			(c)		
Cations	L	S	R	L	S	R	L	S	R	L	S	R
Na	a	a	a	b	b	b	c	cb	c	d	d	ad
	0.25	0.4	0.84	0.5	0.81	1.38	0.4	0.84	1.05	0.45	0.59	0.85
	±0.05	±0.03	±0.026	±0.01	±0.05	+0.36	+0.03	+0.02	+0.044	+0.04	+0.01	+0.01
K	a	a	a	b	ab	b	ca	ca	c	d	dc	d
	1.9	1.65	2.48	2.58	1.7	1.45	1.95	1.54	1.6	2.08	1.43	1.69
	±0.027	±0.056	±0.06	±0.06	±0.12	+0.03	+0.036	+0.06	+0.01	+0.04	+0.05	+0.01
Ca	a	a	a	b	b	b	c	c	c	a	ad	d
	0.34	0.43	0.77	1.23	0.68	1.29	1.4	0.82	2.4	0.28	0.48	1.62
	±0.027	±0.036	±0.046	±0.053	±0.07	+0.01	+0.1	+0.027	+0.26	+0.14	+0.02	+0.098
Mg	a	a	a	ab	b	b	cb	c	ac	abc	d	ad
	0.65	0.38	1.0	0.72	0.46	0.86	0.77	0.76	1.05	0.71	0.55	1.03
	±0.046	±0.046	±0.1	±0.08	±0.036	+0.046	+0.036	0.066	+0.04	+0.03	+0.027	+0.01

Similar letters in their respective columns show insignificant differences, whereas different letters show significant variations.

The increase in root to shoot ratios with increasing salinity have been reported by Graham and Humpherys [7] in *Cenchrus cilliaris*. They considered it a response to inadequate moisture availability. However, the present data on root and shoot length ratios seems to be inconclusive.

Chemical Content

Sodium

The sodium content of leaves, stems and roots increased in all treatments of sets (a), (b) and (c) compared to that of the control (Table 2).

Potassium

The potassium content of leaves increased slightly in the treatment of set (b) and prominently in treatments (a) and (c) compared to the control. However, the increase was more prominent in those sets where sodium was supplemented (i.e. (a) and (c)). The potassium content of stems decreased in sets (b) and (c) and increased in set (a). Conversely, the potassium content of roots decreased in all treatments (sets (a), (b) and (c)) compared to that of the control (Table 2).

Calcium

The calcium content of the leaves increased in all treatment levels of sets (a), (b), and (c). However, the increment was prominent in the treatments of sets (a) and (b), while in set (c) it was lower than other treatments and higher than the control. The calcium content of stems and root followed a similar pattern of significant increase relative to the control (Table 2).

Magnesium

The magnesium content of leaves and stems increased in all treatments of sets (a), (b) and (c). However, the increment was prominent in the treatment of set (b) and was slightly lower in other treatments (sets (a) and (c)) compared to the control. The magnesium content of roots decreased remarkably in set (a) treatment and slightly increased in the treatments of sets (b) and (c) relative to the control (Table 2).

On the basis of the present results on the interaction of salts, it seems likely that the presence of high calcium concentrations mitigates the adverse effects of sodium and magnesium by preventing their uptake on absorption sites. It also appears that the high accumulation of potassium is possibly due to the presence of calcium. The enhancement of potassium uptake in the presence of calcium has been reported extensively [5]. It is interesting to note that sodium usually depresses potassium uptake [4], although the present study concurs with a previous report on *H. rhamnoides* in which NaCl did not reduce potassium levels [14], they considered it an adaptive mechanism of this species.

Although the present results are inconclusive, given the general performance of *H. rhamnoides* we infer that it is a sensitive species to either sodium or magnesium. The presence of high calcium mitigates the adverse effects of these salts.

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