Acta Botanica Hungarica 45 (1–2), pp. 217–226, 2003

EFFECT OF N SUPPLY ON SHOOT AND ROOT MINERAL COMPOSITION IN *RETAMA RAETAM*

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(Received 22 November 2001)

In deserts, biological processes decrease at the end of the vegetation period by lack of soil moisture and increasing heat. Important processes for plant nutrient uptake are negatively affected like N fixation, litter decomposition and denitrification. Desert plants must therefore adapt their mineral household towards best use of available nutrients and storage of minerals in perennial organs. Here we studied this pattern by experiments of the effect of nitrogen nutrition on mineral concentration and plant growth of *Retama raetam* (Forssk.) Webb. Berth for two years in sand culture. In summary, the mineral household of *R raetam* seems to be well adapted to unfavourable desert habitat independent from the N source and N level.

Key words: desert plants, mineral composition, N supply, *Retama raetam*

INTRODUCTION

Retama raetam is one of the common plants in the Egyptian deserts with the exception of saline soils. In deserts, biological processes decrease at the end of the vegetation period by lack of soil moisture and increasing heat (Veste and Breckle 2000). Important processes for plant nutrient uptake are negatively affected like N fixation, litter decomposition and denitrification (Lips 2000). *Retama raetam* grows under severe climatic and edaphic conditions. It uses the ephemeral roots in winter mainly for more mineral absorption (Williams 1953, West and Skujins 1978, Zayed 1994).

Our hypothesis: Desert plants adapt their mineral household towards best use of available nutrients and storage of minerals in perennial organs.

Here we studied the N household pattern by experiments of the effect of nitrogen nutrition on mineral concentration and plant growth of *Retama raetam* (Forssk.) Webb. Berth for two years in sand culture.

MATERIAL AND METHODS

Seeds of *R. raetam* of the same size, weight and colour were collected around Cairo–Suez desert road 70 km of Cairo, and germinated in quartz sand. The experiments were designed similar to Ashraf and Navi (1992). One-week-old seedlings of uniform size and appearance were transferred into containers (10 litre) using washed sand as a growth medium. Each year after treatments were terminated, plants were cut back and new growth was measured. At the end of the experiment the shoot/root systems were analysed for N by C/N analyser, P was determined colourimetrically by using Molybdate-Vanadate method (Gericke and Kurmies 1952). Cation concentration was measured for K, Na, Ca, Mg, Fe, Mn, Zn and Cu by atomic absorption spectrophotometer. Fertilisation treatments consisted of three levels (1.5, 4.5 and 12.0 mM) of N from each of three sources sodium nitrate, ammonium nitrate and ammonium sulphate. Each treatment combination was adjusted to the following nutrient solution [in mM]. Ca [2.25] from calcium chloride, Mg [1.0] from magnesium sulphate. P [0.65] from sodium dihydrogen phosphate, K [1.28] from potassium chloride and soluble micronutrient mix containing B [0.09] Cu [0.03], Fe [0.09], Zn [0.05], Mn [0.1], S [0.3] and Mo [0.003]. All nutrient solutions were adjusted to pH 6.5. Raw data were analysed by Two-Way-ANOVA [Treatments: N level × N Source] and Tukey-Test with the software program SIGMASTAT (Jandel Scientific). A Three-Way-ANOVA was unable to be carried out since the data of N level × N Source × Plant organ (root/shoot) failed the Normality Test criteria and in most cases also the Equal Variance Test.

RESULTS AND DISCUSSION

Effect of N-level and N-source on yield

As the supply of nitrogen increases, yield of shoot and root increases (Figs 1–2, Table 1), although with diminishing returns. For mineral nutrients this phenomenon was first formulated as a law of yield increment by Mitscherlich (1954). The yield response curves for a given nutrient is asymptotic, mostly because the supply of one mineral nutrient is increased, other mineral nutrients or the genetic potential of crops becomes limiting factors (Marschner 1986). Shoot-root ratio decreases if more N is supplied.

Yield is generally higher, if N is given at least partly as nitrate. Ammonium had always a negative impact on growth in comparison to NO_3. Increasing interaction between N source and N level was observed with increasing N level in shoot, and in all cases where NO_3 was at least given partly as

N source. Whether plants grow better with nitrate or ammonium is a matter of great ecological importance (Kirkby 1981, Runge 1983). Calcifuge plants adapted to acid soils have a preference for ammonium. In contrast, calcicole plants adapted to calcareous, high pH soils utilise nitrate preferently. *Retama raetam* belongs clearly to the later group. Contradictory effects of the two nitrogen resources on plant growth were expected for the different effects on cation-anion balance and root-induced pH changes. Although many plants reveal the highest growth with a nitrate/ammonium combination, in case of *R. raetam* it is clear that nitrate is preferred.

Nitrogen nutrition and ionic balance

Root and shoot N and P were increased with higher N level (Figs 3–6). At the same level cation concentration decreased (Figs 7–8). A similar effect was observed when the N source was changed from nitrate to ammonium (Table 1). The N concentration was within the reported sufficiency range for many

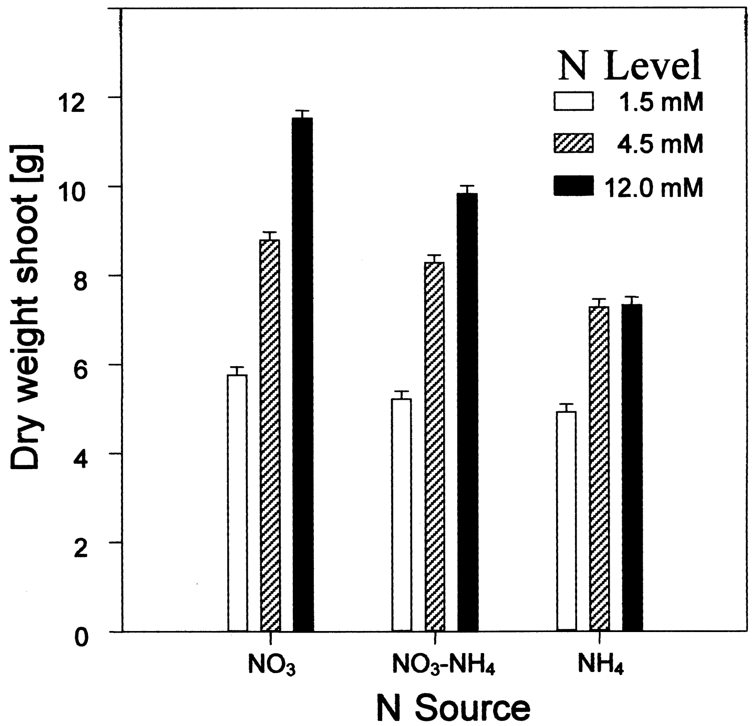

Fig. 1. Plant shoot performance (dry weight) of *R. raetam* grown at three N sources and three N levels of nitrogen supply in sand culture (mean values ±SEM)

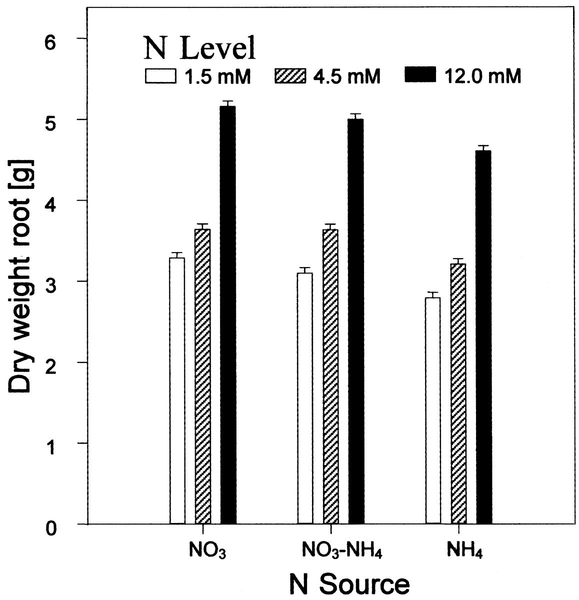

Fig. 2. Plant root performance (dry weight) of *R. raetam* grown at three N sources and three N levels of nitrogen supply in sand culture (mean values ±SEM)

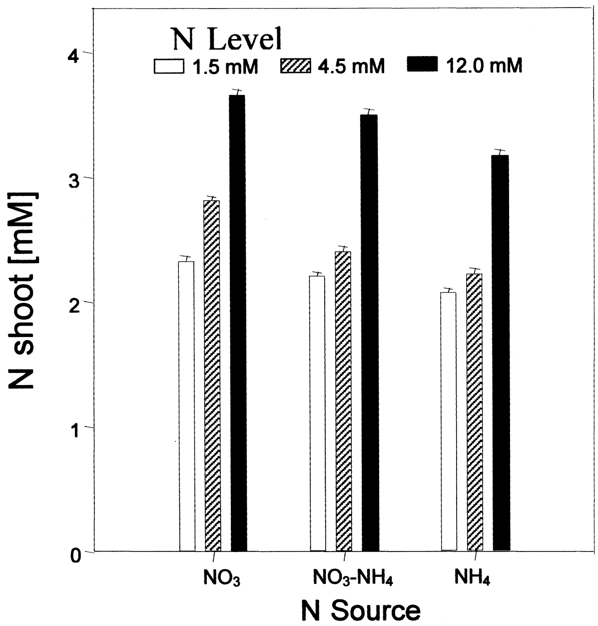

Fig. 3. Shoot nitrogen concentration of *R. raetam* grown at three N sources and three N levels of nitrogen supply in sand culture (mean values ±SEM)

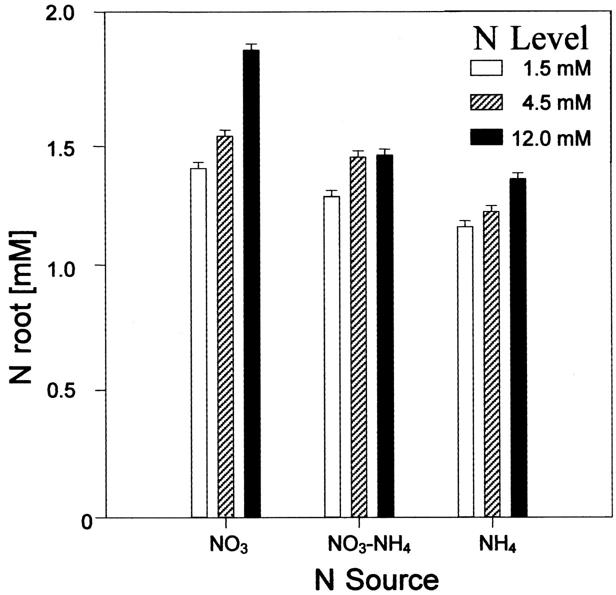

Fig. 4. Root nitrogen concentration of *R. raetam* grown at three N sources and three N levels of nitrogen supply in sand culture (mean values ±SEM)

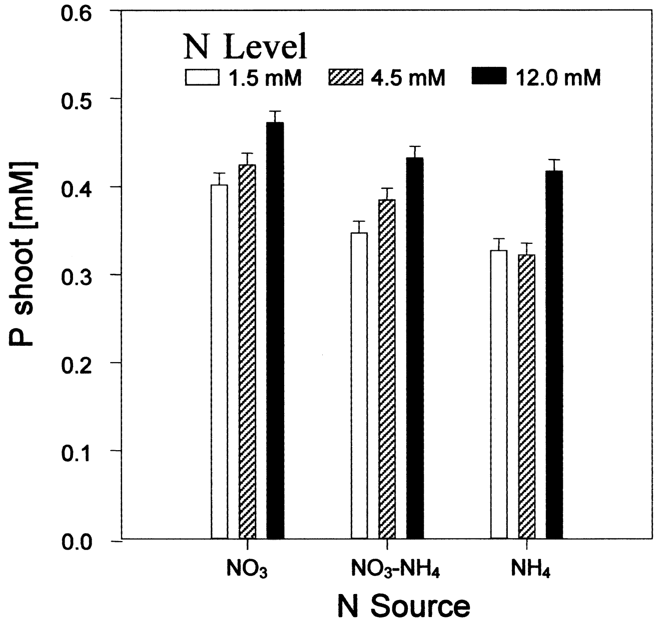

Fig. 5. Shoot phosphorus concentration of *R. raetam* grown at three N sources and three N levels of nitrogen supply in sand culture (mean values ±SEM)

Table 1
Summary of statistic analysis of plant performance and mineral composition of *R. raetam* grown at different N level × N source treatments based on Two-Way-ANOVA and Tukey-test

	Source of variation		Inter-action	Tukey-test	Tukey-test
	N Level	N Source	N Level × N Source	p < 0.05 for N Source	p < 0.05 for N Level
Dry weight (shoot)	$p < 0.001$ at all	$p < 0.001$ at all	$p < 0.001$	at 1.5 mM: NO_3 *vs* NH_4 at 4.5 mM: NO_3 *vs* NH_4 NO_3-NH_4 *vs* NH_4 at 12 mM: all	at NO_3: all at NO_3-NH_4: all at NH_4: 12.0 *vs* 1.5 4.5 *vs* 1.5
Dry weight (root)	$p < 0.001$ at all	$p < 0.001$ at NO_3 *vs* NH_4 NO_3-NH_4 *vs* NH_4	no		
N (shoot)	$p < 0.001$ at all	$p < 0.001$ at all	$p < 0.05$	at 1.5 mM: NO_3 *vs* NH_4 at 4.5 mM: all at 12 mM: all	at NO_3: all at NO_3-NH_4: all at NH_4: 12.0 *vs* 4.5 4.5 *vs* 1.5
N (root)	$p < 0.001$ at all	$p < 0.001$ at all	$p < 0.001$	at 1.5 mM: all at 4.5 mM: all at 12 mM: all	at NO_3: all at NO_3-NH_4: 12.0 *vs* 1.5 4.5 vs 1.5 at NH_4: 12.0 *vs* 1.5 12.0 *vs* 4.5
P (shoot)	$p < 0.001$ at 12.0 *vs* 1.5 at 12.0 *vs* 4.5	$p < 0.001$ at all	no		
P (root)	$p < 0.001$ at 12.0 *vs* 1.5 at 4.5 *vs* 1.5	$p < 0.001$ at all	$p < 0.05$	at 1.5 mM: NO_3 *vs* NH_4 NO_3-NH_4 *vs* NH_4 at 4.5 mM: NO_3 *vs* NH_4 NO_3-NH_4 *vs* NH_4 at 12.0 mM: all	at NO_3: all at NO_3-NH_4: 12.0 *vs* 1.5 4.5 *vs* 1.5 at NH_4: 12.0 *vs* 1.5
Cation (shoot)	$p < 0.001$ at 1.5 *vs* 12.0 at 1.5 *vs* 4.5	$p < 0.001$ at all	$p < 0.001$	at 1.5 mM: all at 4.5 mM: NO_3 *vs* NH_4 NO_3-NH_4 *vs* NH_4 at 12.0 mM: NO_3 *vs* NH_4	at NO_3: 1.5 *vs* 12.0 1.5 *vs* 4.5 at NO_3-NH_4: all at NH_4: 1.5 *vs* 4.5 1.5 *vs* 12.0
Cation (root)	$p < 0.05$ at 4.5 *vs* 12.0 at 1.5 *vs* 12.0	$p < 0.001$ at NO_3 *vs* NH_4; NO_3-NH_4 *vs* NH_4	no		

desert plants (El-Ghonemy 1977, El-Ghonemy *et al.* 1978), and higher than that reported by Ahmed and Rizk (1963) in *R. raetam* seeds.

Although an inverse effect is reported between rhizosphere pH and P uptake (Marschner 1986), P concentration in *R. raetam* was the highest at the most alkaline nitrate N level both for root and shoot (Figs 5–6). The assimilation of N has usually an important impact on ion uptake and pH balance in the plant and plant-soil interface. Nitrate and ammonium are the major sources of inorganic nitrogen taken up by the roots of higher plants. Most of the ammonium has to be incorporated into organic compounds in the roots. Nitrate is mobile in the xylem and can also be stored in the vacuoles of roots and shoots (Marschner 1986) Assimilation of nitrate causes intracellular pH increase, that has to be neutralised either by internal production of strong organic acids of excretion of alkaline OH^- into the rhizosphere (Raven and Smith 1976, Raven 1988). Thus, *R. raetam* seems to be very effective in balancing ion uptake even under extreme N-nutrition levels.

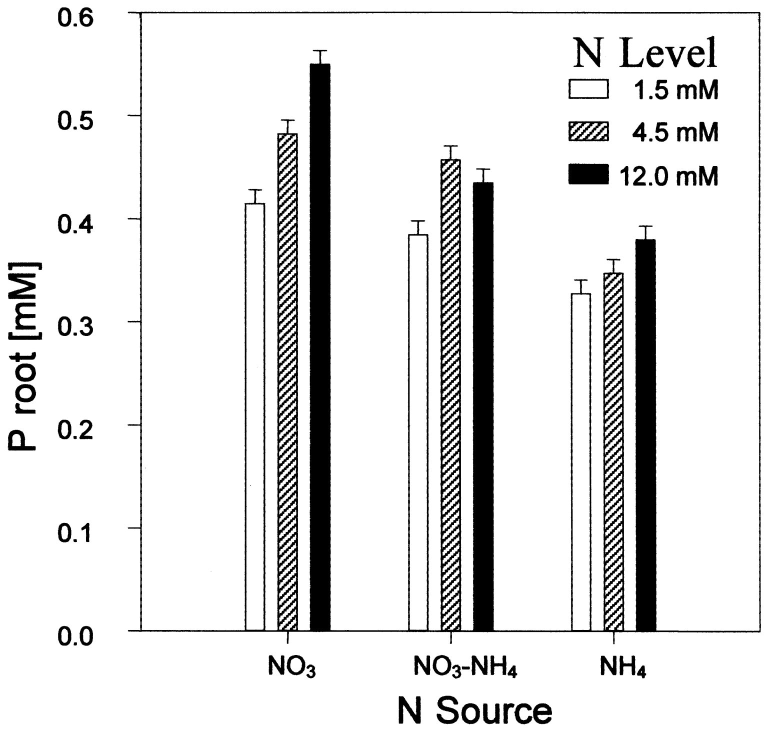

Fig. 6. Root phosphorus concentration of *R. raetam* grown at three N sources and three N levels of nitrogen supply in sand culture (mean values ±SEM)

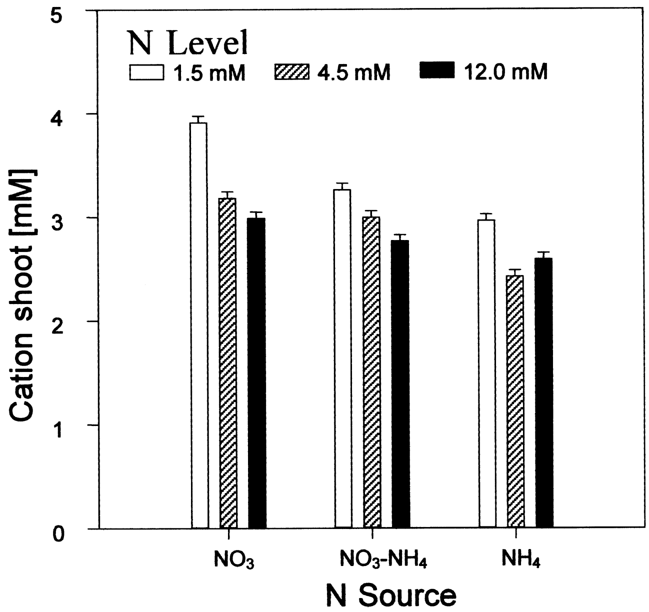

Fig. 7. Shoot cation concentration of *R. raetam* grown at three N sources and three N levels of nitrogen supply in sand culture (mean values ±SEM)

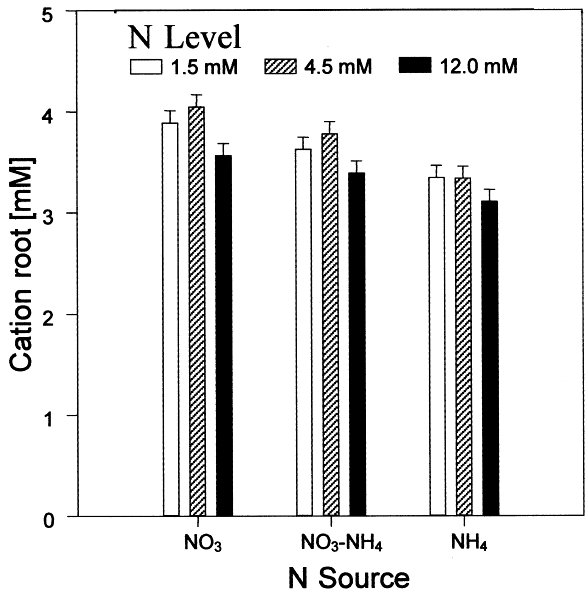

Fig. 8. Root cation concentration of *R. raetam* grown at three N sources and three N levels of nitrogen supply in sand culture (mean values ±SEM)

Nitrogen nutrition and the sink-source relationships

Most cultivated plants reduce their root biomass relative to their shoot production, if N supply is increased. *Retama raetam* is an exception since this plant obviously utilised roots as important storage reservoir. The fact that *R. raetam* increase the relative root biomass with increasing N supply – independent from the N source – is a substantial evidence for the plants special adaptation to desert conditions.

CONCLUSION

The mineral household of *R. raetam* seems to be well adapted to unfavourable desert habitat conditions by a surplus of N shoot storage over cations with increasing N supply independent from the N source.

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