Differences Among *Triticum dicoccum*, *T. monococcum* and *T. spelta* in Rate of Nitrate Uptake

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Abstract: Three groups of wheat cultivars *Triticum dicoccum*, *T. monococcum* and *T. spelta* were grown hydroponically under controlled conditions. At the age of 21 days, the plants were analysed to determine their rate of nitrate uptake, the net NO_3^- uptake capacity and total nitrogen content. The rate of nitrate uptake varied from 2.7 (*T. dicoccum*) to 9.3 (*T. monococcum*) μmol NO_3^-/g FW/h; in the economically important species *T. spelta* it ranged between 3.1–6.9 μmol NO_3^-/g FW/h. In *T. diccoccum* and *T. spelta* these values represent about 80–90% estimated V_{max}. Both groups were significantly different from *T. monococcum*. This collection was characterized by the highest V_{max} but its nitrate uptake rate per g fresh weight reached only 45–67% V_{max}. Within each group there were the intra-specific differences. Nitrate uptake capacity of the individual species or varieties was significantly affected by differences in development of root system. These results were compared with registered cultivar *T. aestivum* cv. Munk.

Keywords: nitrate uptake; *Triticum dicoccum*; *Triticum monococcum*; *Triticum spelta*

Nitrogen, one of the most important macronutrients, is consumed in the greatest quantity and most often limits plant growth. Its concentration in soil solution can range from less than 1mM to more than 10mM, depending on environmental factors and fertilizer supply (Marschner 1995). The first step in NO_3^- acquisition by plants is the active transport across plasma membrane of root cells. Physiological studies have demonstrated at least three different NO_3^- uptake systems in plants (for review see Forde 2000). Plants grown in the environment without nitrates have constitutive high affinity system (cHATS) with low K_m and V_{max}. When NO_3^- are presented in the cultivation media for some hours or days, inducible transport system with higher parameters K_m (20–100μM) and V_{max} (3–8 μmol NO_3^-/g of roots/h) indicated as iHATS is induced. In the environment with high nitrate concentration (over 500 μmol) low affinity transport system (LATS) is responsible for additional acceleration of nitrate uptake (Crawford & GLass 1998).

The primary aim of this study was to find inter-species and intra-species differences in nitrate uptake by wheat plants.

MATERIAL AND METHODS

Three species of wheat (*T. dicoccum*, *T. monococcum* and *T. spelta*) were grown hydroponically under 16 h/8 h photoperiod at temperatures 22°C/15°C, respectively (Table 1). Nutrient solution containing 158μM Ca $(NO_3)_2$, 70.5μM KNO_3, 55.2μM KH_2PO_4, 41.3μM $MgSO_4$, 47.5μM KCl and micronutrients were aerated continuously and replaced two times a week. At the age of 21 days, the wheat plants were analyzed to determine their dry weight, the net rate of NO_3^- uptake, the net NO_3^- uptake capacity and total nitrogen content of shoot and root. The nitrate uptake rates were estimated by depletion from the medium. Intact plants were transferred into fresh nutrient solution with 300μM NO_3^-. The rate of nitrate uptake was determined from the dynamics of NO_3^- depletion and it was expressed as μmol NO_3^- per 1 g of root fresh weight per hour (μmol NO_3^-/g FW/h). Nitrate uptake capacity of the whole root system was expressed as μmol NO_3^- per plant per hour (μmol NO_3^-/plant/h). Maximum rate of nitrate uptake (V_{max}) was calculated using data analysis program Enzffiter (Biosoft, Cambridge, UK).

Table 1. List of tested species and cultivars

Number	Cultivar	Origin
	Triticum dicoccum	
1	*T. dicoccom* (Kroměříž)	
2	*T. dicoccom* (Prague-Ruzyně)	
3	Kahler Emmer	GER
4	May-Emmer	CHE
5	Weisser Sommer	GER
6	*T. dicoccom* (Tapioszele)	
7	Krajova-Podbranc (Toman)	CSK
8	Poering Jaarma (Nachitchevan.)	AZE
9	*T. dicoccom* (Balkan)	
	Triticum monococcum	
10	*T. monococcum* (Leningrad)	SUN
11	Escana	ESP
12	*T. monococcum*	GEO
13	*T. monococcum*	ALB
14	*T. monococcum* (Tabor)	
15	*T. monococcum* No.8910	DNK
	Triticum spelta	
16	*T. spelta* (Kroměříž)	CSK
17	Fuggers Babenhauser Zuchtweize	GER
18	*T. spelta* (Uhříněves)	CSK
19	Baulaender Spelz	DEU
20	Ostro	CHE
21	Altgold	CHE
22	Oberkulmer Rotkorn	CHE
23	Redoute	BEL
24	Rubiota	CZE
25	Franckenkorn	DEU
	Triticum aestivum	
M	Munk	DEU

Dried shoot and root were ground up and digested in sulphuric acid; total nitrogen content was estimated spectrophotometrically using Scalar San ^{PLUS} Analyzer and Bertholet reaction.

RESULTS AND DISCUSSION

Under the experimental conditions use, the current rate of nitrate uptake varied from 2.7–4.0 μmol NO_3 at *T. dicoccum* to 5.6–9.3 μmol NO_3^-/g FW/h at *T. monococcum* seedlings. In the economically important species *T. spelta* it was 3.1–6.7 μmol NO_3^-/g FW/h (Figure 1 and 2). In depletion experiments most tested cultivars (except *T. dicoccum*, cultivars No. 8 and 9) exhibited features of saturable kinetics. The highest V_{max} values (about 13.3 μmol NO_3^-/g FW/h) were found in *T. monococcum* group, the lowest in *T. dicoccum* (in average 4.7 μmol NO_3^-/g FW/h). High intra-species differences were found within collection of *T. spelta*. Cultivar No. 20 (V_{max} 3.66 μmol) which was significantly different from the values for cultivars No. 23, 26 and 16; their V_{max} 7.7–8.4 is similar to modern registered cultivar of bread wheat *T. aestivum* cv. Munk. Both plant cultivation and depletion experiments were conducted at nitrate concentrations below 0.4mM. Under such conditions, the rate of nitrate uptake corresponds to the activity of inducible high affinity transport system. Inducible components of HATS were isolated and cloned from several higher plant species e. g. *Arabidopsis thaliana* (Filleur & Daniel-Vedele 1999), *Nicotiana plumbaginifolia* (Fraisier *et al*. 2000), *Zea mays* (Quaggiotti *et al*. 2003), and more recently *Hordeum vulgare* (Tong *et al*. 2005). At sufficient NO_3^- supply, current rate of nitrate uptake in *T. spelta* roots represented about 80–90% estimated V_{max}, or (in case of cultivars No. 18 and 19) approached it. On the other hand, in roots of *T. monococcum* this ratio is relatively low – only 45–60%.

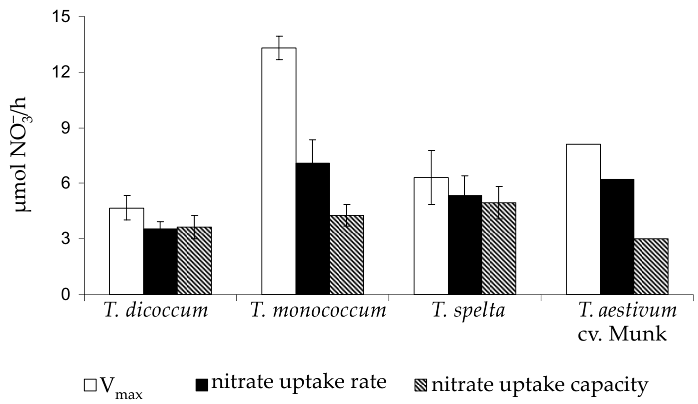
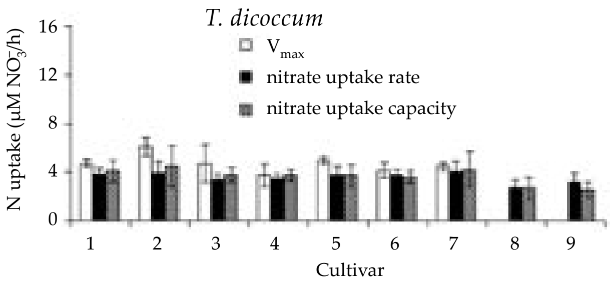
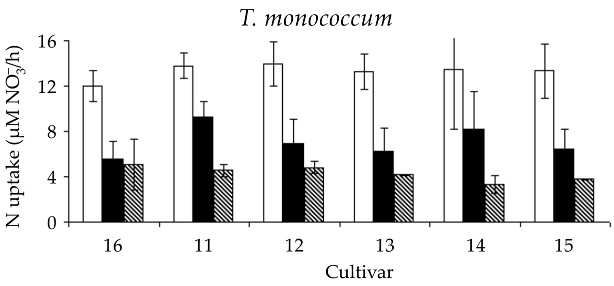


Figure 1. Inter-species differences in nitrate uptake
V_{max} = maximum rate of nitrate uptake (μmol NO_3^-/g FW/h); nitrate uptake rate = rate of NO_3^- uptake per g of fresh root (μmol NO_3^-/g FW/h); nitrate uptake capacity = rate of NO_3^- uptake per plant root system (μmol NO_3^-/plant/h)





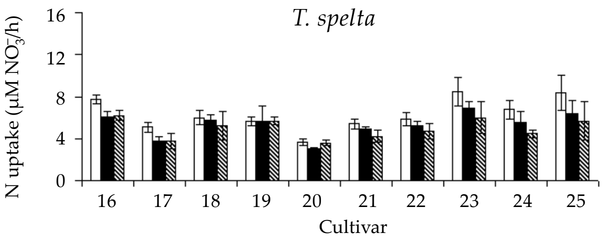


Figure 2. Intra–species differences in nitrate uptake V_{max} – maximum rate of nitrate uptake (μmol NO_3^-/g FW/h), nitrate uptake rate – rate of NO_3^- uptake per g of fresh root (μmol NO_3^-/g FW/h), nitrate uptake capacity – rate of NO_3^- uptake per plant root system (μmol NO_3^-/plant/h)

The net rate of NO_3^- uptake per plant, specified as "nitrate uptake capacity", is strongly modified by root development. It was found, that the rate of nitrate uptake by root of wheat reached its maximum at tillering, the increase of net uptake capacity at the later stages of development was caused mainly by enlargement of root system (Trčková & Kamínek 2000). In all tested species the NO_3^- uptake capacity was higher in comparison to bread wheat cv. Munk. Moreover, within each group there were found the intra – species differences.

Inter-species and varietal differences in total nitrogen content were rather low; under the experimental conditions uses, they varied between 0.61–0.69% in root and 0.73–0.82% in shoot, respectively (results did not shown). Higher concentrations were found only in root of *Triticum dicoccum* (0.67–0.81%). The main fraction of acquired nitrogen was accumulated in shoot; this part represented 67% at *T. monococcum*, 75% (*T. dicoccum*) or more at *T. spelta* and *T. aestivum* cv. Munk (Figure 3).

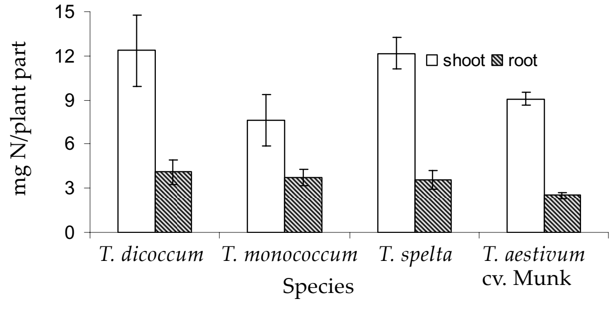


Figure 3. Intra–species differences in nitrogen allocation

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