Effect of Genotype Variability on Nitrate Uptake and Assimilation of Wheat Cultivars

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ABSTRACT

Nitrate concentration of the soil, at the start of growing season, is high due to mineralization of soil organic N during the Fall and the addition of N fertilizers. It may be useful to exploit this N form as much as possible. Therefore, the nitrate uptake, assimilation and dry matter production of several wheat cultivars were examined in a series of experiments using a hydroponic culture system. Seedlings were grown at two rates of nitrates (0 and 1.0 mM) and the experiments lasted for 26 days. Significant genetic variation in the growth and nitrate uptake were observed. The Atila and Yavarous cultivars consistently produced large seedlings absorbing higher quantities of nitrate from the nutrient solution, compared to the Falat, Star and Seri 11 cultivars which produced smaller seedling and took up lower amounts of nitrate. However, apart from seedling vigor, there was evidence that some cultivars were more efficient physiologically in assimilating nitrate. For comparable amounts of nitrate taken up from solution, total dry matter production in this group of cultivars was considerably greater than others. Results of this work revealed that genetic differences among wheat cultivars affect nitrate uptake, which in turn indicated the influence of plant status and in particular root system on the potential of nitrate uptake.

Keywords: Genetic variability, Nitrate assimilation, Nitrate uptake, Wheat.

INTRODUCTION

Ammonium and nitrate are the most important N forms utilized by cereals although urea is also supplied to plants as fertilizer. Nitrate, however, is the most common form of N taken up by cereal plants in the field, and efficient utilization of soil and fertilizer N is an important and desirable agronomic character in wheat (*Triticum astivum L.*). Under most soil conditions, ammonium fertilizer is rapidly nitrified to nitrate by soil organisms (Epstein, 1972; Addiscott *et al.*, 1991; Ehdaie and Waines, 2001). In the early growth season, nitrate tends to be high in the soil and so it would be desirable to utilize as much of this form as possible. There are clear indications that activation of its absorption by plants is under genetic control (Epstein, 1972; Banziger *et al.*, 1991; Moghaddam *et al.*, 1998) and that considerable differences exist among cultivars. The variation is due to differences in the size and morphology of the roots, the demand for mineral elements caused by differences in relative growth rate (Schimansky and Marschner, 1971; Isfan, 1993), uptake and transport (Rroco and Mengel, 2000), and use efficiency. This present study evaluated the genetic variations of wheat cultivars for nitrate uptake and its assimilation rate at the seedling stage. Based on differences in nitrate uptake and dry matter its accumulation, wheat cultivars were categorized into two main groups (Fathi, present communication). Fong, Star and Falat were small plants, which took up less nitrate but had higher relative growth rates than the semi-dwarf cultivars, Atila, Atrak and Showa. Therefore, the preliminary experiments were undertaken to investigate a greater number of

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cultivars representing four genetic groups. The aim of this study was to examine the response of the wheat cultivars to nitrate use looking at nitrate uptake and dry matter production in a larger number of cultivars.

MATERIALS AND METHODS

This study was conducted as three separate experiments due to insufficient space in the glasshouse. Nineteen wheat cultivars obtained from the collection of the Ahwaz Agricultural Station in Khuzestan were used (Table 1). They were either commercial cultivars or advanced breeding lines. The cultivars were classified into four groups according to their similarity pedigree:

- Group 1: cultivars derived form semidwarf parents, with high nitrate demand. Atlia and Showa were assigned as the leading cultivars.
- Group II: cultivars which are mostly derived form Khuzestan wheat breeding cultivars. The leading cultivar of this group, Falat, has been found to have low nitrate demand in the early growth stage.
- Group III: cultivars derived either from Veenac or Atrak. Star, the leading cultivar in this group, has low nitrate demand.
- Group IV: the leading cultivar Fong has been recognized as a high demand cultivar.

Table 1. Pedigree of wheat cultivars used for the study of nitrate uptake.

Cultivars	Pedigree
Group I	
Atila	Kauzs × Seri 82
ChenAltar	Ogusta / Sefid
Seri 20	Kauz/ Lopatare / Kauz
Yavarous	Semit 5 × mald 3
Seri 11	Turaca / Chil
Group II	
Falat	Vees (5) × Kauz 1
Arvand	Rosan × Karj
Darab 2	Maya × Nac 11
Chenab	Mrbi 1 × Snipe
Coleah	Iraq × Selection (M98)
Group III	
Atrak	Kauz 5 Selection inter
Star	SWM 7215 / Trt
Maron	Arvand × Snb, S
Veenac	Vee 41/Mice Research
Showa	Shwa / Mald / Aza / Srn
Group IV	
Fong	Vee 9/3 / Coox / Doves
Zagrous	Tans / Oputa / Vee
Cemareh	Omrabi-5 / Awalbit–3
Kavir	M-75 –18 / Red

Growth Conditions

Seeds were sterilized by immersion in 70% ethanol for 1 minute, soaked for 5 minutes in 1% sodium hypochlorite and thoroughly rinsed with de-ionized water. The seeds were then sown in square plastic pots containing sterilized sand. Pots were irrigated with de-ionized water in a glasshouse at 20 ±4°C temperature and with a 12 h. photoperiod.

Eight days after emergence the seedlings were moved to 6 L round plastic tanks with plastic lids. Each lid had 25 holes. Seedlings were supported by inserting their roots through holes in the base of tubes (7-ml capacity) which were placed in the lid holes. Twenty-four seedlings were placed in each pot and grown for 26 days in a hydroponic system culture in a 1 mM nitrate solution (Table 2) at a pH of 7.0. The nutrient solution in each pot was renewed at 10, 15 and 19 days after seedling transfer. On day 20, the plants were transferred to a nitrate free solution (Table 2) for 24 h. and then the plants were harvested (H_1). The remaining plants were transferred to a 1 mM nitrate solution during which time the solutions were changed every 48 h. On day 26 (H_2) the remaining 12 plants (H_2) were harvested and roots and shoots were separated. The experimental design was a randomized complete block with four replicates.

Table 2. Compositions of solutions used for hydroponic studies of nitrate uptake and assimilation.

	Nitrate solutions	
	0.0 mM	1.0 mM
	(mg L^{-1})	
KNO_3	-	34.1
$Ca(NO_3)_2$, $4H_2O$	-	79.9
$MgSO_4$, $7H_2O$	7.6	7.6
KH_2PO_4	10.2	10.2
K_2SO_4	218.0	189.4
$CaSO_4$,$2H_2O$	430.5	372.7
Trace elements [a]	0.36	0.36
Fe-EDTA	21.8	21.8

[a] ($MnSO_4$, $7H_2O$ 28mg L^{-1}, Na_2 MoO_4, $2H_2O$ 6mg2^{-1}, $CaSO_4$, $5H_2O$14mg L^{-1}, NaCl 145 mg L^{-1}, $ZnSO_4$, $7H_2O$ 18mg L^{-1}, $CuSO_4$, $5H_2O$ 31 mg L^{-1}, H_3BO_3 116 mg L^{-1})

Measurements

The nitrate concentration of the nutrient solution was measured in the solutions before the first harvest (H_1), and between H_1, and the final harvest (H_2). The absorbence of the nutrient solution was measured using a spectrophotometer (model lambda 5, UK) at 210 nm wave length (1). Nitrate concentrations of plant parts at H_1 and H_2 were measured as unreduced nitrate by the E. coli method (McNamara *et al.*, 1971). The relative growth rate (RGR), nitrate assimilation, nitrate assimilation efficiency (NAE) and nitrate uptake efficiency (NUE) were determined. Growth rate was calculated based on an increment of the total dry weight during six days.

Linear regressions were calculated for (a) the increase in nitrate between H_1 and H_2 day period and the increase in dry weight over the same time, and (b) the total nitrate uptake over 26 d and total dry weight at H_2. To compare the response of different groups of cultivars, the slopes and intercepts of the regressions was compared using SAS methods.

Definition of Parameters

Plants were partitioned into shoots and roots after harvest, dried at 80°C for two days and their dry weights measured.

- The relative growth rate was calculated as RGR= $(LnW_2-LnW_1)/\ (t_2-t_1)$, where W_1 and W_2 are total plant dry weights at times t_1 and t_2.
- Nitrate accumulation was calculated from the difference between the nitrate content in root and shoot at H_1 and H_2.
- Nitrate assimilation was estimated by subtracting the nitrate accumulation in both shoot and root from total nitrate taken up by the plants during the 34 h.

RESULTS

The inclusion of the Group 1 cultivars in each experiment allows a comparison to be made between the three experiments. The general consistency in nitrate uptake and growth of Group 1 cultivars in these experiments allows the results of the experiments to be compared.

Experiment 1

There were significant differences in root and shoot growth among the cultivars, which were not related to their cultivar groupings (Table 3). Seri 11 and ChenAltar (Group I) and Arvand and Chenab (Group II) produced significantly more root growth than the other cultivars at both harvests. A similar difference, although not as large, was observed also with shoot growth. Falat had the greatest RGR and the smallest plants. The growth rates of the 10 cultivars were not significantly different from one another, however there were differences in the RGR. Seri 20 is not a semidwarf but had quite a different RGR. There were significant differences between cultivars both in total amount of nitrate taken up over the six days and in the nitrate, which accumulated in the plant tissue (Table 4).

However, as with the dry matter and growth rate data, there was no clear distinction between the two groups. There was no significant difference between cultivars in Groups I and II in nitrate uptake per g root dry weight (Table 4). Total nitrate uptake per plant did not differ significantly between Seri 20 and ChenAltar, Arvand and Chenab but Seri 20, Arvand and Chenab took up significantly more nitrate than the other cultivars. Falat and Darab2 had the lowest total nitrate uptake (Table 4). The relationship between an increase in plant dry matter and uptake of nitrate over the six days for the

Table 3. Effect of 1mM nitrate on root, shoot and total dry matter production and growth rate of 10 wheat cultivars in experiment 1.

Cultivar	Root (mg $plant^{-1}$)		Shoot (mg $plant^{-1}$)		Total (mg $plant^{-1}$)		RGR [c]	GR [d]
	H_1 [a]	H_2 [b]	H_1	H_2	H_1	H_2	(mg $plant^{-1}$ day^{-1})	(mg $plant^{-1}$ day^{-1})
Group1								
Atila	62	114	176	401	237	514	13.2	46
Yavarous	53	102	171	398	223	501	13.4	46
Seri 11	67	114	168	420	234	532	13.1	50
Seri 20	87	142	222	447	308	588	10.8	47
ChenAltar	75	138	188	480	262	618	14.3	59
Group II								
Falat	39	94	106	311	144	406	17.4	44
Darab2	48	95	163	407	210	501	14.3	48
Chenab	83	163	230	464	313	627	11.6	52
Coleah	70	114	196	370	266	484	9.9	36
Arvand	77	165	225	512	303	679	13.5	63
LSD (5%)	16	23	38	80	53	95	3.8	NS

[a] Harvest1, [b] Harvest2, [c] Relative growth rate, [d] Growth rate.

Table 4. Total nitrate concentration, increase in nitrate uptake, nitrate uptake per root dry weight and indices of N use efficiency of wheat cultivars in experiment 1.

	Total NO_3^- uptake (μ mol $plant^{-1}$) (0-26 day)	NO_3^- uptake (μ mol $plant^{-1}$) (20-26 day)	NO_3^- uptake (μ mol $root^{-1}Dw^{-1}$ d^{-1}) (20-26 day)	$\Delta DM/\Delta NO_3^-$ uptake (20-26 day)	Total NO_3^- uptake (0-26 day)
Group1					
Atila	1838	956	3699	0.301	0.286
Yavaraous	1812	937	4002	0.305	0.283
Seri 11	1758	856	3117	0.337	0.299
Seri 20	2234	1185	3461	0.233	0.263
ChenAltar	2169	1181	3695	0.306	0.286
Group 2					
Falat	1450	827	4100	0.346	0.282
Darab2	1659	857	4022	0.339	0.305
Chenab	2246	1202	3340	0.264	0.279
Coleah	1918	952	3465	0.230	0.254
Arvand	2450	1374	3774	0.274	0.276
LSD (5%)	285	216	NS	NS	NS

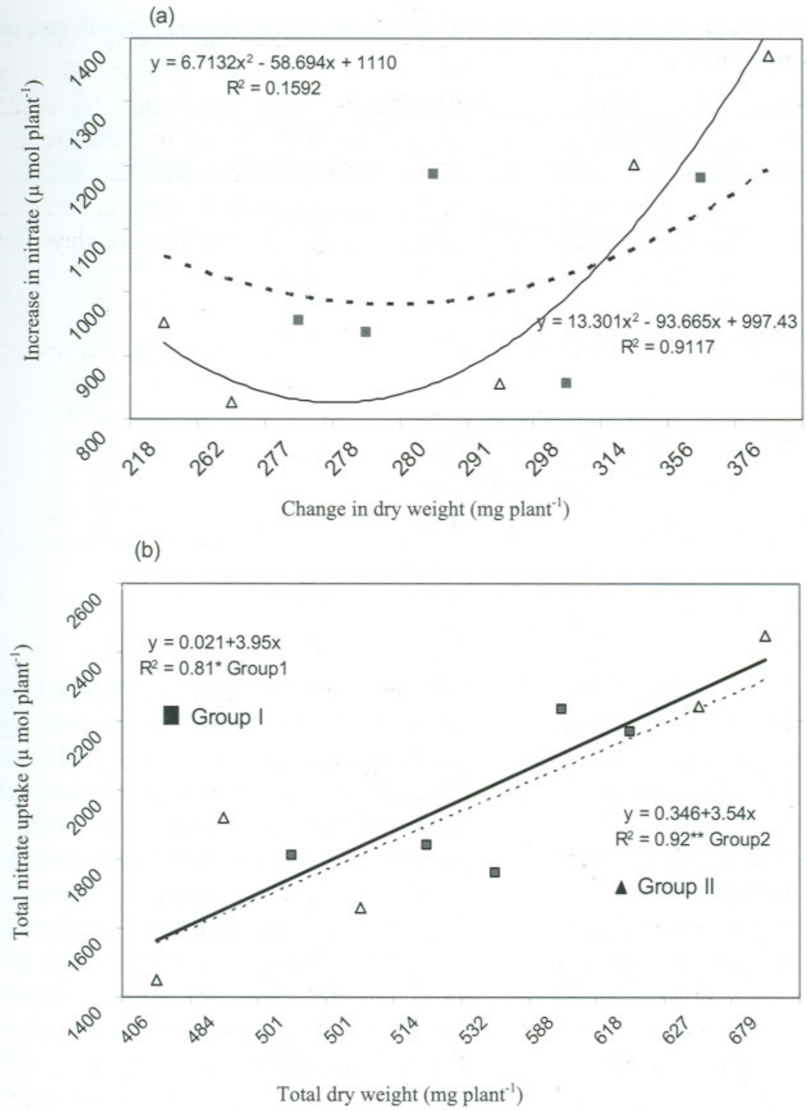


Figure 1. Relationship between an increase in dry weight and nitrate over 6 days, and total dry weight and total nitrate uptake over 26 day for 10 wheat cultivars in Experiment 1.

two groups were not significant (Figure 1a). There were significant linear relationships between the total nitrate uptake of the plants and the total dry weight at H_2 (Figure 1b), but a comparison of the regressions showed that the relationships between dry matter production and nitrate uptake are not significantly similar. There was no significant difference in two indices of N use efficiency (TDM/ nitrate uptake, ΔDM/ Δnitrate) between the wheat cultivars (Table 4).

Experiment 2

There were significant differences between the ten wheat cultivars in root, shoot and total plant dry weights at both harvests (Table 5). At the first harvest, Seri 20 and Maron had significantly higher root growth than the other cultivars. The remaining cultivars did not differ significantly. At the second harvest, root dry weights of Veenac, Atrak, Showa, Yavarous, Star, Seri 11 and

Table 5. Effect of 1mM nitrate on root, shoot and total dry matter production and growth rate of wheat cultivars in experiment 2.

	Root (mg plant^{-1})		Shoot		Total		RGR [c]	GR [d]
	H_1 [a]	H_2 [b]	H_1	H_2	H_1	H_2	(mg plant^{-1} day^{-1})	(mg plant^{-1} day^{-1})
Group I								
Atila	88	168	192	396	280	563	11.80	47
Yavaraous	86	140	189	382	276	522	10.71	41
Seri 11	69	150	170	386	239	537	13.61	50
Seri 20	130	198	242	468	371	663	9.75	49
ChenAltar	95	163	204	481	305	667	13.62	55
Group III								
Star	71	147	148	351	218	497	14.11	47
Maron	121	234	268	538	390	773	11.44	64
Atrak	78	127	157	318	235	445	10.88	35
Veenac	66	122	149	295	216	416	11.63	33
Showa	65	130	146	337	210	475	13.64	44
LSD (5%)	28	49	52	90	80	129	2.73	13

[a] Harvest1, [b] Harvest2, [c] Relative growth rate, [d] Growth rate.

Atila were not significantly different but those of Maron and Seri 20 were again greater. Shoot dry weight was higher in Maron, Seri 20, Atila and Yavarous than in the others at first harvest. It was higher in Maron and Seri 20 and lowest in Showa, Star and Veenac at the secod harvest.

In experiment 2, as in experiment 1, the differences in growth were between cultivars rather than between the two groups. RGR was significantly different between cultivars and ranged from 14.11 mg plant^{-1} in Star to 9.75 mg plant^{-1} in Seri 20. Within Group I cultivars, the RGR of Seri 20 was significantly lower than that of Seri 11 (Table 5). The high RGR for Star is consistent with the results of the preliminary experiment. The growth rates of the semidwarf cultivars in experiment 2 were similar to those in experiment 1. The significant difference in growth rate is largely due to the high growth rate of Maron; there was no significant difference in the growth rates of the other cultivars. Total nitrate uptake per plant differed

Table 6. Total nitrate content, increase in nitrate uptake and nitrate uptake per root dry weight in experiment 2.

	Total NO_3^- uptake (μmol plant^{-1}) (0-26 day)	NO_3^- uptake (μmol plant^{-1}) (20-26 day)	NO_3^- uptake (μ mol root^{-1} Dw^{-1} d^{-1}) (20-26 day)	ΔDM/ ΔNO_3^- uptake (20-26 day)	Total NO_3^- uptake (0-26 day)
Group1					
Atila	1994	1249	3272	0.227	0.282
Uavaraous	1871	1146	3373	0.218	0.289
Seri 11	1771	1110	3360	0.269	0.303
Seri 20	2282	1413	2920	0.208	0.291
Chenalter	2156	1091	3519	0.302	0.279
Group III					
Star	1655	1047	3292	0.266	0.300
Maron	2484	1487	2836	0.259	0.311
Atrak	1563	954	3108	0.225	0.289
Veenac	1511	870	3062	0.244	0.275
Showa	1589	1031	3368	0.262	0.310
LSD (5%)	481	296	NS	NS	NS

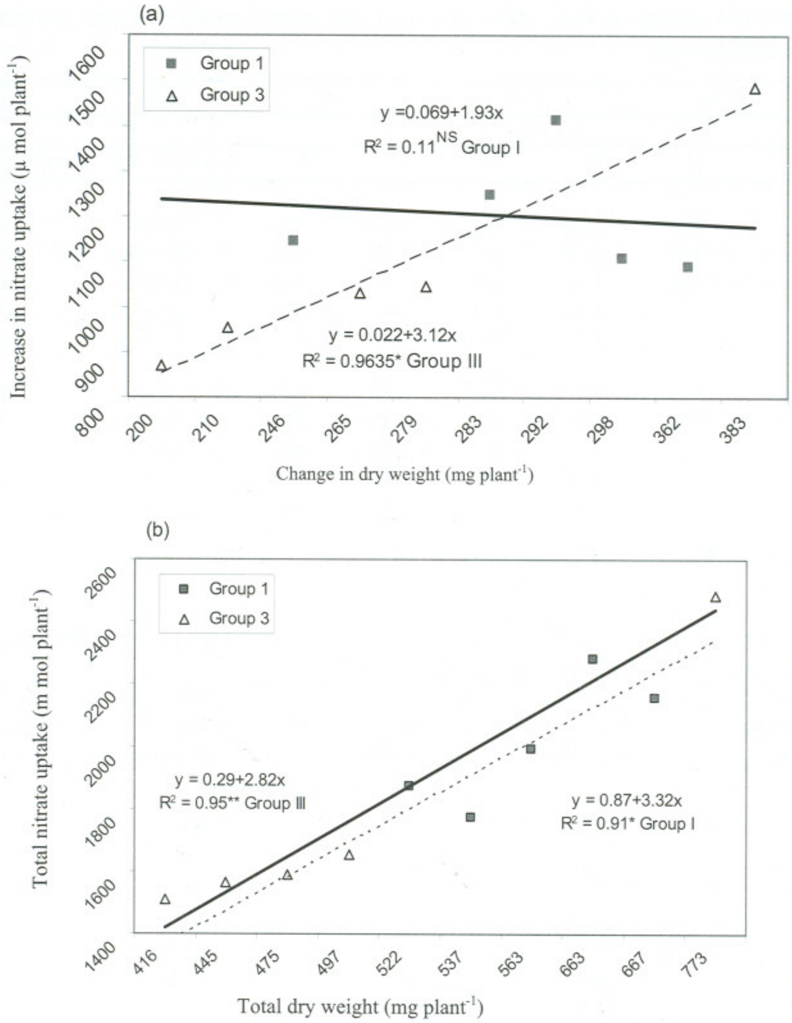


Figure 2. Relationship between an increase in dry weight and nitrate over 6 days, and total dry weight and total nitrate uptake over 26 days for 10 wheat cultivars in Experiment 2.

between cultivars but nitrate per g root dry weight did not differ significantly. Maron had a significantly higher nitrate uptake than the other cultivars, while Veenac had the lowest uptake (Table 6).

The relationship between an increase in nitrate uptake and change in dry weight over the six days for the two groups were not significant (Figure 1a.). However, there were positive relationships between total nitrate uptake and total dry weight for cultivars in both groups (Figure 2b). Maron was different from the other Group II cultivars because of its high dry matter production and high nitrate uptake. However, comparisons of the regressions demonstrated statistically significant differences. Therefore, the relationships between nitrate uptake and plant dry matter for Groups I and III are similar. There were no significant differences between cultivars for either TDM/ nitrate uptake or ΔDM/ Δnitrate (Table 6).

Experiment 3

The 9 wheat cultivars differed significantly in dry matter production at both har-

Table 7. Effect of 1mM nitrate on root, shoot and total dry matter production and growth rate of wheat cultivars in experiment 3.

	Root		Shoot		Total		RGR[c]	GR[d]
	(mg plant^{-1})							
	H_1[a]	H_2[b]	H_1	H_2	H_1	H_2	mg plant^{-1} day^{-1}	mg plant^{-1} day^{-1}
Group I								
Atila	85	161	186	367	269	528	11.62	44
Yavaraous	62	105	153	290	216	394	10.30	30
Seri 11	80	131	166	291	246	420	8.12	29
Seri 20	110	173	192	411	303	590	11.37	49
ChenAltar	99	160	195	409	304	385	12.33	50
Group IV								
Fong	54	145	129	400	184	545	19.67	59
Zagrous	53	124	130	304	183	429	14.12	40
Cemareh	59	117	134	310	192	427	12.70	39
Kavir	83	172	174	368	256	540	11.96	48
LSD (5%)	22	23	30	81	43	90	6.1	15

[a] Harvest 1, [b] Harvest 2, [c] Relative growth rate, [d] Growth rate.

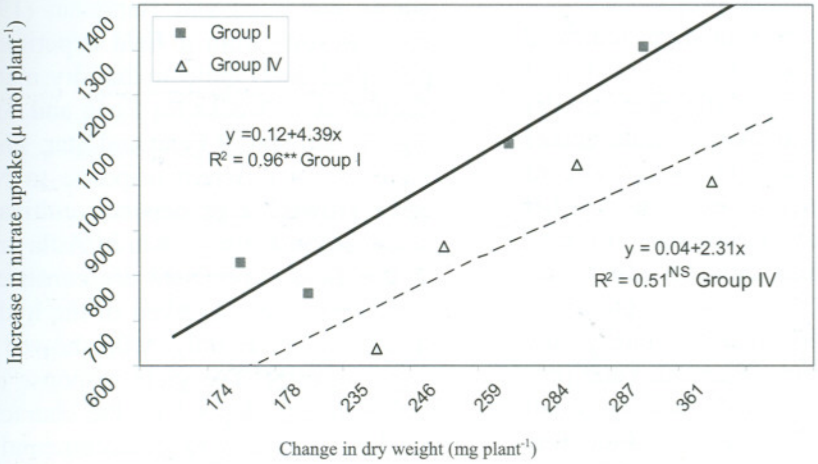
Table 8. Total nitrate content, increase in nitrate uptake and nitrate uptake per root dry weight, and indices of N use efficiency of wheat cultivars in experiment 3.

	Total NO_3^- uptake (μmol plant^{-1}) (0-26 day)	NO_3^- uptake (μmol plant^{-1}) (20-26 day)	NO_3^- uptake (μ mol root^{-1} Dw^{-1} d^{-1}) (20-26 day)	$\Delta DM/\Delta NO_3^-$ uptake (20-26 day)	Total NO_3^- uptake (0-26 day)
Group1					
Atila	1807	1090	2993	0.241	0.296
Yavaraous	1286	758	2940	0.250	0.323
Seri 11	1377	828	2545	0.192	0.303
Seri 20	2143	1307	3053	0.222	0.277
ChenAltar	2012	1200	2913	0.202	0.289
Group IV					
Fong	1883	1007	3341	0.461	0.294
Zagrous	1439	863	3151	0.290	0.301
Cemareh	1242	638	2230	0.404	0.335
Kavir	1786	1047	2659	0.266	0.315
LSD (5%)	261	161	590	NS	NS

vests (Table 7). Root dry matter production of Seri 20 was significantly higher than the other cultivars at the first harvest. Fong, Zagrous, Cemareh and Yavarous had the lowest root dry weight at the first harvest. At the second harvest, root dry weight was higher in Seri 20, Kavir and Atila and lower in Yavarous, ChenAltar and Zagrous. Shoot dry weight did not differ between Seri 20, Atila, Kavir and Seri 11 but was significantly higher for these than the others at the first harvest. There were also no differences between Seri 11, Fong, Kavir and Atila in shoot growth at the second harvest, but it was low in Seri 11, Zagrous, Cemareh and Yavarous (Table 7). Total plant dry weight at H_1 was not different between Seri 20, Atila, Kavir and Seri 11 but was lower in Zagrous, Fong, Cemareh and Yavarous. At the second harvest, plant dry weight did not differ between Seri 20, Fong, Atila and Kavir but was different in Zagrous, Cemareh, Seri 11 and Yavarous (Table 7).

The time period of experiment 3 was shorter than the other two experiments and the semidwarf cultivars showed lower growth rates and nitrate uptake than Seri 11 and Yavarous, which is inconsistent with experiments 1 and 2. RGR was significantly different between cultivars due to the high RGR of Fong, there were few significant differences (Table 7). There were also significant differences between cultivars in growth rate. Fong had a much higher growth rate than the other cultivars (Table 8).

Atila, Zagrous, Cemareh, Yavarous and Seri 11 did not differ in their growth rates. Seri 11 and Yavarous were significantly lower in growth rate than Seri 20, Kavir and Fong. There were a significant differences in the NO_3^- uptake between these cultivars (Table 8). Cemareh had a significantly lower uptake that the other cultivars. However, they were no differences among Atila, Seri 20, and Fong which they had high NO_3^- uptake. Nitrate uptake per plant also differed among the wheat cultivars, Seri 20 had a significantly higher uptake than all other cultivars except Fong. Nitrate uptake was low in Zagrous, Seri 11, Yavarous and Cemareh. The linear correlation between the change in plant dry weight and NO_3^- uptake over the six days was significant for the Group I but not for Group IV



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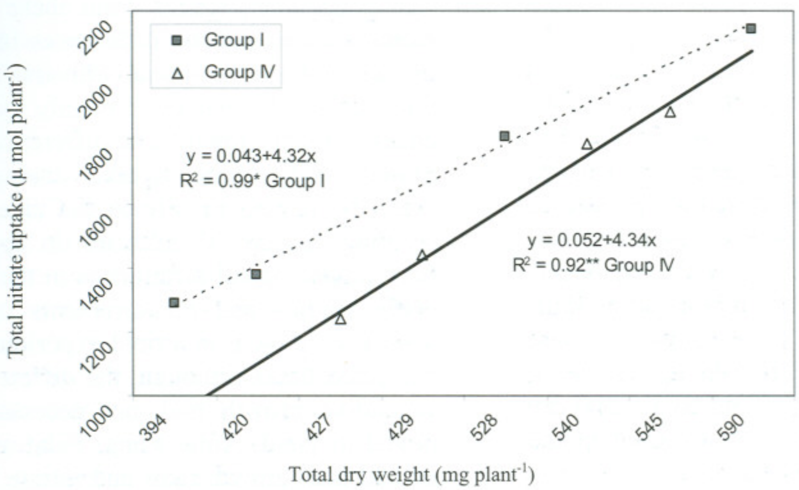

Figure 3. Relationship between an increase in dry weight and nitrate over 6 days, and total dry weight and total nitrate uptake over 26 days for 9 wheat cultivars in Experiment 3.

(Figure 3a). There were significant linear correlations between the total nitrate uptake and the total dry weight at H_2 (Figure 3 b). A comparison of the regression indicated that Groups IV and I, had the same slopes but different intercepts, i. e. the lines were parallel. Therefore, nitrate uptake in Group IV, was lower for the same amount of day matter production. This trend was observed in the ΔDM/ Δnitrate and TDM/ nitrate, where the values for the Group IV cultivars tended to the higher than these of Group I, although the difference was not significant.

DISCUSSION

The results of this present study indicated that in seedlings of wheat cultivars, 1 mM nitrate solution caused differences in dry weight of the root and shoot, nitrate uptake and nitrate assimilation. The major aim of these experiments was to examine whether there were any genetic differences in nitrate uptake in these cultivars. The results reported suggested that at least two groups of cultivars could be identified as one group. The first group, namely, Star and Falat produced small seedlings and took up small amounts of nitrate. The second group was the semidwarf cultivars including Atila and Yavarous, which took up a greater amount of nitrate.

The trend of an increased nitrate uptake with greater plant dry weight over six days in experiment 1 was not statistically different between the two groups (Figure 1a), which suggests that the differences between cultivars were mainly related to the size of the plant. There were differences in dry matter production, which were reflected in differences in NO_3^- uptake. In both the preliminary experiments and in experiment 1, there was a consistent result among cultivars, namely Atila had high nitrate uptake and dry weight, whereas Falat had low nitrate uptake and dry weight (Tables 3 and 4).

The genetic differences in nitrate uptake appeared to be largely due to the differences in the size of the plants, particularly roots, rather than differences in the ability of cultivars to assimilate nitrate. There were few differences in the rate of nitrate uptake per g root, indicating the size of root system was responsible for differences in NO_3^- uptake. Perby and Jensen (1983) found that the differences in N uptake of wheat cultivars were related to root size. In addition, differences among the wheat cultivars in net ion uptake may also be due to different flux rates into and out of the roots (Webb, 1995; Sinclair, 1998; Rroco and Mengel, 2000).

In all the experiments, cultivars which appeared to grow more vigorously took up more nitrate. These results are in agreement with those of Ehdaie and Waines (2001) for wheat and Reed and Hangman (1980) for corn. Results from a field experiment (unpublished data) indicate that dry matter production at 10 weeks for Fong and Atila was higher than that of Falat and Star. Therefore, there was a different response to N at the early growth stage between cultivars. The responses in early growth in Atila and Fong in this field experiment are consistent with those responses observed in the hydroponic studies, however only Atila showed a grain response to N. The yield response of cultivars will also depend on the characteristics of their response to environmental conditions during latter stages of growth, particularly to water and temperature stresses.

In conclusion, results from these experiments showed genetic differences in nitrate uptake between the wheat cultivars. The differences can be explained mainly by differences in plant growth. The difference in the growth and nitrate uptake characteristic could be related mainly to the size of the seedling. Group IV cultivars do appear to have physiological differences in the hydroponic studies and measurements of early vegetative growth in a field experiment (unpublished data), although, the differences in vegetative growth may not necessarily be linked to yield. Atila, Fong, Falat and Star all had high growth rates and nitrate uptake, but in a field experiment the grain yield of Atila, and Falat were responsive to N in grain yield, while soil N fertilization had no significant effect on the grain yield of Fong and Star. Therefore, high vegetative growth early in the growing season, although promoting NO_3^- uptake from the soils, is not always related to the final grain yield response. However, it is possible to have a cultivar such as Atila that can take up nitrate more efficiency and which may be more responsive to increased nitrate in the soil during growing season.

REFERENCES

1. Addiscott, T. M., Whitmore, A. P. and Powlson, D. S. 1991. *Farming Fertilizer and the Nitrate Problem*. CAB International. Wallingford, UK. 170 pp.
2. Banziger, M., Feil, B., Schmid, J. E. and Stamp, P. 1992. Genotypic Variation in Grain N Content of Wheat as Affected by Mineral N Supply in the Soil. *Eur. J. Agron.*, **1**: 155-162.
3. Edhaie, B., and Waines, J. G. 2001. Sowing Date and N Rate Effects on Dry Matter and N Partitioning in Bread and Durum Wheat. *Field Crops Res.*, **73**: 47-61
4. Epstein, E. 1972. *Mineral Nutrition of Plants: Principles and Perspective*, Wiley John and Sons, New York, U. S. A. pp: 325-344.
5. Glass, A. D. M., and Perely, J. E. 1980. Varietal Differences in Potassium Uptake by Wheat. *Plant Physiol.*, **62**: 160-164.
6. Isfan, D. 1993. Genotypic Variability for Physiological Efficiency Index of N in Oats. *Plant Soil.*, **154**: 53-59.
7. McNamara, A. L., Meeker, G. B., Shaw, P. D. and Hageman, T. 1971. Use of Assimilator Nitrate Reducates from *Escheirchia coli* and Formate as a Reductive System for Nitrate Assays. *J. Agric. Food Chem.*, **19**: 229-231.
8. Moghaddam, M., Ehdaie, B. and Waines, J. G. 1998. Genetic Variation for and Interrelationships among Agronomic Traits in Landraces of Bread Wheats from Southwestern Iran. *J. Gent. Breed.*, **52**: 73-81.
9. Perby, H., and Jensen, P. 1983. Varietal Difference in Uptake and Utilization of N and other Microelements in Seedlings of Wheat. *Physiol. Plant.*, **58**: 223-230.
10. Reed, A. J. and Hageman, R. H. 1980. Relationship between Nitrate Uptake, Flux, and Reduction and the Accumulation of Reduced N in Maize: I. Genotypes Variation. *Plant Physiol.*, **66**: 1179-1183.
11. Rroco, E. and Mengel, K. 2000. N Losses from Entire Plants of Spring Wheat (*Titicum aestivum*) from Tillering to Maturation. *Eur. J. Agron.*, **13**: 101-110.
12. Schimansky, C. and Marschner, H. 1971. Suitability Uptake by Wheat, Maize and four Varieties of Barley. *Z. Pflanzenernahe.*, **129**: 141-147.
13. Sinclair, T. R. 1998. Historical changes in Harvest Index and Crop N Accumulation. *Crop Sci.* **38**: 638-643.
14. Webb, J., and Bradley, R. 1995. A Comparison of the Response of Two Cultivars of Late-autumn-sown Wheat to Applied N. *J. Agric. Sci. Cambridge.*, **125**: 11-24.