IN THE NAME OF ALLAH,
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Studying the Variation in Nitrogen Use, Uptake and Utilization Efficiency in Different Barley Genotypes under Different N Application Levels in Jordan

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Abstract. Greenhouse experiment was carried out to evaluate the variation in yield, N use efficiency, N uptake efficiency and N utilization efficiency in different barley genotypes under three different N application levels. Three different barley groups were used, namely wild progenitors of barley (*Hordeum spontaneum*), landraces and two improved varieties (Rum and Acsad 176). Broad genetic variation was detected in the studied genotypes in grain yield, biological yield, and N use, uptake and utilization efficiency. Rum variety significantly showed the highest grain yield and grain N use efficiency, whereas the Jordanian landraces and Acsad 165 variety exhibited moderate values. However, among the *H. spontaneum* accessions, we were not able to identify N use effective genotypes. Two *H. spontaneum* accessions were distinguished by high N utilization efficiency under low and high N levels. The obtained results suggest that some Jordanian barley germplasm appears to have a potential source of genes for widening the genetic variation for N use, uptake and utilization efficiency.

Introduction

Plants that are efficient in absorption and utilization of nutrients greatly enhance the efficiency of applied fertilizers, reducing input costs and preventing losses of nutrients to the ecosystem. Therefore, plant breeders are much concerned with producing cultivars with improved nitrogen use efficiency. Large differences are known to exist among species and cultivars in absorption, translocation, and utilization of mineral nutrients (Baligar *et al.*, 2001). The improvement of N use efficiency (NUE) in barley cropping system can be achieved through two main strategies; (i) adopting more efficient crop management practices (such as nutrient rate, timing of N application, and placement), and (ii) breeding more nutrient use efficient cultivar. Genotypic variation in N efficiency could generally be attributed to high N uptake and/or high N utilization (Sattelmacher *et al.*, 1994).

Nitrogen is one of the largest input costs that growers face in barley production in Jordan, typically accounting for at least 20-30% of variable costs depending on crop rotation (Bdour and Abdel-Ghani, 2008). According to Al-Rawashdeh and Abdel-Ghani (2008), Jordanian soils are suffering from N deficiency, which is mainly due to high calcium carbonate content in the soil (15-35%), alkaline soil pH (ranging from 7.7 to 8.0) and low soil organic matter (<1%). In such soils, N could be lost in gaseous form, mainly as ammonia (NH_3) by volatilization (Koelliker and Kissel, 1988), whereas much as 70% of N fertilization applied to the soil surface could be lost by NH_3 volatilization (Whitehead and Raistrick, 1990; Sigunga *et al.*, 2002). Therefore, under these conditions, maximization of NUE is essential to improve the economic yield, to give the opportunity for farmers to reduce their input cost per unit area, and to minimize the environmental impact of nitrogen application. So, breeding and selecting varieties with high NUE under low N stress condition were interesting objectives for plant breeders (Wang *et al.*, 2003; Xu *et al.*, 2006; Pei *et al.*, 2007).

Wild barley (*Hordeum vulgare* subsp. *spontaneum* (C. Koch) Thell, in short *H. spontaneum*) is the sole progenitor of cultivated barley (Harlan and Zohary, 1966), while barley landraces (*Hordeum* *vulgare* L. ssp. *vulgare,* in short *H. vulgare*) have evolved through natural as well as farmer-directed selection (Harlan, 1975; Frankel *et al.*, 1995). Natural populations of *H. spontaneum* and barley landraces from the Fertile Crescent show a high degree of variability in morphological and developmental traits, disease resistance, protein content, and allozymes (Nevo *et al.*, 1984; Weltzien, 1988, 1989; Weltzien and Fischbeck, 1990; Jaradat, 1991, 1992). Landraces and wild barley were reported to be as a rich source of genes for adaptation to environments where drought stress is common (Ceccarelli and Grando, 1991; Grando and Ceccarelli, 1995). However, there is little information about NUE of barley germplasm from Jordan as a part of Fertile Crescent. Therefore, the objective of this study was to compare the differences in yield, N use efficiency, N uptake efficiency and N utilization efficiency in different barley genotypes under different N application levels. In this study, a genetically broad material of barley from arid and semiarid environments from Jordan was used, including *H. spontaneum*, old landraces and two improved varieties.

Materials and Methods

Plant materials and experimental conditions

Eight genotypes from three different groups have been tested: 3 *H. spontaneum* (wild barley, in short W) accessions, 3 barley landraces (in short, L), and two improved varieties (Rum and Acsad 176). The pot experiment was carried out under greenhouse conditions in 2004/2005 growing season at Mutah University Agricultural Experimental Station in Karak (31º 03' N, 35º 40' E), Jordan. Wild barley and barley landraces were collected from three different eco-geographical regions in Jordan, namely; Mafraq (32° 21' N, 36° 12' E), Ajloun (32° 24' N, 35° 49' E), and Shoubak (30° 32' N, 35° 35' E), while the two improved varieties were generously provided by the National Center for Agricultural Research and Extension (NCARE). *H. spontaneum* and barley landraces are two-row, while improved varieties are from the six-row type. The plastic pots used in this study were 20 cm in diameter and 40 cm deep. The pots were filled with 8 kg soil taken from a field which was left fallow for many years. The soil used in this investigation is calcareous which was collected from the soil surface (0-15 cm), and thereafter, air-dried, ground, pass through 5 mm mesh screen and thoroughly mixed. The soil used in the pot experiment contained 56% sand, 15% silt, 29% clay, alkaline pH of (7.8), 1.3% organic matter, 640 ppm total nitrogen (N), 18 ppm available (olsen) phosphorus (P), 464.2 mg available potassium (K) kg^{-1} soil, 22% calcium carbonate, cation exchange capacity (CEC) of 52.7 dS m^{-1}, and electrical conductivity EC (1:1) of 0.4 dS m^{-1}. The sowing was done on December 15, 2004 and 10 seeds were sown 2 cm deep in each pot. One week after sowing, the seedlings were thinned to 5 plants pot^{-1}. The experiment had three N treatments; no N application as control (0 kg ha^{-1}), intermediate N application (20 kg N ha^{-1}) and high N application (40 kg N ha^{-1}) and eight barley genotypes as plant materials. The treatment combinations were replicated three times. N was applied in two portions; the first portion was applied before planting and the second portion was added at early boot stage as urea (46%). The experiment was watered and weeded as required during the experiment.

Estimation of biomass N use efficiency, grain N use efficiency, N uptake efficiency and N utilization efficiency

At maturity (i.e. 50% of peduncles turned yellow) the five plants in each pot were harvested, and afterwards the plants were separated into straw and grains, and then dried for 48 hours at 75°C in force-draft oven to constant weight. The samples were analyzed for total N content using the standard macro-Kjeldahl procedure. N uptake was determined by multiplying dry weight of plant parts (grain and straw) by nitrogen concentration and summing over parts for total plant uptake. Biomass N use efficiency (i.e. N use in grain and straw) (NUE_1), grain N use efficiency (NUE_2), N uptake efficiency (NUE_3), and N utilization efficiency (NUE_4) were computed following the definitions suggested by Moll *et al.* (1982) as follows:

$$NUE_1 = \frac{Biomass\ in\ fertilized\ pot\ \left(g\ plant^{-1}\right) - biomass\ in\ control\ pot\ \left(g\ plant^{-1}\right)}{Quantity\ of\ N\ applied\ \left(g\ plant^{-1}\right)}$$

$$NUE_2 = \frac{Grain\ yield\ in\ fertilized\ pot\ \left(g\ plant^{-1}\right) - \text{Grain}\ yield\ in\ control\ pot\ \left(g\ plant^{-1}\right)}{Quantity\ of\ N\ applied\ \left(g\ plant^{-1}\right)}$$

$$NUE_3 = \frac{\text{Biomass}\,N-uptake\ \ in\ \ fertilized\ \ pot\ \ \left(g\ \ plant^{-1}\right) - \ Biomass\,N-uptake\ \ in\ \ control\ \ pot\ \ \left(g\ \ plant^{-1}\right)}{Quantity\ \ of\ \ N\ \ \ applied\ \ \left(g\ \ plant^{-1}\right)}$$

$$NUE_4 = \frac{\text{Grain}\ yield\ \ in\ \ fertilized\ \ pot\ \ \left(g\ \ plant^{-1}\right) - \ \text{Grain}\ yield\ \ in\ \ control\ \ pot\ \ \left(g\ \ plant^{-1}\right)}{\text{Biomass}\,N-uptake\ \ in\ \ fertiliyed\ \ pot\ \ \left(g\ \ plant^{-1}\right) - \ Biomass\,N-uptake\ \ in\ \ control\ \ pot\ \ \left(g\ \ plant^{-1}\right)}$$

Statistical analysis

The experimental design was a randomized complete block design (RCBD) with factorial arrangement of treatments (genotypes and N application levels) with three replications. Analysis of variance (ANOVA) was used to test genotype and N application rate effects as well as their interaction. Data were analyzed by two way analysis of variance using the SAS statistical package (SAS institute, 2003), and the differences between the means were compared using Fisher's least significant difference (LSD) at $P \leq 0.05$ (Steel and Torrie, 1980).

Results and Discussion

The differences among varieties in yield and N uptake

A broad variation was found among the investigated barley genotypes in grain yield and biological yield (Tables 1 and 2), while genotypes did not significantly differ in straw yield regardless of N application levels. The highest grain yield was obtained in improved varieties (range = 2.13 to 2.84 g plant^{-1}), followed by landraces (range = 1.77 to 2.28 g plant^{-1}), while the lowest grain yield was recorded *H. spontaneum* accessions (range = 0.72 to1.07 g plant^{-1}). Biological yield ranged over varieties from 4.83 to 8.29 g plant^{-1} variety; biological yield obtained by Rum variety (8.29 g plant^{-1}) was significantly higher than biological yields recorded by other genotypes (range 4.83 to 6.45 g plant^{-1}). On the other hand, differences of N uptake amount between genotypes were significant regardless of N application rate. N uptakes amount in grain, straw and biomass of improved varieties and landraces were significantly higher than *H. spontaneum* genotypes; grains N uptakes were ranged from 35.22 to 52.42 mg N plant^{-1}, from 30.68 to 36.24 mg N plant^{-1}, and from 5.18 to 17.56 mg N plant^{-1}, while biomass N uptake efficiency ranged from 38.72 and 60.9 mg N plant^{-1}, ranged from 36.44 to 43.27 mg N plant^{-1} and from 11.0 and 18.89 mg N plant^{-1} in improved varieties, barley landraces and *H. spontaneum* accessions, respectively. These results are in line with previous studies (Moll *et al.*, 1982; Ortiz-Monasteri *et al.*, 1997; Al-Rawashdeh and Abdel-Ghani, 2008) which revealed high genetic variability among genotypes within the same species in N uptake efficiency.

Effect of N application rate on yield and N uptake

Grain yield, straw yield and biological yield were affected significantly ($P \leq 0.01$) by increasing N application rate (Table 1). The increase in these two parameters was more prominent with increasing N application level (Table 2). These results indicate that plants grown in soils with sufficient amount of available N could accumulate more dry matter and N in their tissue and consequently more grain yield. Soil N is an important factor which plays a key role in achieving quantitatively and qualitatively high yields; it has been estimated that on average only 40-60% of mineral N-dressing is taken up by the crop and that percentage decreases as the N-input increases, resulting in higher residual soil N amounts that can readily be leached (Ortiz-Monasterio *et al.*, 1997; Foulkes *et al.*, 1998; Austin, 1999; Raun and Gordon, 1999; Derici and Schepers, 2001).

Mean squares of analysis of variance revealed significant effects of N application level on N uptake in plant tissue (Table 1); grain N uptake in grain and total above ground biomass increased with increasing N application rate, whereas straw yield N uptake was significantly decreased with increasing soil N application rate. The results in Table 2 show that grain and biomass N uptakes were increased by three and two times when N was applied at 20 kg N ha^{-1} and by two and three times when N applied at 40 kg ha^{-1}, respectively, as compared with their respective controls.

Interactive effects of genotypes and N on yield and N uptake

The interactive effect of genotypes and N levels on grain yield, straw yield and biological yield are shown in Table 4. Grain yield was significantly increased in all barley genotypes by 20 kg N ha^{-1} application compared to the control treatment, while increasing N application to 40 kg ha^{-1} significantly increased the grain yield only in Rum and Mafraq (L) as compared with 20 kg ha^{-1} N application treatment. Similarly, biological yield in all tested genotypes was significantly increased by 20 kg N ha^{-1} application;

however, further significant increases in biological yield was recorded at 40 kg N ha^{-1} as compared with 20 kg N ha^{-1} in all tested barley genotypes except *H. spontaneum* accession collected from Ajloun and the two landrace barley accessions collected from Ajloun and Shoubak. That Rum gave the highest grain and biological yield with N application might indicate that the new selected germplasm produces higher grain yield and biological yield when grown under intermediate or high levels of N. Similarly, more recent CIMMYT bread wheat cultivars out-yielded old cultivars and exhibited an increase in nitrogen use efficiency under medium to high N fertility (Ortiz-Monasteri *et al.*, 1997), pointing that the current strategy of selecting and evaluating new varieties under medium to high N levels has resulted in germplasm that produces higher yield when grown under medium or high levels of N fertility. CIMMYT bread wheat from 1950 to 1985 gradually not only became more responsive to N fertilization, but also more efficient in using applied N. Our results also in line with Bumb (1995), who reported that the increase in yield potential using new high yielding varieties is possible only with adequate application of fertilizers.

Table 4 shows the interactive effect of genotypes and N application levels on grain, straw and biomass N uptake. In general, improved varieties and barley landraces showed the highest biomass and grain N uptakes, and the highest grain yield at the same time, demonstrating that the higher grain and total above ground biomass N uptake of improved varieties and landraces were mainly due to their higher grain yield compared with *H. spontaneum* accessions. Papakosta and Gagianas (1991) and Nagarajan (1999) reported differences among genotypes in N uptake n in grain and straw, depending on environmental factors. The N uptake was higher in grain than in straw (Table 2), indicating the remobilization of N from vegetative parts to grains (Tables 2 and 3). In accordance, Yoshida (1972) reported that N uptake for wheat plants are associated with soil fertility level; large movement of pre-stored N reserves in source organs to sink organs (i.e. grains) can occur under low soil fertility conditions.

Table 1. Analysis of variance for the effects of variety and salt level on the grain yield , biological yield, straw yield, Grain N uptake, Biomass N uptake and Straw N uptake

Character	Replication (2 d.f.)	Genotype (G) (7 d.f.)	Nitrogen rate (N) (2 d.f.)	G × N (14 d.f.)	Error (46 d.f.)
Grain Yield (g plant^{-1})	0.065	33.32**	35.90**	14.11**	17.80
Biological Yield (g plant^{-1})	1.59	78.20*	429.14**	187.54*	224.17
Straw yield (g plant^{-1})	0.89	23.92**	120.84**	13.82	31.88
Grain N uptake (mg plant^{-1})	167.37	14871.57**	12885.65**	6150.88**	5316.17
Biomass N uptake (mg plant^{-1})	240.02	14614.41**	9444.80**	6305.73**	4483.07
Straw N uptake (mg plant^{-1})	2.56	280.50**	206.82**	327.86**	80.96

*. ** Significant at 0.05 and 0.01 probability level, respectively.

Table 2. Effect of different nitrogen rates and genotypes and their interactions on some agronomic traits and N uptake

	Grain yield (g plant^{-1})	straw yield (g plant^{-1})	Biological yield (g plant^{-1})	Grain N uptake (mg plant^{-1})	Straw N uptake (mg plant^{-1})	Biomass N uptake (mg plant^{-1})
Nitrogen rate (Kg N ha^{-1})						
0	0.73^{c}	1.74^{c}	2.86^{b}	9.70^{c}	9.87^{a}	18.78^{c}
20	1.98^{b}	4.21^{b}	3.95^{b}	30.92^{b}	5.90^{c}	36.82^{b}
40	2.39^{a}	4.70^{a}	8.84^{a}	41.94^{a}	6.83^{b}	47.26^{a}
LSD (0.05)	0.36	0.67	1.28	6.25	0.77	5.74
Genotypes (G)						
Mafraq (W)	0.72^{c}	3.30^{bc}	5.80^{b}	5.18^{d}	6.70^{cde}	11.00^{d}
Mafraq (L)	1.81^{b}	3.04^{bc}	4.83^{b}	31.77^{b}	5.62^{e}	37.40^{bc}
Ajloun (W)	1.07^{c}	4.88^{a}	5.64^{b}	17.56^{c}	12.01^{a}	29.57^{c}
Ajloun (L)	1.77^{b}	3.55^{bc}	5.14^{b}	30.68^{b}	5.76^{e}	36.44^{bc}
Shoubak (W)	0.98^{c}	3.74^{b}	4.97^{b}	11.07^{cd}	7.81^{bc}	18.89^{d}
Shoubak (L)	2.28^{ab}	3.59^{bc}	6.45^{ab}	36.24^{b}	7.02^{cd}	43.27^{b}
ACSAD 65	2.13^{b}	2.83^{c}	5.95^{b}	35.22^{b}	5.95^{de}	38.72^{bc}
RUM	2.84^{a}	3.48^{c}	8.29^{a}	52.42^{a}	8.47^{b}	60.90^{a}
LSD (0.05)	0.58	1.09	2.09	10.2	1.26	9.37
N x G	**	NS	**	**	**	*

[1] Within treatment (genotype and N application rate) means within each column followed by the same letter are not significantly different at $P < 0.05$ according to LSD.

Table 3. Interactive effects of different barley genotypes and nitrogen rates on grain and straw yield, biological yield, grain N uptake, straw N Uptake and biomass N uptake

Genotype	Nitrogen Rate (kg N ha^{-1})	Grain Yield (g plant^{-1})	Straw Yield (g plant^{-1})	Biological Yield (g plant^{-1})	Grain N Uptake (mg plant^{-1})	Straw N Uptake (mg plant^{-1})	Biomass N Uptake (mg plant^{-1})
Mafraq (W)	0	0.26 h	1.41 a	1.67 i	1.55 l	7.88 d-f	9.43 j
	20	0.76 gh	3.85 a	4.61 e-i	5.71 j-l	5.78 f-i	11.49 ij
	40	1.16 f-h	9.97 a	11.12 b	8.29 i-l	6.45 e-h	12.09 ij
Mafraq (L)	0	0.62 gh	1.45 a	2.07 i	10.44 i-l	6.20 e-h	16.64 h-j
	20	1.91 d-f	3.05 a	4.96d-i	29.45 e-h	4.99 HI	34.44 d-g
	40	2.92 bc	4.55 a	7.47c-e	55.44 bc	5.67 g-i	61.10 b
Ajloun (W)	0	0.83 gh	1.53 a	2.35 h-i	13.89 h-l	3.64 i	17.53 h-j
	20	2.30 c-e	4.50 a	6.80 c-f	37.92 c-g	7.62 d-g	45.54 b-e
	40	2.21 c-e	4.04 a	6.25 c-g	40.25 b-f	6.02 e-h	46.24 b-e
Ajloun (L)	0	0.69 gh	4.44 a	5.13 d-i	4.36 kl	20.51 a	24.87 f-j
	20	1.15 f-h	4.87 a	6.02c-g	25.29 f-i	7.53 d-g	32.82 e-h
	40	1.37 e-g	4.39 a	5.76 c-h	23.01 f-j	7.99 c-e	31.01 e-h
Shoubak (W)	0	0.54 g-h	2.12 a	2.66 g-i	2.25 l	10.11 c	12.35 ij
	20	1.06 f-h	3.57 a	4.63 e-i	12.34 h-l	5.99 e-h	18.33 g-j
	40	1.34 e-g	6.29 a	7.62 b-e	18.64 h-l	7.34 d-g	25.98 f-i
Shoubak (L)	0	1.31 e-g	2.35 a	3.66 f-i	20.30 g-k	8.74 cd	29.04 f-h
	20	2.87 b-c	4.30 a	7.17 c-f	43.59 b-e	6.19 e-h	49.77 b-d
	40	2.67 b-c	5.84 a	8.51 b-d	44.85 b-e	6.14 e-h	50.99 bc
ACSAD 65	0	1.01 f-h	1.72 a	2.73 g-i	15.07 h-l	7.82 d-g	22.90 g-j
	20	2.48 b-d	3.50 a	5.98 c-g	36.73 d-g	4.35 hi	41.08c-f
	40	2.90 b-d	6.25 a	9.16 b-c	53.85 b-d	5.68 g-i	52.17bc
RUM	0	0.60 gh	2.03 a	2.63g-i	9.76 i-l	13.38 b	23.14 g-j
	20	3.33 b	4.07 a	7.40 c-e	56.32 b	4.75 hi	61.06b
	40	4.58 a	10.28 a	14.85 a	91.19 a	7.30 d-g	98.49 a
LSD (0.05)		1.0	-	3.63	17.67	2.18	16.23

Genotype means within each column followed by the same letter are not significantly different at $P < 0.05$ according to LSD.

Table 4. Analysis of variance for the effects of variety and salt level on the biomass N use efficiency (NUE_1), grain N use efficiency (NUE_2), N uptake efficiency (NUE_3), and N utilization efficiency (NUE_4)

Character	Replication (2 d.f.)	Genotype (G) (7 d.f.)	Nitrogen rate (N) (1 d.f.)	G × N (7 d.f.)	Error (34 d.f.)
NUE1	9379.12	92597.70**	38308.13**	38245.33	90852.63
NUE2	527.43	15845.55**	944.74	1674.22	8103.84
NUE3	226599.70	5586129.88**	595858.56**	792203.79	2330607.20
NUE4	5.56×10^{-3}	4.5×10^{-2}	4.60×10^{-4}	8.90×10^{-3}	4.70×10^{-2}

N use, uptake and utilization efficiency

The interactive effects of genotypes and N application levels on NUE components were not significant (Table 4); for this reason, the results of the mean values of NUE components of the genotypes are presented separately for each N application level (Table 5). The effect of N fertilization was highly significant on biomass N use efficiency and N uptake efficiency, while grain yield N use efficiency and N utilization efficiency was not significantly affected (Table 5). Increasing N application rate from 20 to 40 kg N ha^{-1} significantly increased biomass N use efficiency from 78.46 to 134.96 g biomass g^{-1} N applied and N uptake efficiency from 441.11 to 663.94 mg N uptake in grain g^{-1} N applied, whereas a slight increase in grain yield N use efficiency and N utilization efficiency was detected, although non-significant. Based on grain yield N use efficiency, improved cultivars and Jordanian barley landraces were found to use N with the highest efficiency, whereas *H. spontaneum* accessions exhibited an almost two to four times lower grain N use efficiency. Similarly, Gorny (1991) found that cultivars and breeding lines from Syria and Ethiopian landraces were distinguished by a high N use efficiency under low N nutrition and they were recommended as donors germplasm under N stress conditions. Moreover, a broad variation was found among tested barley genotypes in the efficiency of N uptake and utilization at low and high N levels (Table 5). Under intermediate and high N levels, improved varieties and barley landraces exhibited medium to high N uptake efficiency values, while *H. spontaneum* accessions were not used N effectively. The two *H. spontaneum* accessions collected from Mafraq (W) and Ajloun (W) were found to utilize the soil N with

Table 5. Biomass N use efficiency (NUE_1), grain N use efficiency (NUE_2), N uptake efficiency (NUE_3), and N utilization efficiency (NUE_4) as affected by nitrogen rates and barely genotypes

Genotype	NUE1		NUE2		NUE3		NUE4	
	$g_{biomass}\ g^{-1}\ N_{applied}$		$g_{grain}\ g^{-1}\ N_{applied}$		$mg\ N_{uptake\ in\ biomass}\ g^{-1}\ N_{applied}$		$g_{grain}\ mg^{-1}\ N_{uptake\ in\ biomass}$	
	20 kg N ha^{-1}	40 kg N ha^{-1}	20 kg N ha^{-1}	40 kg N ha^{-1}	20 kg N ha^{-1}	40 kg N ha^{-1}	20 kg N ha^{-1}	40 kg N ha^{-1}
Mafraq (W)	74.87 abc	240.58 a	12.63 cd	22.74 bc	52.4 d	67.7 d	0.120 a	0.16 a
Mafraq (L)	73.52 abc	137.38 abc	32.74 bc	58.50 ab	453.0 bc	1131.8 ab	0.063 b	0.05 b
Ajloun (W)	22.57 c	16.15 c	11.69 d	17.34 c	202.4 cd	156.1 cd	0.023 c	0.04 b
Ajloun (L)	113.27 a	99.21 c	37.55 b	35.13 abc	712.9 ab	730.7 abc	0.063 b	0.05 b
Shoubak (W)	50.25 bc	126.41abc	13.37 cd	20.37 c	152.2 d	346.8 cd	0.053 b	0.11 ab
Shoubak (L)	89.34 ab	123.51abc	39.66 b	34.78 bc	527.8 b	558.8 bcd	0.070 b	0.057 b
ACSAD 65	82.51abc	106.97 bc	37.37 b	66.86 ab	462.9 bc	1022.4 ab	0.067 b	0.057 b
RUM	121.33 a	229.58 a	69.40 a	69.67 a	965.4 a	1297.10 a	0.060 b	0.043 b
Mean	78.46 b	134.96 a	31.80 a	40.67 a	441.1 b	663.94 a	0.065 a	0.071 a
LSD (0.05)	61.76	124.08	20.63	36.52	280.4	650.53	0.020	0.091

Genotype means within each column followed by the same letter are not significantly different at $P < 0.05$ according to LSD.

the highest efficiency, whereas the landraces, *H. spontaneum* accessions Shoubak (W) and improved varieties exhibited an almost two to three times lower utilization efficiency, indicating the high variation in protein content in the eight tested barley genotypes. That wild and weedy cereals posses genes that can contribute to high grain-protein percentage that have been previously demonstrated in wild barley (Nevo and Beiles, 1992), wild wheat (Lefy and Feldman, 1987), and wild oat (Frey *et al.*, 1984). Similarly, Sinebo *et al.* (2004) studied the N efficiency in barley and found significant genotypic differences for N uptake and N utilization under sub-optimal N supply. Prestel *et al.* (2004) successfully selected N efficient maize genotypes when screening was performed under low N levels. Kassel and Becker (1999) found a high genetic variation in 70 genotypes of rape from different groups including lines and hybrids.

The differences of N efficiency in different genotypes and its analysis

Based on average grain yield and average grain N-use efficiency (NUE2) obtained under high N application rate (Tables 2 and 5), tested barley genotypes could be classified into three groups. The first group was efficient and responsive (ER). ER group included genotypes having the above average grain yield and N use efficiency; barley landraces collected from Mafraq, Acsad 176 and Rum fall into this group. The second group contained genotypes that are non-efficient and responsive (NER). These genotypes produced above average grain yield, but N use efficiency was lower than the average. Landraces collected from Ajloun and Shoubak fall into this group. Genotypes showed below average grain yield and N use efficiency formed the third group (non-efficient and non-responsive, NENR). The three wild barley genotypes fall into this group. However, efficient and non-responsive (ENR) genotypes were not identified. From a practical point of view, the genotypes, which fall into the ER group, are the most desirable because they can produce well with an efficient use of soil N. Genotypes belong to this group can be used in improving the yield potential of barley.

Conclusion

In conclusion, improved varieties and landraces had higher grain N use efficiency under low and high N supply due to its ability to increase grain mass to a greater extent than to *H. spontaneum* accessions. Moreover, some *H. spontaneum* accessions exhibited high N utilization efficiency under low and high N levels. Results indicate that Jordanian barley germplasm could be a potential source for widening the variation and introduction of new genetic factors responsible for high N use, uptake and utilization efficiency. However, limited number of genotypes was used in the current study. Therefore, testing higher number of genotypes is highly recommended in future studies.

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دراسة الاختلافات في كفاءة استعمال النيتروجين وامتصاصه واستخدامه في عدد من التراكيب الوراثية للشعير تحت مستويات مختلفة من النيتروجين في الأردن

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الكلمات المفتاحية: الشعير، كفاءة امتصاص النيتروجين، كفاءة استعمال النيتروجين، كفاءة استخدام النيتروجين.

ملخص البحث. تم إجراء التجربة في البيت الزجاجي لتقييم الاختلافات في الإنتاج وكفاءة استعمال النيتروجين وامتصاصه واستخدامه في عدد من التراكيب الوراثية لثلاثة مستويات من النيتروجين لثلاثة مجاميع من الشعير وهي الشعير البري، والسلالات المحلية، والأصناف المحسنة (رم وأكساد ١٦٥). لقد كان هناك تبايناً وراثياً واسعاً ما بين الطرز الجينية في الصفات المدروسة مثل إنتاج الحب والوزن البيولوجي وكفاءة استعمال النيتروجين وامتصاصه واستخدامه. أظهر الصنف رم فروقاً معنوية في إنتاج الحب وكفاءة استعمال النيتروجين، بينما أظهرت السلالات المحلية الأردنية وصنف أكساد ١٦٥ قيماً متوسطة. ومن ناحية أخرى، لم يكن بالمستطاع تمييز طرز جينية في الشعير البري ذات كفاءة عالية في استعمال النيتروجين. أظهر تركيبان وراثيان من الشعير البري تفوقاً في استخدام النيتروجين تحت ظروف التسميد المنخفض والعالي. وأظهرت الدراسة أن بعض السلالات المحلية الأردنية تعتبر مصدراً رئيساً للجينات لتوسع قاعدة التباين الوراثي لكفاءة استعمال النيتروجين وامتصاصه واستخدامه.