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Research Application Summary

Genetic variation in durum wheat in N-use efficiency and heritability of traits at different N fertilizer application levels

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Abstract

Twelve durum wheat (*Triticum durum* L.) genotypes were evaluated for Nitrogen Use Efficiency (NUE) and related traits using two rates of nitrogen fertilizer application (69 kg N ha^{-1} and 115 kg N ha^{-1}) in a randomized complete block design with three replications. The experiment was done on a Vertisol at Adet Agricultural Research Center in the 2009 main cropping season. The highest Nitrogen Utilization efficiency (73.1 %), Nitrogen Use Efficiency for protein (55.0 %) and NUE (38 %) were recorded for genotype Asassa. Yerer was the poorest in NUE (22 %), Nitrogen Uptake Efficiency (57.7 %), and NUTE (37.9 %). All nitrogen use efficiency traits responded negatively to nitrogen fertilizer. All the traits, except Nitrogen Utilization efficiency, did not respond to the genotype by nitrogen interaction effect. NUE was positively correlated with NUPE (r = 0.81), Nitrogen Use Efficiency for Protein (r = 0.76), and NUTE (r = 0.56). Heritability value of NUE traits was low.

Key words: Durum wheat, genetic variation, nitrogen use efficiency

Résumé

Douze génotypes de blé dur (*Triticum durum* L.) ont été évalués pour leur efficacité dans l'utilisation de l'azote (NUE) et autres caractéristiques en appliquant deux doses d'engrais azoté (69 kg N ha^{-1} et 115 kg N ha^{-1}) dans un bloc aléatoire complet avec trois réplications. L'expérience a été réalisée sur du vertisol au Centre de recherche agricole Adet au cours de la saison agricole 2009. Les valeurs élevées d'efficacité dans l'absorption de l'azote (73,1%), d'efficacité d'utilisation de l'azote pour les protéines (55,0%) et d'efficacité dans l'utilisation de l'azote (38%) ont été enregistrées pour le génotype Asassa. Le génotype Yerer était le plus pauvre en termes d'efficacité dans l'utilisation de l'azote (22%), en efficacité dans l'absorption d'azote (57,7%). Tous les traits d'efficacité dans l'utilisation de l'azote ont répondu négativement à l'engrais azoté. Tous les traits, à l'exception de l'efficacité de l'utilisation de l'azote, n'ont pas été influences par l'effet d'interaction génotype x azote.

L'efficacité dans l'utilisation de l'azote était positivement corrélée avec NUPE (r = 0,81), l'efficacité de l'utilisation de l'azote pour la protéine (r = 0,76), et NUTE (r = 0,56). La valeur d'héritabilité des traits d'efficacité dans l'utilisation de l'azote était faible.

Mots clés: Blé dur, variation génétique, efficacité d'utilisation de l'azote

Background

Growth, development and yield of wheat are strongly affected by poor soil fertility. The problem of nitrogen deficiency is often acute in many areas where soils typically have low organic matter contents (Broadbent, 1981). Mamo and Haque (1988) reported that due to continuous cropping for longer period and low manure and fertilizer inputs, the nutrient status of Ethiopian soils is generally low and nitrogen is the most limiting nutrient for crop production. Thus, to improve crop production and productivity there is a need to apply nitrogen fertilizer, with great emphasis on the efficiency of N utilization. Considering the high cost and the detrimental effects of nitrogen deficiency on crop production, the efficient use of nitrogen in crop production has become a desirable agronomic, economic, and environmental goal (Le Gouis *et al*., 2000).

Under low or sub-optimal N levels, efficiency of N use can be improved partly through breeding and selection of genotypes efficient in nutrient use (Ma and Dwyer, 1998). Moreover, it can also be improved through improved agronomic practices. To improve grain yield and grain protein content, genotypic selection with high N use efficiency (NUE) should be incorporated into the production system in order to improve durum wheat productivity and quality. However, information on NUE of durum wheat varieties in Ethiopia in general and in Amhara region in particular is meager. The objective of this study was to evaluate the genetic variability of durum wheat genotypes for N-Use Efficiency and related components.

Study description

The experiment was conducted at Adet Agricultural Research Center (37^0 29'E latitude, 15^0 16' N longitude and elevation of 2240 m above sea level) in northwestern Amhara during the 2009 main cropping season. The area received a mean annual rainfall of 1230 mm and the soil of the experimental site is a Vertisoil with a pH of 6.0 (Tesfaye Zegeye *et al*., 2000).

Twelve improved durum wheat genotypes (Navigator, Selam, Metaya, Mosobo, Megenagna, Yerer, Ude, Robe, Asassa, Foka, Boohai, and Bichena) were evaluated for their NUE under two N fertilizer levels (69 kg N ha^{-1} and 115 kg N ha^{-1}). The experiment was laid in a randomized complete block design with three replications. Plot size was 3 m^2 (2.5 m x 1.2 m) with a spacing of 1.5 m between blocks and 0.4 m between plots. Each plot had six rows with 0.2 m spacing. All data were collected from the central four rows. All the plots received Diammonium Phosphate (DAP) at the rate of 46 kg P_2O_5 ha^{-1} at sowing. Nitrogen was applied in split where one fourth was applied at sowing, one fourth at tillering, and the remaining half at heading. Seeds of the varieties were hand drilled at the seed rate of 150 kg ha^{-1}. Other management practices were applied as recommended.

At maturity, the four centre rows were hand harvested for grain quality determination. Grain protein content was determined using Near Infra Red Reflectance (NIR) grain Analyzer of In-fratec 1241 (FOSS, Denmark). Grain nitrogen content was calculated by dividing the grain protein content by a factor of 5.7. Straw nitrogen was analyzed using Kjeldahl method. Total plant nitrogen content was determined by adding the nitrogen contents of the grain and the straw. Nitrogen uptake efficiency (NUPE) was calculated by dividing the total N uptake by the amount of applied N and multiplying by 100. Nitrogen use efficiency (NUE) was calculated by dividing grain yield by the amount of applied nitrogen. Data were subjected to Analysis of variance (ANOVA) using SAS software of Windows Version 6.12 (SAS Institute, 2001). Least significance difference (LSD) test was used to separate treatment means (Steel and Torrie, 1980). Heritability (H) in broad sense for NUE was computed with the formula used by Falconer (1989).

Results and discussions

Nitrogen uptake efficiency significantly ($P<0.01$) responded to the main effects of genotype and nitrogen fertilizer, but not to the interaction effect (Table 1). The highest uptake efficiency was recorded for Asassa, Megenagna and Robe and the lowest uptake efficiency was recorded for Mosobo (Table 2). The best genotype in its uptake efficiency outperformed the poorest by 20.4 %. The variation among genotypes could be due to difference in their root density and distribution which can cause differences in the exploitation of water and nutrients. The existence of genotypic differences in terms of N uptake has been reported for wheat (Dhugga and Waines, 1989). Nitrogen uptake efficiency also differed between the nitrogen levels. NUPE was higher (64.8 %) at the lower N rate and lower (55.316 %) at the higher nitrogen rate. This finding is inline with Ortiz-Monastero *et al.* (1997) but contrary to the findings of Soon *et al.* (2006). NUPE has positive and significant correlation with NUEP ($r = 0.82^{**}$) and NUE ($r = 0.81^{**}$) (Table 3).

Table 1. Analysis of variance table for nitrogen uptake efficiency (NUPE), nitrogen use efficiency for protein (NUEP), nitrogen utilization efficiency (NUTE), nitrogen use efficiency (NUE)

Source of variation	df	NUPE	NUEP	NUE	NUTE
Genotype (G)	11	180.554**	150.991**	107.634**	128.692**
Nitrogen (N)	1	1619.753**	354.134**	612.850**	64.676ns
G X N	11	115.959ns	53.164ns	19.370ns	61.604**
Error	46	71.333	47.676	24.461	23.289

* and ** denote significant differences at 5% and 1% probability level, and ns denote non-significant differences.

Table 2. Nitrogen uptake efficiency (NUPE), nitrogen use efficiency for protein (NUEP) and nitrogen use efficiency (NUE) of durum wheat genotypes grown under two N fertilizer levels at Adet in 2009

Genotype	NUPE (%)	NUEP (%)	NUE (%)
Navigator	57.2	39.0	27.6
Selam	55.7	37.0	29.8
Metaya	60.8	38.4	32.7
Mosobo	58.1	38.0	31.0
Megenagna	62.4	41.5	34.3
Yerer	57.7	40.9	21.9
Ude	50.8	37.2	25.7
Robe	61.7	42.1	31.6
Asassa	73.1	54.9	37.9
Foka	57.7	40.1	29.2
Boohai	65.1	46.0	32.8
Bichena	60.4	44.2	33.6
Over all mean	60.1	41.6	30.7
LSD (5%)	14.27	11.61	8.35
CV (%)	14.06	16.59	16.12

Table 3. Correlation between traits of durum wheat genotypes grown under two N- levels at Adet in the 2009 cropping season

Trait	NUPE	NUEP	NUTE	NUE
NUPE	1.00			
NUEP	0.82^{**}	1.00		
NUTE	0.04	0.18	1.00	
NUE	0.81^{**}	0.76^{**}	0.56^{**}	1.00

*and ** denote significant difference at 5 % and 1% probability level

Nitrogen use efficiency for protein (NUEP). Nitrogen use efficiency for protein responded to the main effects of genotype and N fertilizer, but not to the interaction effect (Table 1). Genotypes differed significantly (P<001) in NUEP. The highest NUEP was recorded for Asassa (55.0 %) and the lowest (37.0 %) was recorded for Selam (Table 2). Nitrogen use efficiency for protein also differed significantly (P<0.01) between the N fertilizer levels. NUEP has inverse relationship with nitrogen fertilizer levels where NUEP decreased from 43.8% to 39.4 % when N fertilizer level increased from 69 kg N ha^{-1} to 115 kg N ha^{-1}. This is because the nitrogen uptake efficiency of the genotypes was higher at the lower nitrogen level and this affected NUEP. It has positive and significant correlation with NUE ($r = 0.76^{**}$) (Table 3).

Nitrogen utilization efficiency (NUTE). Nitrogen utilization efficiency responded to the genotype by N fertilizer interaction effect (Table 1). Selam, Mosobo, Megenagna, Yerer, Ude, Foka and Bichena had higher NUTE at the lower nitrogen rate (69 kg ha^{-1}) (Table 4). Genotypic difference in NUTE has been reported for maize (Akintoye *et al*., 1999) and wheat (Dhugga and Waines, 1989). The highest NUTE was obtained from Bichena at the lower nitrogen level (59.10 %) and Yerer gave the lowest from the higher nitrogen rate (36.53 % (Table 4). Varieties with better NUPE also had better NUTE. NUTE is positively correlated with NUE ($r = 0.56^{**}$) (Table 3).

Nitrogen use efficiency (NUE). Nitrogen use efficiency was significantly ($P<0.01$) affected by the genotype and nitrogen fertilizer effects, but not by the interaction effect (Table 1). Genotypes differed in NUE. The most efficient genotype was Asassa (38.00 %) followed by Megenagna (34.3 %) and the least efficient genotype was Yerer (22.00 %) (Table 3). Cox *et al*. (1985) working with wheat observed genetic difference for NUE at different nitrogen levels. NUE also differed between the nitrogen fertilizer levels where it increased from 27.77 % with 115 kg N ha^{-1} to 33.6 % with 69 kg N ha^{-1}. Similar results were reported by Buah *et al*. (1998) in sorghum genotypes and McCullough *et al*. (1994) in maize hybrids. Genotypes have higher NUE at the lower nitrogen application because of their better ability to absorb more nitrogen from the soil as well as their better ability to convert the absorbed nitrogen to grain yield. NUPE and NUTE are components of NUE thus it was positively correlated with NUPE ($r = 0.81^{**}$), NUTE ($r = 0.56^{**}$) and NUEP ($r = 0.76^{**}$) (Table 3).

Table 4. Nitrogen utilization efficiency (NUTE %) of durum wheat genotypes grown under two N fertilizer levels at Adet in 2009

Genotype	Nitrogen fertilizer levels	
	69 kg N / ha	115 kg N / ha
Navigator	47.85	48.54
Selam	58.33	48.10
Metaya	49.76	59.01
Mosobo	58.87	47.57
Megenagna	57.48	51.85
Yerer	39.28	36.53
Ude	51.29	49.25
Robe	49.83	53.10
Asassa	49.81	55.80
Foka	53.18	48.49
Boohai	49.67	52.03
Bichena	59.07	51.41
Overall mean	52.03	50.14
CV	9.6	9.26
LSD (5%)	7.2	7.2

Heritability of traits. The heritability of nitrogen use efficiency of the genotypes was 20 % which indicates the difficulty of improving NUE through direct selection. Falconer (1989) pointed out that as the number of genes involved in the inheritance of a trait becomes greater, so does the influence by the environment. This indicated that the breeder is ineffective in improving through direct selection. To improve nitrogen use efficiency, indirect selection is better than the direct selection. Selecting traits with high heritability and positive correlation to NUE can help breeders to improve nitrogen use efficient of durum wheat genotypes.

Conclusion

Nitrogen fertilization is one of the most used strategies for increasing wheat grain yield and improving grain quality, since it is commonly believed that it can increase grain yield and grain protein content. Growing N-use efficient genotypes to achieve high yield and high concentration of protein in the grain has to be supported by an adequate N supply. On the other hand, some genotypes still perform well in terms of NUE when high rates of N fertilizer are applied because generally the rate of N use efficiency usually decreases with increasing rate of N application. Genotypes evaluated in this study differed in NUE and related components. Of the 12 genotypes Assasa and Megenagna had higher NUE and related traits. Therefore, Assasa and Megenagna are recommended for production for higher grain yield, grain quality and efficient nitrogen fertilizer use.

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