Response of Different Durum Wheat (*Triticum turgidum* Var. Durum) Varieties to Added Nitrogen Fertilizer

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Abstract

Twelve durum wheat genotypes were evaluated for their grain yield 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 Vertisol at Adet Agricultural Research Center in the main cropping season 2009. All agronomic traits respond positively to applied nitrogen rates. The highest grain yield (33.8 Qt·ha^{-1}) was reported from Asassa variety. Grain yield increased by 8.8 Qt·ha^{-1} with the increase of nitrogen rates by 46 kg N ha^{-1}. Studied traits, except days to heading, grain filling period and biomass production efficiency, others did not respond to the genotype by nitrogen interaction effect. Grain yield was positively correlated with plant height (r = 0.53), total plant biomass (r = 0.81).

Keywords

Durum Wheat, Grain Yield, Nitrogen

Subject Areas: **Agricultural Science, Genetics**

1. Introduction

Ethiopia is the second largest wheat producer in the sub-Saharan Africa. Both bread (*Triticum aestivum* L.) and durum (*Triticum turgidum* var. durum) wheats are important food crops in Ethiopia. According to [1] about 1,479,287 hectares of land were covered by wheat with an expected production of 2.7 million tons of wheat grain. Durum wheat yields on farmers' fields in Ethiopia vary from 0.8 t·ha^{-1} to 2.5 t·ha^{-1} with average productivity of less than a ton per hectare. Productivity of durum wheat in Ethiopia is below its potential due to lack of using high yielding improved genotypes, use of suboptimal production practices and using low levels of fertilizer application. Yield progress in durum wheat has generally been lower than that of bread wheat. However, du-

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rum wheat grain yields of 5 - 6 t/ha can be obtained with irrigation and use of improved genotypes and better production practices [2].

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 [3]. [4] reported that due to continuous cropping for longer period and low manure and fertilizer inputs, the nutrient status of Ethiopian soils was generally low and nitrogen was 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 grain production. Considering the high cost and the detrimental effects of nitrogen deficiencies on crop production, the efficient use of nitrogen in crop production has become a desirable agronomic, economic, and environmental goal [5]. Grain yield could be improved through improved agronomic practices and growing high yielder cultivars. Cultivar selection with high N responsive should be tailored into the production system in order to improve durum wheat productivity. Under low or sub-optimal N levels, grain yield can be improved partly through breeding and selection of genotypes [6]. The ability of plants to take up limited amounts of soil N could be crucial in determining grain yields and yield related [7]. Information on durum wheat varieties grain yield response to nitrogen in Ethiopia in general and in Amhara region in particular is meager. Therefore, this research was conducted to evaluate the genetic potential and variability of durum wheat genotypes for grain yield and related components.

2. Materials and Methods

2.1. Description of the Study Area

The experiment was conducted at Adet Agricultural Research Center (37˚29'E latitude, 15˚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, average temperature during growing season was 26˚C and the soil of the experimental site is Vertisoil with a pH of 6.0 [8].

2.2. Experimental Design and Procedure

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 × 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.

2.3. Data Collection

Central four rows were hand harvested at maturity for grain yield, biomass yield and grain quality determination. Grain yield was recorded from the central four rows at 12% moisture content. Total biomass yield was determined after harvesting and air drying. Days to heading (DH) was determined by counting the number of days from the first day of sufficient rain fall to initiate germination to the date when 50% of the plants headed. Days to maturity (DMA) was determined by calculating the number of days from the date of effective rainfall to the date where 90% of the plants matured fully. Plant height (PH) was recorded by measuring the height of plants from the ground level to the top of the spikes from five randomly selected plants per plot. Data on fertile tiller number per plant (TN), spike length (SPL), number of spikelet per spike (Sp/Sp), and Kernel number per spike (K/SP) were recorded from five randomly sampled plants in each plot. Grain yield was recorded from the central four rows at 12% moisture content. Total biomass yield was determined by harvesting, air drying and weighing plants from the four central rows.

2.4. Data Analysis

Analysis of variance (ANOVA) was performed using SAS software of Windows Version 6.12 [9] and [10]. Least significance difference (LSD) was used to separate treatment means [11]. Variance components and genetic parameters were computed

3. Results and Discussions

Days to heading showed significant difference ($P < 0.0001$) among varieties (**Table 2**). Yerer (66 days) took longer days to head where as Asassa (57 days) and Megenagna (58 days) took relatively shorter period. Boohai and Ude took equal days (61 days). Likewise Selam and Metaya took similar days to heading (60) (**Table 1**). The analysis of variance for this trait has also shown significant difference for the interaction effect ($P \leq 0.0001$). Halve of the genotypes have responded positively but other reacted negatively to the applied nitrogen (**Table 3**). It correlated positively with days to maturity ($r = 0.37^{**}$), but negatively ($r = -0.52^{**}$) with grain filling period (**Table 4**). Days to maturity is divided into days to heading and grain filling period. When days to heading is long then grain filling period would be shorter and vice versa.

Genotypes differed very markedly ($P < 0.0001$) in their days to maturity (**Table 2**). The late maturing genotype was Navigator which took 113 days and followed by Yerer with 112 days to mature. Foka (109 days), Mosobo (109 days) and 109 for Megenagna were found to be early maturing genotypes (**Table 1**). Days to maturity positively correlated with grain filling period ($r = 0.5$) (**Table 4**).

Genotypes differed ($P < 0.0001$) very significantly in their grain filling period (GFP) (**Table 2**). The maximum GFP was recorded for Navigator (53 days) and Asassa (53 days) and the shortest grain filling period was recorded for Yerer (46 days) (**Table 1**). Grain filling period of genotypes significantly ($P < 0.001$) varied at different levels of N applications. Maximum GFP was 54 days recorded by Megenagna at the lower nitrogen level and the shortest was by cultivar Yerer at the lower nitrogen level. Some cultivars increased their GFP as nitrogen dose increased while some others gave inverse result (**Table 3**). Positive correlation was observed with DMA ($r = 0.5^{**}$) and negative correlation with ($r = -0.52^{**}$) DH (**Table 4**).

Table 1. Genotypic mean, grand mean, LSD and CV of agronomic parameter of durum wheat genotypes grown at AARC in 2009 cropping season.

Genotypes	DH	DMA	GFP	PH	SEP#	HI	NT/P	K/SP	SP/SP	SPL	GY (Qt·ha^{-1})	TPB	TSW
Navigator	60	113	53	99	7.2	0.34	3.9	35.70	14.96	4.9	25.3	74.98	36.3
Selam (DZ-2178)	61	110	49	110	8.3	0.31	4.2	39.90	15.83	5.27	26.4	89.06	43.0
Metaya (DZ-2212)	61	110	49	116	8.5	0.33	4.2	40.30	16.20	5.33	29.7	89.34	42.0
Mosobo (DZ-2178)	59	109	50	112	8.8	0.32	4.6	41.60	16.20	5.70	27.7	86.83	43.7
Megenagna (DZ-2023)	58	109	51	116	8.8	0.31	4.0	40.70	16.57	5.63	30.8	101.3	46.3
Yerer (CD-94026-4Y)	66	112	46	80	7.2	0.29	4.6	38.40	17.17	6.73	20.1	69.77	35.7
Ude (CD 95294-2Y)	61	111	50	81	7.7	0.35	4.5	38.80	14.57	4.83	23	66.97	42.7
Robe (DZ-1640)	67	109	49	105	9.0	0.33	3.9	43.80	17.23	6.00	28	85.64	37.3
Asassa (DZ-2085)	57	110	53	106	7.3	0.35	4.0	390	15.30	5.02	33.8	97.59	42.0
Foka	60	109	49	114	7.8	0.3	4.6	39.90	16.30	5.23	26.6	90.71	39.7
Boohai	61	112	51	116	7.7	0.33	4.3	40.00	15.30	5.25	29.8	92.00	45.7
Bichena (DZ-393-4)	60	111	50	119	7.3	0.35	4.2	36.80	16.20	5.12	29.7	85.56	46.3
Grand mean	60.4	110	49.9	106	8	0.33	4.3	39.7	15.99	5.43	27.6	85.8	41.7
LSD (5%)	2.7	3.49	3.33	11.6	0.1	0.08	1.1	6.4	1.26	0.71	7.84	17.9	6.4
CV (%)	2.6	1.9	3.94	6.5	6.9	13.7	14.5	9.52	4.68	7.73	16.8	12.37	9.1

Note: DH: Days to heading, DMA: days to maturity, GFP: Grain filling period, PH: plant height, Sep: *Septoria* score, Hi: Harvest index, NT·P^{-1}: Tiller number per plant, K·SP^{-1}: kernels per spike, SP·SP^{-1}: Spike lets per spike, SPL: spike length, Gy: grain yield, TPB: total plant biomass, TSW: Thousand seed weight.

Table 2. ANOVA for Agronomic traits.

source	df	DH	DMA	GFP	PH	SEP	TN/P	SPL	SP/SP	K/SP	GY	TPB	HI	TSW
G	11	28.0^{**}	9.6^{*}	23.9^{**}	1067.6^{**}	0.008^{NS}	0.4^{NS}	1.72^{**}	4.09^{**}	29.9^{*}	80.3^{**}	652.4^{**}	0.003^{NS}	83.86^{**}
NL	1	0.22^{NS}	8.0^{NS}	8.7^{NS}	685.10^{**}	0.006^{NS}	3.6^{**}	1^{*}	3.6^{*}	136.10^{**}	1376.81^{**}	13608.4^{**}	0.00005^{NS}	150.22^{**}
G*N	11	5.76^{*}	7.4^{NS}	14.3^{**}	39.5^{NS}	0.003^{NS}	0.35^{NS}	0.18^{NS}	0.5^{NS}	3.14	10.29^{NS}	55.11^{NS}	0.003^{NS}	24.89^{NS}
error	46	2.47	8.1	3.9	47.6	0.004	0.38	0.18	0.6	14.34	21.53	112.7	0.002	14.28

**Highly significant; *significant; NS: non-significant, G: genotype, NL: nitrogen level, G*N: interaction.

Table 3. Mean DH and GFP of genotypes grown at AARC in 2009 cropping season at two N fertilizer levels.

Genotype	DH		GRF	
	69 kg N ha^{-1}	115 kg N ha^{-1}	69 kg N ha^{-1}	115 kg N ha^{-1}
Navigator	58	61	54	52
Selam (DZ-2178)	62	60	49	48
Metaya (DZ-2212)	59	62	49	49
Mosobo (DZ-2178)	59	59	50	50
Megenagna (DZ-2023)	58	59	52	50
Yerer (CD-94026-4Y)	67	65	43	49
Ude (CD 95294-2Y)	63	60	47	53
Robe (DZ-1640)	61	60	47	50
Asassa (DZ-2085)	57	57	53	53
Foka	60	60	50	49
Boohai	61	61	49	52
Bichena(DZ-393-4)	60	60	52	48

Table 4. Correlation value between traits of durum wheat genotypes grown at two N-levels at AARC in 2009 cropping season.

Trait	DH	DMA	GFP	PH	TN/P	SPL	Sp/Sp	K/Sp	Tsw	Gy	TBP
DH	1.00										
DMA	0.37^{**}	1.00									
GFP	-0.52^{**}	0.50^{**}	1.00								
PH	-0.27^{*}	−0.18	0.08	1.00							
TN/P	0.21	0.20	−0.04	0.12	1.00						
SPL	0.14	−0.15	-0.30^{*}	0.05	0.17	1.00					
Sp/SP	0.16	−0.18	-0.37^{**}	0.24^{*}	0.15	0.66^{**}	1.00				
K/Sp	0.03	−0.13	−0.10	0.19	0.09	0.51^{**}	0.47^{**}	1.00			
Tsw	−0.14	−0.14	−0.01	0.44^{**}	0.17	−0.09	0.02	0.29^{*}	1.00		
Gy	-0.32^{**}	−0.09	0.21	0.53^{**}	0.18	0.01	0.09	0.30^{*}	0.40	1.00	
TBP	-0.27^{*}	−0.11	0.14	0.61^{**}	0.30^{*}	0.18	0.22	0.28^{*}	0.35	0.81^{**}	1.00

Note: *significant at 5% and **significant at 1% probability level.

The genotypes differed ($P < 0.0001$) highly in their height (PH) (**Table 2**). Bichena, the tallest plant with mean height of 119.3 cm, was 49.5% taller than Yerer, the shortest with mean height of 79.9 cm (**Table 1**). Genotypes responded positively for the added fertilizer showing an average increment of 6.2 cm when nitrogen input increased from 69 kg N ha^{-1} to 115 kg N ha^{-1}. There was no variety by nitrogen interaction. Keulen and Seligman (1987) have reported that the supply of nitrogen increases plant height which is in accordance with the result of this experiment. Plant height was positively correlated with total plant biomass ($r = 0.61^{**}$), grain yield ($r = 0.53^{**}$) and ($r = 0.44^{**}$) 1000 grain weight (**Table 4**). Positive correlation of plant height with number of tillers, number of grains per spike and 1000 grain weight was reported by [12]. However, [13] reported Negative correlation of plant height with grain yield which is contradictory with the result of this trial.

The number of fertile tillers per plant (TN/P) has showed significant difference ($P < 0.004$) for the added fertilizer (**Table 2**). There was an increase in the number of fertile tillers from 4.02 to 4.5 with the increase in nitrogen levels from 69 kg N ha^{-1} to 115 kg N ha^{-1} which attributed to the reduction in mortality of tillers and enabling the production of more tillers from the main stem [14]. [15] observed the increment of wheat yield components with the increase in nitrogen input.

Number of spike lets per spike (SP/SP) showed significant difference ($P < 0.0001$) among the tested genotypes (**Table 2**). The highest SP/SP was observed from Robe with average of 17.2 SP·SP^{-1} followed by Yerer (17.167) and Megenagna (16.6). On the contrary, varieties Asassa (15.30), Boohai (15.3), Navigator (15.00) and Ude (14.60) were the least in their SP·SP^{-1} (**Table 1**). The levels of nitrogen (**Table 3**) positively affected the SP·SP^{-1} *i.e.*, the SP·SP^{-1} increased from 15.8 to 16.2 when nitrogen increased from 69 kg N ha^{-1} to 115 kg N ha^{-1}, respectively. The trait have shown positive association with kernels per spike ($r = 0.47^{**}$) and spike length (0.66^{**}) (**Table 4**). These correlation results are in conformity with [16] findings. Research results of [17] also showed the increased number of SP/SP with the increased levels of nitrogen which is in agreement with this research result.

Kernels per spike (K/SP) have revealed highly significant difference ($P = 0.04$) among the tested genotypes (**Table 2**). The highest kernel number per spike was recorded by Robe (43.8) and Megenagna (41.7) followed by Mosobo (41.6) and Metaya (41.3) while Navigator recorded the lowest number of 35.7 (**Table 1**). There was also positive significant reaction to added fertilizer ($P = 0.003$) where mean K·SP^{-1} have increased from 38.4 to 41.1 when rate of nitrogen changed from 69 kg N ha^{-1} to 115 kg N ha^{-1}, respectively. [18] in rice have observed the reduction of grain number in N deficient soil; [15] have also found a relative increment of K·SP^{-1} with nitrogen level, which are in accordance with this experiment. This trait was positively correlated with spike length ($r = 0.51^{**}$) and ($r = 0.47^{**}$) Spike length (**Table 4**).

Spike length (SPL) was highly and significantly ($P < 0.0001$) affected by varieties (**Table 2**). The longest SPL was recorded from Yerer (6.733 cm) and the shortest from Navigator (4.83 cm) and Ude (4.9 cm) (**Table 1**). It also gave positive significant response ($P = 0.0212$) to the two nitrogen doses (**Table 3**). Longer spike length was observed in the higher nitrogen application (5.55 cm) than to the lower (5.32 cm). The positive effect of N-fertilizer on SPL was also obtained by [15]. Spike length had positive relationship with number of SP/SP ($r = 0.66^{**}$) and ($r = 0.51^{**}$) K/SP (**Table 4**). These correlation results are in agreement with the findings of [19].

The genotypes varied ($P < 0.0001$) in their thousand seed weight (TSW) (**Table 2**). The superior varieties for this trait was Bichena (46.33 gram) and Megenagna (46.33) but Yerer being relatively inferior with 35.67 gram (**Table 1**). The trait have also showed positive significant response for the nitrogen levels ($r = 0.0022$). When nitrogen increased from 69 kg N ha^{-1} to 115 kg·ha^{-1} thousand seed weight increased by an average of 7.2% across most of the cultivars. [20] and [15] have also reported significant and positive response of TSW to high rat of nitrogen. This trait, as part of yield component, was positively correlated with grain yield ($r = 0.4$) (**Table 4**). It was evident from the results that TSW had pronounced influence upon wheat yield. The present findings are similar to the [21] findings who observed positive association of TSW with grain yield. [12] has also reported positive correlation of TSW with K/SP and grain yield.

Total plant biomass (TPB) varied ($P < 0.0001$) among the tested genotypes (**Table 2**). Highest plant biomass was recorded from Megenagna (101.342 Qt·ha^{-1}) followed by Asassa (97.59 Qt·ha^{-1}). The least yielder were Yerer (69.77 Qt·ha^{-1}) and Ude (66.97 Qt·ha^{-1}) (**Table 1**). It also responds positively and significantly to the nitrogen levels. Mean total plant biomass increased by 38.2% when nitrogen application changed from 69 kg N ha^{-1} to 115 kg N ha^{-1}. The same result have also found by [15]. Positive correlation was observed with plant height ($r = 0.61^{**}$) and grain yield ($r = 0.81^{**}$) (**Table 4**). TPB includes both grain yield and Stover. If plant height increased vegetative content will increase and if grain yield increased, TPB will increase. Similar correlation result was also reported by [22].

All the genotypes have shown significant difference ($P < 0.0008$) among them for their grain yield (**Table 2**). Mean varieties grain yield was 27.6 Qt·ha^{-1}. The highest grain yield was recorded from Asassa (33.82 Qt·ha^{-1}) and Megenagna (30.8 Qt·ha^{-1}). The least yielding cultivar was Yerer (20.1 Qt·ha^{-1}). Asassa (the high yielder) significantly out yield by 40.6% to Yerer (poor yielder) (**Table 1**). In addition to response to genotypes, the trait has also exhibited highly significant and positive response to added N fertilizer ($P < 0.0001$). The application of nitrogen linearly increased the grain yield of the cultivars and maximum response was exhibited from the highest nitrogen input. The varieties have shown an average yield increment of 8.8 Qt·ha^{-1} when nitrogen increased to 115 Kg N ha^{-1} which is in accordance with [23] speculation and [15] finding. Wheat yield was positively correlated with thousand grain weight ($r = 0.4$), plant height ($r = 0.53^{**}$) and ($r = 0.36^{**}$) harvest index (**Table 4**). The positive correlations with kernels per spike, harvest index and thousand grain weight could attribute to more efficient partitioning of dry matter to the spike in the cultivars. This was substantiated by positive correlations with harvest indexes. Similar correlation results were also reported by [24].

4. Conclusions and Recommendations

Nitrogen fertilization is one of the most used strategies for altering wheat grain yield and quality, since it is commonly believed that it can increase grain yield, grain protein percentage or both of them. Growing genotypes to achieve high yield grain yield must be supported by an adequate N supply. The present study was designed with the objectives of improving the productivity of durum wheat through identifying high yielder genotypes. The tested genotypes were Navigator, Metaya, Selam, Mosobo, Megenagna, Yerer, Ude, Robe, Asassa, Foka, Boohai and Bichena.

- The tested genotypes showed significant variation for all agronomic traits studied. Days to heading has ranged from 59 days for Bichena to 66 days for Robe. Late maturing genotype was Navigator (113 days) where Megenagna was relatively early maturing. Long grain filling period was obtained for Asassa (53 days) and short for Yerer (46). The tallest genotype was Bichena (119 cm) while the shortest one was Ude (81 cm).
- The lowest value of kernels per spike (35.7), spike lets per spike (14.96), spike length (4.9 cm), total plant biomass (74.98 Qt·ha^{-1}) and thousand seed weight (36.33 gram) was recorded by navigator. The highest grain yield (33.8 Qt·ha^{-1}) and total plant biomass (101.3 Qt·ha^{-1}) was obtained from Asassa and Megenagna respectively. The lowest grain yield (20.1 Qt·ha^{-1}) was recorded by Yerer.
- The values of all agronomic traits increased due to an increase in nitrogen rate except for Septoria and harvest index. Plant height has increased by 6.2 cm; kernels per spike increased from 38.4 to 41.1; spike length increased by 0.21 cm; Spike lets per spike increased from 15.78 to 16.2, tiller number from 4.5 to 4.0; grain yield increased by 8.8 Qt·ha^{-1} and total plant biomass increased by 38.2% when nitrogen rate increased from 69 to 115 kg N ha^{-1}.
- Days to heading (DH) and grain filling period (GFP) were affected by the interaction effect but none of them showed uniform result as to whether nitrogen increased or decreased.
- Strong correlation was obtained between yield and plant height ($r = 0.53$) and total plant biomass ($r = 0.81$).

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