e-ISSN 2795-4362
p-ISSN 2795-4340

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GPH-INTERNATIONAL JOURNAL OF AGRICULTURE & RESEARCH

GPH - JOURNAL OF AGRICULTURE & RESEARCH

10.5281/zenodo.13933741 | Vol. 07 Issue 09 Sept - 2024 | Manuscript ID: #01564

Effect of Nitrogen Rates on Yield, Yield attributing traits and Quality of Recently Released Durum Wheat Varieties in Bale Highlands of Ethiopia

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Abstract:

Proper rate of fertilizer application is the major factor that hinders yield and quality of durum wheat production. Site specific fertilizer recommendation is not done in study area. This Research activity was conducted at Sinana and Gololcha districts of East Bale and Bale zone for three years (2016-2018), to assess the effect of nitrogen fertilizer rate on yield, yield attributing traits and grain quality of durum wheat varieties. Factorial combinations of four durum wheat varieties (Toltu, Dire, Bekelcha and Ingliz) and five rates of nitrogen (46,92,138,184 and 230 kg N ha^{-1}) were laid out in a randomized complete block design (RCBD) with three replications. The main effects of nitrogen and variety significantly ($P < 0.05$) influenced plant height, spike length, kernels per spike, biomass yield, grain yield, harvest index ,TKW, HLW and grain protein content. Variety Diredurum wheat variety recorded the highest grain yield (4650 kg ha^{-1}) in statistical parity with Bekelcha (4563 kg ha^{-1}). The lowest yield was obtained from local variety Ingliz (3653 kg ha^{-1}). Combined analysis of the results revealed that grain yield was significantly affected by main effects of varieties and N fertilizer rates. The highest N rate (230kg N ha^{-1}) recorded the highest grain yield (4536 kg ha^{-1}). The lowest yield (3815 kg ha^{-1}) was recorded by the lowest N rate (46 kg N ha^{-1}). Bekelcha variety gave the highest grain protein content(14.6%). The lowest grain protein content (12.9g) was recorded from local variety Ingliz. The highest grain protein content (15.1%) was obtained from the application of the highest N rate (230kg N ha^{-1}), the lowest (12.8%) was from the lowest N rate (46kg N ha^{-1}).The economic analysis indicated that optimum grain yield and quality of the improved durum wheat varieties by application of 92 kg ha^{-1} Nitrogen fertilizers.

Keywords:

Durum wheat; Test Weight; Nitrogen rate; Grain protein Content; Grain Yield.

INTRODUCTION

Cereals are the most abundant field crops globally and considered as staple foods for humanity. Wheat is one of the most important cereal crops with an outstanding role in worldwide population nutrition (M. Ciudad et al, .2020). Wheat (*Triticum* spp.) is one of the most important cereal crops worldwide in total production and use (Evans, 1998).Durum or macaroni wheat is indigenous to Ethiopia and it has been under cultivation since ancient times. Ethiopia is considered to be the center of genetic diversity of this crop. Durum wheat is grown in 8-10% of all the wheat cultivated areas in the World, whereas in Ethiopia it constitutes about 30% of wheat production (CSA, 2020). In Oromia region Arsi and Bale zones are favorable environmental conditions for durum wheat production. Nowadays durum wheat is considered as potential crop by the government for food industry as import substitution and one means of income diversification for the farmers. With the increasing number of processing industries, the demand for durum wheat grains for pasta processing is growing-up in the country.

Locally produced durum wheat grains are censured to be of poor quality and do not meet the minimum quality standard of pasta production. Grain yield and grain quality under different nitrogen rates for most of the recently released durum wheat varieties in Ethiopia is limited. It is, therefore, necessary to improve durum wheat productivity and grain quality through nitrogen fertilizer management and selection of genotypes with high nitrogen use efficiency to make durum wheat production rewarding to farmers, and to satisfy the demand of the processing industries.

The low yield of durum wheat could be mainly due to the use of low yielding landraces by farmers, weeds, diseases, insect pests, low fertility and moisture stress in the major durum wheat growing areas (Tesfaye, 1988). Soil degradation and depletion of soil nutrients are among the major factors threatening sustainable cereal production in the Ethiopian highlands. The low yield is primarily allied to the depletion of soil fertility due to continuous nutrient uptake of crops, low fertilizer use and insufficient organic matter application (Kidane Giorgis, 2015). Low soil fertility, especially low nitrogen, is a major a biotic stress that limits crop productivity for smallholder farmers in Ethiopia. Nitrogen (N) is the most essential mineral nutrient required abundantly for crop growth and yield formation, and determining productivity and quality of produce (Manschadi and Soltani, 2021). Available soil nitrogen is often insufficient and mineral fertilizers should be supplemented. Therefore, this study was designed to determine the effect of nitrogenous fertilizer rates on yield, yield attributing traits and grain quality of durum wheat varieties and to determine economically optimum nitrogen application rate for higher yield and quality of durum wheat varieties.

MATERIAL AND METHODS

The experiment was conducted for three years (2016-2018) at three locations (Sinana on-station, Sinana on-farm and Gololcha) in main cropping season. The treatments were consist of combinations of four durum wheat varieties that includes three recently released durum wheat varieties (Toltu, Dire and Bekelcha) from Sinana Agricultural Research Center and one local check (land race variety Ingliz) and Five levels of nitrogen fertilizers (46,92,138,184 and 230 kg N ha^{-1}). The experiment was laid out as Randomized Complete Block design (RCBD) in a factorial arrangement with three replications. Treatments were assigned to each plot randomly. The size of each plot was 2.4 m x 2.5 m=6 m^2 and the distance between rows, plots and replication was 0.2, 0.5, and 1.5 m, respectively. Phosphate fertilizer in the form of TSP (46%P_2O_5) at the recommended rate of 46 P_2O_5 ha^{-1} was applied uniformly to each plot. Nitrogen was applied as split-application, $^1/_4$ at planting, $^1/_2$ at tillering and $^{1}/_{4}$ at an thesis. All the other recommended management practices to the crop were done uniformly to raise the crop.

Statistical data analysis

Analysis of variance (ANOVA) was done using Gen Stat 15th edition and means comparisons for the significantly different variables were made among treatments using least significant differences (LSD) test at 0.05 level of significance.

RESULTS AND DISCUSSION

Physico-chemical properties of the experimental Site

Selected physico-chemical properties of the soil were determined for composite surface soil (0-30 cm) samples collected before sowing (Table1). Accordingly, the texture of the soil of the experimental site is dominated by the clay fraction. The clay texture indicates the high degree of weathering that took place in geological times and the high nutrient and water holding capacity of the soil. Soil pH values for both locations varied from 6.45 to 6.48 for soils of the experimental sites (Table 1). Soil pH status was categorized as slightly acidic soil Jones (2003). Based on these results the pH value is optimum range for most crop production since most plant prefers the pH range 5.5 to 7.0. Soil Organic Matter values for both locations varied from 2.38 to 4.98 for soils of the experimental sites (Table 1). As the rating range established by Tekalign,(1991) soil organic matter content categorized under moderate and low for Sinana on- Station and Sinana on-farm, respectively. Soil total Nitrogen values for both locations varied from 0.22 – 0.33. As ratings suggested by Landon (1991) for soil total nitrogen soils of the experimental site were rated into moderate and low for Sinana on- station and Sinana on-farm, respectively**.** Available Phosphorous values for both locations varied from 4.5-20.58 ppm (Table 1). According to the rating established by Cottenie (1980) the studied soils have low to high phosphorus content for Sinana on-farm and Sinanaon-station, respectively**.** Adequate phosphorus results in higher grain production, improved crop quality, greater stalk strength, increased root growth, and earlier crop maturity.

Cation exchange capacity values were ranged from 24.45 to 38.53 cmol kg^{-1}for soils of the experimental sites. Based on the rating established by Hazelton (2007) the soils of the study sites were moderate and high for sinana on-Farm and Sinana on-station, respectively**.**

Table 1. Soil physico-chemical properties of the Sinana on- station and Sinana on-farm

Location	Textural class	pH	OM (%)	TN (%)	Available P (ppm)	CEC (cmol kg^{-1})
Sinana on- station	Clay	6.45	4.98	0.33	20.58	38.53
Sinana on -farm	Clay	6.48	2.38	0.22	4.5	24.45

Effects of Nitrogen fertilizer rates and Durum wheat varieties on

Plant Height

Plant height was significantly affected by varieties (Table 2). The local cultivar Inglizi produced significantly taller plants (122cm) than all the improved varieties. This was followed by the improved variety Bekelcha (88.9cm), which also produced significantly taller plants than Toltu and Dire. The shorter suture of the improved varieties compared to the local cultivar may be related to the pattern of modern wheat breeding which always aims at developing dwarf or semi-dwarf wheat for enhanced partitioning of carbohydrate towards the grain. The main effect of Nitrogen application rates and the interaction effect did not significantly influence plant height (Table 2).

Grain Yield

The result of analysis of variance indicated that there were significant differences ($P < 0.05$) among nitrogen rate treatments and varieties for grain yield, while interaction was not significant (Table 2). Grain yield increased as rate of nitrogen applied increased from the lowest to the highest level. Mean Grain yield ranged from 3815 kg ha^{-1} for the lowest treatment (46 kg N ha^{-1}) to 4536 kg ha^{-1} for the highest treatment (230 kg N ha^{-1}) indicating grain yield variation under the different nitrogen rate treatments. The lowest grain yield (3815 kg ha^{-1}) was recorded by the lowest nitrogen rate (46 kg N ha^{-1}). The highest grain yield (4536 kg ha^{-1}) was recorded by the highest nitrogen rate (230 kg N ha^{-1}). The remaining three nitrogen rates 92,138 and 184 kg N ha^{-1} gave statistically similar grain yield 4370, 4519 and 4439 kg/ha, respectively. The analysis of variance also revealed that significant differences ($P < 0.05$) among tested varieties. Mean grain yield ranged from 3653 kg/ha for local variety Ingliz to 4650 kg/ha for improved variety Dire. Improved variety Bekelcha also produced statistically significant grain yield (4563 kg ha^{-1}) with Dire. Toltu variety recorded statistically different grain yield (4477 kg/ha) to local check (3653 kg/ha). The three improved varieties gave statistically much higher grain yield than the Local variety. These results clearly indicated that the improved durum wheat varieties are more productive and responsive to nitrogen fertilizer than the local variety.

Table 2: Mean value of plant height and grain yield of durum wheat varieties grown under different Nitrogen fertilizer rates

	Plant height(cm)						**Grain yield kg h^{-1}**					
N kg h^{-1} N	46	92	138	184	230	Mean	46	92	138	184	230	Mean
Variety												
Toltu	81.6	82.8	86.7	84.2	85.7	84.2^{c}	3986	4496	4647	4574	4684	4477^{b}
Dire	81.8	84.1	85.3	84.6	85.5	84.3^{c}	4120	4567	4833	4791	4937	4650^{a}
Bekelcha	86.8	88.3	89.6	89.4	90.3	88.9^{b}	4003	4583	4769	4673	4788	4563^{ab}
Ingliz	121.9	122.3	121.6	122.5	122.2	122.1^{a}	3151	3834	3826	3717	3736	3653^{c}
Mean	93.0	94.3	95.8	95.2	95.9		3815^{c}	4370b	4519^{ab}	4439^{ab}	4536^{a}	
CV (%)			7.4						12.7			
LSD(0.05)												
V			1.77						140			
N			NS						156			
VxN			NS						NS			

Means with the same letter are not significantly different at 5% level of significance; NS=Non significant; N=Nitrogen =Variety; CV (%) = Coefficient of variation.

Biomass yield and Harvest index

The combined analysis of variance over years revealed that the main effects of Nitrogen fertilizer rates and durum wheat varieties were significant differences ($P < 0.05$) on the aboveground biomass and harvest index, while interaction was not significant for the two parameters (Table 3). Biomass yield increased as rate of nitrogen applied increased from the lowest to the highest level. Mean biomass yield ranged from 8414 kg ha^{-1} for the lowest treatment(46 kg N ha^{-1}) to 11897 kg ha^{-1} for the highest treatment (230 kg N ha^{-1}) indicating large biomass yield variation under the different nitrogen rate treatments. This is in agreement with the findings of Amanuel *et al.* (1991) who reported a significant increase of biomass yield as a result of nitrogen rate increase in wheat. The highest nitrogen rate treatments significantly reduced harvest index (40%) as compared to the lowest rate. The second lowest treatment 92 kg ha^{-1} had resulted in the highest harvest index (52%), in statistical parity with the lowest nitrogen rate of 46 kg ha^{-1} with a harvest index value of 51%. In the case of varieties, statistically all improved varieties were ranging from 48-49% suggesting nearly an equal early assimilation and utilization of nitrogen nutrients of those varieties, while lowest harvest index (42 %) was recorded for variety Ingliz.

Table 3: Mean value of bio-mass yield and harvest index of durum wheat varieties grown under different Nitrogen fertilizer rates

	Biomass yield (kg ha^{-1})						Harvest index(%)					
N kg ha^{-1}	46	92	138	184	230	Mean	46	92	138	184	230	Mean
Variety												
Toltu	8090	8836	9924	10371	11697	9784	54	55	49	45	41	49a
Dire	8303	9389	9460	10931	11971	10011	53	52	53	45	42	49a
Bekelcha	8300	8649	9887	10782	11676	9859	50	55	50	44	42	48a
Ingliz	8961	9337	10996	11664	12243	10640	45	48	41	37	36	42b
Mean	8414^{d}	9053^{d}	10067^{c}	10937^{b}	11897^{a}		51^{ab}	52^{a}	48^{b}	43^{c}	40^{c}	
CV (%)			25.1						21.4			
LSD (5%)												
V			NS						3			
N			717						3			
VxN			NS						NS			

Means with the same letter are not significantly different at 5% level of significance; NS=Non significant; N=Nitrogen; V=Variety's (%)= Coefficient of variation.

Thousand Kernels and hectoliter Weight

The result showed significant differences ($P < 0.05$) among nitrogen rate treatments and durum wheat varieties for TKW and HLW while their interaction was no significant (Table 4). The maximum TKW was observed for treatments 138 kg N ha^{-1} (45.6 g). This might be attributed to a better nutritional status of the plants which resulted in good grain filling and development. The minimum TKW was achieved in the lowest treatment which was significantly different from 92 kg N ha^{-1} (41.3 g). ANOVA demonstrated that durum wheat varieties differed significantly in TKW. Improved variety Bekelcha gave the highest TKW (46.6g) while the lowest was recorded by local variety Ingliz (42.9g).Toltu and Dire were statistically identical for thousand kernel weights. The highest HLW was obtained from the variety Toltu (82.3 kg hl^{-1}) in statistical parity with Dire (81.95 kg hl^{-1}). The lowest HLW was recorded by Local variety Ingliz (81.02 kg hl^{-1}). According to this study all varieties had HLW> 81 kg hl^{-1} which most millers demand as standard for semolina milling (Session, 2004). In general, HLW was ranged from 81.02-82.3 kg hl^{-1} for the varieties under this study. According to Atwell (2001) hectoliter weight may range from about 57.9 kg hl^{-1} for poor wheat to about 82.4 kg hl^{-1} for sound wheat.

Table 4: Mean value of thousand kernels weight and hectoliter weight of durum wheat varieties grown under different N rates

	TKW (g)						HLW (kg hl^{-1})					
N kg ha^{-1}	46	92	138	184	230	Mean	46	92	138	184	230	Mean
Variety												
Toltu	41.0	42.6	45.5	45.0	45.2	43.9b	81.7	82.7	82.5	82.4	82.4	82.3a
Dire	40.5	44.1	45.2	45.5	44.9	44.1b	81.4	82.1	82.2	82.1	82.0	82ab
Bekelcha	43.6	46.3	48.1	47.3	47.6	46.6a	80.8	81.9	82.0	81.8	82.3	81.7b
Ingliz	40.3	42.6	43.5	44.0	44.0	42.9c	80.3	81	81.3	81.3	81.3	81.0c
Mean	41.3c	43.9b	45.6a	45.5a	45.5a		81.1	81.9	82.0	81.9	82.0	
CV (%)			6.9						2.9			
LSD(0.05)												
V			0.78						0.59			
N			0.87						NS			
VxN			NS						NS			

Grain protein content

In this study results showed significant differences (P < 0.05) among nitrogen rate and varieties for grain protein content while the effect of interaction between various nitrogen rate application and varieties was non significant (Table 4). The highest grain protein content (15.1%) was recorded for the highest nitrogen rate (230 kg N ha-1). Kirrilov and Pavlov (1989) also reported that applied nitrogen increased wheat grain protein content by 20.29 %. Grain protein content of the cultivars ranged from 12.9% (Ingliz) to 14.6% (Bekelcha) (Table 5). Grain protein contents of improved varieties Bekelcha, Toltu and Dire were significantly higher than the local cultivar Ingliz. This variation in grain protein content of the cultivars may be attributed to their variation in nutrient uptake and translocation capacities to the sink.

Table 5: Mean value of grain protein content of durum wheat varieties grown under different Nitrogen fertilizer rates

Grain protein content (%)						
N kg ha^{-1}	46	92	138	184	230	Mean
Variety						
Toltu	13.0	13.8	14.5	14.4	15.3	14.2b
Dire	12.9	13.4	14.2	14.7	15.4	14.1b
Bekelcha	13.3	13.6	14.6	15.6	15.8	14.6a
Ingliz	12.1	12.7	12.9	13.5	13.7	12.9c
Mean	12.8e	13.4d	14.1c	14.5b	15.1a	
CV (%)			6.1			
LSD(0.05)						
V			0..22			
N			0.24			
VxN			NS			

PARTIAL BUDGET ANALYSIS

Partial budget and marginal analysis were performed for nitrogen fertilizer rate and the decision for selecting the profitable treatment was made based on the highest marginal rate of return (Table 5). The Marginal analysis indicated that changing from the first treatment (46 kg N ha^{-1}) to the second treatment (92 kg N ha^{-1}) has resulted the highest marginal rate of return (212%), which means that investing 1 birr in treatment number two acquire a return of 2.12 birr. There for, the best nitrogen rate for durum wheat productivity and profitability in the high lands of bale is 92 kg N ha^{-1}.

Table 6: Partial budget analysis result for nitrogen rate study on durum wheat varieties

	Treatments (Nitrogen kg ha^{-1})				
	46	92	138	184	230
Average yield(kg/ha)	3815	4370	4519	4439	4536
Adjusted yield(kg/ha)	3434	3933	4067	3995	4082
Gross field benefits(Birr/ha)	46359	53096	54905	53933	55107
Cost of Nitrogen(Birr/ha)	1500	2999	4499	5998	7498
Cost of labour to apply Nitrogen (Birr/ha)	35	70	105	140	175
Harvesting, packing and transportation (Birr/ha)	3949	4523	4678	4594	4694
Total costs that vary(Birr/ha)	5484	7592	9282	10732	12367
Net benefits (Birr/ha)	40875	45504	45623	43201	42740
MRR%		212	7		

Cost of urea 1500 Birr 100 kg^{-1}or (32.60 Birr kg^{-1} N); urea application of 46 kg N ha^{-1} one person@ 35 Birr/person/day; 92kg N ha^{-1} two person@ 35Birr/ person/day;138 three person @ 35Birr / person/day; 184 four person@ 35 Birr / person/day; and 230 kg N ha^{-1} 5 person @ 20 Birr/ person/day; harvesting, packing and transportation 115 Birr per 100 kg; sale price of wheat grain 1350 Birr per 100 kg .

CONCLUSION AND RECOMMENDATIONS

The result of the current study indicated that balanced and adequate soil nutrient management is one important practice for increasing durum wheat yield component and yield. The results of the experiment revealed that nitrogen fertilizer application significantly influenced durum wheat agronomic traits and grain quality attributes. Therefore, from the results of three years' data over locations; it was observed that 92 kg N ha^{-1} was the most promising and economically feasible nitrogen rate for recently released durum wheat varieties in the highlands of Bale and Similar agro-ecology. All improved varieties had the highest grain protein content, which is essential for past processing and better nutrition value. The results also imply that there is a need to formulate variety-specific fertilizer recommendation rates for enhancing the productivity and grain quality of durum wheat for pasta/macaroni making.

ACKNOWLEDGEMENTS

The authors are grateful to all staff of the Sinana Agricultural Research Centre especially those in the Cereal Crops Technology Generating Team for valuable contributions in data collection. Oromia Agricultural Research Institute is acknowledged for financing the experiment.

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