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Determination of Nitrogen fertilizer Requirement of Durum Wheat on Growth and Grain Yield At Butajira Ethiopia

Wubshet Teshome

Ethiopian Biodiversity Institute Crop and Horticulture Directorate
2Hawassa University College of Agriculture
Email address: *info@ibc.et.org*

Abstract

Optimum Nitrogen fertilizer rate requirement of crops vary from place to place due to several environmental factors. Therefore, there is a need to determine area specific N fertilizer recommendations for available varieties. Accordingly, an experiment was conducted to evaluate the effect of N fertilizer rate on growth and yield of durum wheat at Butajira. The durum wheat variety, Ejersa, was used as a test crop. The experiment has four levels of N (0, 23, 46 and 69 kg ha-1) arranged in factorial combination using randomized complete block design with three replications. Nitrogen significantly extended days to heading and physiological maturity. Plant height, spike length and straw yield were significantly increased with increasing N levels. Kernel per spike, thousand seed weight, grain yield and total biological yields were significantly increased up to 46 kg N ha-1 rates, but further increase in N did not bring additional increment of these parameters. Harvest index was decreased with increasing N levels. Grain yield increased from 2.02 t ha-1 at 0 kg N ha-1 to 4.37 t ha-1 at 46 kg N ha-1 with no further increase at higher N levels. There is a 115.3 % increase in grain yield at 46 kg N ha-1 compared to the control. Nitrogen uptake was influenced by the application of N fertilize compared to the control and application of 69 kg N ha-1 increased N uptake by 220 %. A rate of 46 kg N ha-1 was found to be economically acceptable with MRR of 1056.22. Therefore, application of 46 kg N ha-1 level could be recommended as an economically feasible choice for the study area; however, it is useful to undertake further research across soil type, years and locations to put the recommendation on a wider scale.

Keywords: Nitrogen, Wheat, Yield, Yield Component.

1. Introduction

Wheat is one of the major and widely cultivated cereal crops in the southern regions of Ethiopia. It covers 15.5% of the total area and 16% of the total production from cereal in the region ***[1]***. Wheat in Gurage zone covers 13,736 ha with an average yield of 1,911 kg ha-1 ***[2]***. It is mainly produced for home consumption and marketing. It is grown during the main cropping season (June to November). The straw after harvest is either left in the field for animal feed or used as cover for roofs, and rarely for sale.

The low national mean yield (1379 kg ha-1) of wheat is primarily due to depleted soil fertility ***[3]***, low fertilizer usage ***[4]*** and unavailability of improved crop management practices ***[5]***. The use of appropriate agronomic practices in wheat production is indispensable for high and sustainable yield.

Low soil fertility ***[4]*** and very limited spread of improved varieties; ***[3]*** further worsen the problem of wheat production. Integrated nutrient management involving use of chemical fertilizers supplemented with compost may provide an alternative and better strategy to enhance the productivity of wheat .Therefore, efforts to reintroduce integrated nutrient management will play an important role to meet the challenge of crop productivity.

The main wheat production problems at Butajera area are low use of improved wheat cultivars, low soil fertility, higher fertilizer cost, disease and erratic rain fall. Farmers in the Woreda use both inorganic fertilizers and compost with blanket recommendation due to low soil fertility (personal communication with the office of agriculture, 2010). The objectives of N fertilizer use is to reduce the use of inorganic fertilizer, restore organic matter in the soil, enhance nutrient use efficiency and maintain soil quality for sustained crop With these points in view, field experiment were conducted in Butajira area of Gurage zone (SNNPRS) with the following objectives

Ø To investigate the effects of chemical fertilizer on growth and grain yield of Wheat, and
Ø To determine the economic benefit of inorganic fertilizer

2. Materials and Methods

2.1. Description of the study area

Field experiment was conducted at Butajira located in, Guraghie Zone of the South Nations, Nationalities and Peoples Region (SNNPR). It is about 138 km away from Addis Ababa. The experimental site is located at an elevation of 1960 meter above sea level in the direction of 080 06.4220 North latitude and038024.9090 East longitudes

Based on ten years (2000 to 2009) meteorological data, the average annual rainfall of Butajira area is 1093.52mm with a range of 504.7 mm to 1783.3 mm. The rain fall distribution was uneven. The average annual temperatures was 18.6 0C.

3.2. Experimental treatments and design

The treatments were four levels of N (0, 23, 46,69 kg ha-1), urea as source of N fertilizer. Some of the farmers in the experimental area used 150 kg ha-1 urea for wheat ***[7]***.The experimental factors were arranged in randomized complete block design (RCBD) in factorial arrangement with 3 replications. Gross plot size was 2 m wide and 4 m long, which accommodated 10 rows with 0.2 m apart.

3.3. Planting material and cultural practices

Wheat variety commonly known as Ejersa was used as planting materials, which has a high yielding, drought and rust resistance characteristics ***[8]***. The experimental field was prepared by using oxen driven local plow and plowed four times; wheat was planted on July 6, 2010 in rows at the rate of 150 kg ha-1. Nitrogen was applied in two splits 1/2 at sowing and 1/2 at mid tillering stage before flowering. Triple super phosphate (TSP) (46 % P2O5) was applied to all treatments at the rate of 50 kg ha-1. The field was weeded twice by hand (at 40 and 65 days after planting) during the cropping season to control weeds. Moreover, all the necessary field management practices were carried out uniformly to all plots. The crop was finally harvested at maturity on November 13, 2010.

2.4. Data collection

2.4.1. Soil sampling and analysis

Soil samples were taken randomly from 5 spots of the experimental plot from 0-30 cm depths from each replication before planting. The samples were subjected to analysis of textural class, pH, CEC, available P, organic carbon (OC) and total N using standard ***[9]***. After harvest soil samples were taken from each plot for total N analysis.

2.4.2. Plant sampling and analysis

At harvest, five plants samples were taken from each plot to analyze total N content (%)***[9]***. A mixture of four grams per plot of each grain and straw was taken, grounded and sieved for analysis. Total N uptake by the above ground wheat biomass was calculated using the nitrogen content of the mixture of grain and straw.

2.4.3 Crop data

Phenology, Days to heading, Days to maturity, Plant height, Spike length, Yield and yield components, Total biological yield and Harvest index were obtained and carefully analyzed.

2.5. Economic analysis

For estimation of the total cost, market prices of the inputs were taken from the market assessment at the time of planting in Butajira town. Wheat market price was taken at harvest. The economic analysis was carried using partial budget analysis procedures ***[10]***. The average grain yield was adjusted down ward by a 15 % to reflect the difference between the experimental yield and yield of farmers. Nitrogen level was decided based on the acceptable marginal rate of return to be equal or more than 100%. For estimating the total cost, the market price of Urea fertilizer was taken from the market assessment at the time of planting. The unit price of grain at harvest and urea were 6.0 and 8 Birr kg-1 respectively. The price of preparing, transporting and applying compost was 0.12 Birr kg-1.

2.6. Statistical analysis

Analysis of variance was carried out using ***[11]***. The statistical significance was determined using F- test. The mean differences were separated by Tukey test of significance at 1 and 5 % probability level of significance.

3. Results and Discussion

3.1. Rainfall

Total rainfall of the growing period (July to November) showed that the experimental site was in the range of 500-1200 mm per year of the rainfall required for wheat production [9]. Total rainfall of the long term (10 years) (July to November) was 599.6 mm and the total rainfall during the growing period was 921.9 mm, which was 54 % higher than the long term period (Table 1).

Amount of rainfall during flowering, heading, spike formation, grain filing and grain development was 56.7% higher than the long term (September to October) and seemed optimum rainfall for the reproductive stages. The optimal way of applying nitrogen to rain fed cereals depend on the interaction among rainfall (amount and distribution), soil nitrogen, and seasonal nitrogen uptake [10,11] reported that responses to N depend on both the quantity and distribution of rainfall during the growing season.

Table 1 : Long term (2001-2010) and growing season average rainfall of the study area

Months	Long term RF(mm)(2001_2010)	Growing season RF (mm)	Difference (%)
July	212.54	394.80	+85.75
August	160.22	169	+5.48
September	161.34	274.60	+70.20
October	48.51	53.70	+10.70
November	16.95	29.80	+75.81
Total	599.6	921.9	+53.76

Source: Hawassa Meteorology Agency, Hawassa, 2011

3.2. Physico-chemical properties of the experimental soil

The pH of the soil was slightly acidic with a value of 6.02 (pH-H_2O). According to [11], the optimum pH (KCL) range for wheat production is from 4.1 to 7.4 [13] also reported that the preferable pH range for most crops and productive soils are 4 to 8. Thus, the pH of the experimental soil was within the range for the productive soils. Cation exchange capacity (CEC) is an important parameter of soil, because it gives an indication of the type of clay mineral present in the soil and its capacity to retain nutrients against leaching [11]. According to[6], CEC of the experimental soil is 35.9 which are in the range of 25 to 40 c mol/kg (high to medium) that could be considered as optimum for crop production.

The experimental site was under maize cultivation before we used this site for the present study. The high organic matter content of the experimental soil might be due to more organic carbon content (3.34%) which might have contributed to the low level of total N (0.14%) in the soil (Table 2). [12] Indicated that OC influences many soil biological, chemical and physical properties that favorably influence nutrient availability. Organic matter also acts as the main storehouse of many nutrients, including nitrates, phosphates, sulphates and others [14]. [6] Also rated 0.2 **%** total N as low, 1.74-2.90 % OC as high and greater than 2.90 % OC as very high. Thus, OC and total N contents of the experimental soils were very high and low, respectively.

Table 2: Initial Physico-chemical properties of the experimental soil

Sample	Particle size (%)			pH	Av. P	Total N	CEC	OC
	Sand	Silt	Clay	(H_2O)	(mg kg-1)	(%)	(cmol kg-1)	(%)
Soil	46.25	26.25	27.5	6.02	26.2	0.14	35.9	3.34

Av. P = Available Phosphorus, N= nitrogen, CEC= Cation Exchange Capacity, OC= organic Carbon

3.3. Effect of N fertilizer on durum wheat

3.3.1. Phenology

There was an increase in days to heading due to application of N fertilizer over the control. Nitrogen application at the rate of 69 kg ha-1 extended days to heading by 12 days (20%). This might be due to the greater N uptake at higher N level, which prolonged the vegetative growth that led to delayed in heading. In conformity ***[14]***and ***[6]***reported these days to heading was significantly delayed at the highest N fertilizer dose compared with the lowest rate on wheat. Moreover, ***[6]***reported that N application significantly affected days to heading of wheat.

Table 3: Mean comparison of phonological aspects of durum wheat as affected by N application, Butajira, 2010

treatment	Heading	Days to Maturity
N (Kg ha-1)		
0	60d	95d
23	63C	98c
46	68 b	102b
69	72a	106a
Significance level	***	***
CV	1.25	1.41

*Means in a column followed by the same letter of each factor are not significantly different at 5% probability level Tukey test; * = significant at 5%, ** = significant at 1%, *** = Significant at 0.1%.

Days to maturity- Nitrogen level significantly influenced days to physiological maturity (Table 3. Plants treated with N particularly at the highest level of N (69 kg ha-1) remained green, while the spikes, leaves and stems of plants without N became yellow and matured early. Nitrogen application at the rate of 69 kg ha-1 extended days to maturity by 11days (Table 3). The delay in physiological maturity with the highest dose of N might be attributed to the maximum uptake of N fertilizer, which causes high photosynthetic activity that encouraged excessive vegetative growth. Similarly, ***[15]***and ***[14]***) reported that a dose of 100 kg N ha-1 extended the maturity of wheat to 106 days compared with the control which matured in 96 days.

3.3.2. Growth

Plant height- Plant height was significantly affected by N fertilization (Table 4). There was a gradual increase in plant height with each successive dose of N. Application of nitrogen from 0 to 69 kg ha-1 increased plant height with an increase that varied between 3.3 and 7.8 cm compared with the control (Table 4). The increase might be in stem elongation brought about by cell division and expansion as the result of N addition. This finding is supported by the work of ***[16]***who concluded that N fertilizers increased plant height. A positive and linear response of plant height of wheat to applied N fertilizer was also reported by ***[17,18]***reported that early application of N, either all at seeding or split applied increased plant height and concluded that moderate application of N at planting resulted in taller wheat plant height.

Table 4: Mean comparison of growth data of durum wheat as affected by N fertilizer, Butajira, 2010

treatment	Plant height (cm	Spike length (cm
N (Kg ha-1)		
0	57.48d	95d
23	60.73C	98c
46	6235 b	102b
69	65.22a	106a
Significance level	***	***
CV	1.44	2.42

*Means in a column followed by the same letter of each factor are not significantly different at 5% probability level Tukey test; * = significant at 5%, ** = significant at 1%, *** = Significant at 0.1%.

Spike length- Spike length was significantly affected by both N and compost rate but their interaction was not significant (Appendix 3). Nitrogen fertilizer tended to increase spike length in which application of 23, 46 and 69 kg N ha-1 increased spike length by 10.8, 21.6, and 33.6 % respectively, compared with the control (Table 4).

The increase might be, in spike elongation, brought about by cell division and expansion as the result of N addition These results are in consonance with the findings of ***[16]*** who reported that spike length of wheat increased with application of N fertilizer, in which maximum spike length of 7.93 cm was recorded from application of 75 kg N ha-1 , while the minimum 4.26 cm was recorded from the control.

3.3.3. Yield and yield components

Kernels spike-1 - Kernels per spike (NKS) were significantly affected by N level. There was an increase in kernels per spike as rate of N application increased (Table 5). Application of 46 and 69 kg N ha–1 increased spike length by 25.8 compared to the control but not significantly difference from one another.

Application of N at mid-tillering might increase the number of kernels spike–1 by increasing grain sites and thus more florets spikelet –1 ***[6]***. Other researchers also reported increase in kernels spike–1 due to application of N in wheat ***[19, 20, 21, 6, 22]***

Table 5: Mean comparison of yield and yield components of durum wheat as influenced by N application, Butajira, 2010

treatment	kernel spike-1	Thousand Seed Weight (g)	Grain yield (t ha-1)
N (Kg ha-1)			
0	31**c**	32.58**c**	2.02c
23	**33b**	**35.42b**	**3.14b**
46	**39a**	**38.42a**	**4.35a**
69	**39a**	**38.33a**	**4.07a**
Significance level	***	***	**
CV	**4.67**	**4.59**	**10.88**

*Means in a column followed by the same letter of each factor are not significantly different at 5% probability level Tukey test; * = significant at 5%, ** = significant at 1%, *** = Significant at 0.1%.

Thousand seed weight (TSW) **-** Effects of N fertilizer on thousand seed weight were significant while their interaction was not. Thousand seed weight increased as rate of N fertilizer increased up to 46 kg ha-1 but this was not significantly different from the highest rate of N (Table 5). It seemed that lack of adequate soil N and excess N application tended to reduce thousand seed weight. The positive role of N could partly be attributed to its effect on extending grain filling period ***[16]***and ***[22]***This finding is supported by***[17]*** who reported that there was a positive and linear response of seed weight to N fertilizer application. In contrast, ***[6]***reported that application of N fertilizer reduced kernel weight which was balanced by an increase in spike m-2.

Grain yield**-** Significant differences were observed in grain yield due to effects of N fertilizer with no interaction effect. Application of 46 kg N ha-1 increased grain yield by 115.3 and 38.5 % compared to the control and 23 kg N ha-1 respectively, but showed no significant different with 69 kg N ha-1. This may be due to the fact that grains become a dominant sink at maturity and the entire photo-assimilate deposited in the grains produced more weight and ultimately more grain yield. This was in line with the work of ***[18,23]***

Straw yield (SY) - Straw yield was significantly affected by N fertilizer. Straw yield from plots treated with 69 kg N ha-1 was highest, and increased the straw yield by 172.2 % compared to the control. The straw yield showed a linear response to N application and may indicate that N fertilizer favored vegetative growth more than the reproductive growth as evidenced by a reduced HI at the maximum N rate ***[23]***. An increase in wheat straw yield with N application was reported by other researchers ***[22]***. He indicated that N fertilizer increased vegetative biomass leading to a significant increase in straw yield.

Table 3: Mean comparison of straw yield, biological yield and harvest index of durum wheat as influenced by N fertilizer rate.

treatment	Straw yield	Biological yield	Harvest index
N (Kg ha-1)			
0	**3.34d**	**5.35c**	**0.38a**
23	**5.77c**	**8.91b**	**0.36a**
46	**8.37b**	**12.71a**	**0.34ab**
69	**9.09a**	**13.17a**	**0.31c**
Significance level	*******	*******	*******
CV	**9.04**	**8.13**	**10.90**

* = significant at 5%, ** = significant at 1%, *** = Significant at 0.1%.

Total biological yield - Both application of N fertilizer significantly affected total biological. Total biological yield showed an increase as rates of N fertilizer increased up to 69 kg N ha-1 though not significantly different from the 46 kg N ha-1 rate. Application of 46 kg N ha-1 increased total biological yield by 137.6 and 42.6 % compared to the control and 23 kg N ha-1 rates, respectively. Nitrogen has increased vegetative growth, plant height, spike length, and seed spike-1 leading to higher total biological yield. This is in agreement with the finding of ***[22]*** who indicated that increased N level increased total biological yield of wheat. Similar results in wheat were also reported by ***[6,26,]***.

Harvest Index- Application of N fertilizer significantly affected HI (Appendix3). The highest mean value of 0.38 was recorded from the control, but not significantly different from that obtained from 23 and 46 kg N ha-1. Further increase in N rate reduced HI by 22.6% compared to the control. This was due to the fact that adding more N fertilizer increased vegetative growth compared with grain yield by improving cumulative solar radiation intercepted by the crop, and the low rainfall accompanied by high temperature that limited opportunity to partition biomass to grain ***[24]***.. Essentially, climatic condition was such that photosynthesis could proceed at rapid pace, but the size of the sink for storage was limited by the distribution of rainfall. Such a decrease in harvest index with increased rate of N application was in line with the finding of ***[5]***. who reported decline in harvest index of wheat as N rate increased.

3.4. Nitrogen uptake

Effects of nitrogen fertilizer on uptake of N by wheat were statistically significant (Table 7) .Total nitrogen uptake by wheat was increased as rate of N application increased. Application of 23, 46 and 69 kg N ha-1 increased N uptake by 81, 179.2 and 220.1%, respectively, compared with the control. The increase in N uptake was mainly attributed to increased N availability around the root zones and higher dry matter accumulation through increased root growth and effective absorption ***[16,22]***. According to ***[25]***. increase in N uptake could be due to over growth of aerial parts and consequently, increases in the above ground biomass.

Table 4: Mean comparison of nitrogen uptake and soil nitrogen at harvest as affected by N application, Butajira, 2010

Treatments	Nitrogen uptake (kg ha-1)	Post-harvest soil Nitrogen (%)
N (Kg ha-1)		
0	**78.8d**	**1.53d**
23	**142.7c**	**1.78c**
46	**220.1b**	**2.08b**
69	**252.3a**	**2.30a**
Significance level	*******	*******
CV	**7.35**	**2.77**

Means followed by the same letter in the same column are not significantly different at 5% probability level. Tukey test; * = significant at 5%, ** = significant at 1%, *** = Significant at 0.1%.

3.6. Total soil nitrogen at harvest

N fertilizer had a significant effect on total soil nitrogen content of the soil after harvest (Table 7). Total soil N of the control treatment at harvest was 9.3% higher than the pre sowing soil N (Table 7). As rate of N application increased from 0 to 69 kg ha-1 total soil nitrogen at harvest

was linearly increased from 1.53 to 2.3 kg-1. The increase in total soil nitrogen could be due to the fact that portion of the applied N was retained in the soil as residual inorganic N or incorporated into various organic N pools including soil organic matter ***[26]***..

3.7. Economic analysis

The result showed that marginal rate of return (MRR) for the rates of 23 and 46 kg N ha-1 was 970.22 % and 1056.22 %, respectively (Table 8). This means that for every 1.00 birr the farmer invested in fertilizer application, farmers can recover 9.70 and 10.56 birr for the respective rates. Further Increase beyond 46 kg N ha- 1 will incur additional costs without compensating the benefit. According to***[15]***, the minimum acceptable rate of return should be above 100 %.

Therefore, the marginal rate of return obtained for the aforementioned N rates was above the ***[15***minimum acceptable rate of return. For that reason, application of 46 kg N ha-1 which had significantly higher yield with an acceptable marginal rate of return might be taken as profitable rate for the test area.

Table 5: Partial budget analysis on wheat yield as influenced by N fertilizer, Butajira, 2010

Treatments	ADTY (kg ha-1)	GFB	TC Birr ha-1	NB	MRR (%)
N fertilizer (kg-1)					
0	**1818**	**7817.4**	**0**	**7817.4**	
23	**2826**	**12151.8**	**405**	**11746.8**	**970.22**
46	**3915**	**16834.5**	**810**	**16024.5**	**1056.22**
69	**3663**	**15750.9**	**1215**	**14535.9 D**	

ADTY= Adjusted yield, GFB= Gross Field Benefit, TC = Total cost that Vary, NB= Net Benefit, MRR= Marginal Rate of Return D= dominated

4. Summary and Conclusion

The experiment was conducted during 2010 main cropping season on farmer's field under rain fed condition at Butajira to determine the effects of N fertilizer on growth and yield of Durum wheat and on soil characteristics. The factorial combinations of four nitrogen levels (0, 23, 46, and 69 kg N ha-1) were laid out in a randomized complete block design with three replications.

Analysis of a composite soil sample revealed that the soil of the experimental field as sandy clay in texture and slightly acidic (pH=6.02) with 0.14 % total N, 3.34 % organic matter, 26.2 mg kg-1 available phosphorus and 35.90 cmol kg-1 CEC. Post-harvest total N of the soil showed significant increase with increase in N levels, and the highest total N (2.3g kg-1), and the lowest (1.53g kg-1) were recorded from 69 kg N ha-1 and the control, respectively.

Application of different levels of N fertilizer significantly influenced most of the growth parameters and yield and yield components of wheat. Application of N fertilizer delayed days to heading and maturity. Vegetative characters showed an increasing trend when the level of N increased. Plant height, Spike length, total biological yield, and straw yield increased with the level of N fertilization.

Similarly, increase in kernel per spike, grain yield and thousand grain weights were also recorded from application of N fertilizer at the rate of 46 kg ha -1. However, application of N at the highest level decreased harvest index. Therefore, 46 kg N ha-1 proved to be superior to others with respect to most of yield attributes.

Days to heading and maturity were delayed at 69 kg N ha-1. The highest plant height of wheat and spike length of wheat was recorded at the highest N level (69 kg N ha- 1). Grain yield of wheat was higher (4.35 t ha-1) at the rate of 46 kg N ha-1 and the magnitudes of increase in wheat grain yield were 115.3% over the control.

The partial budget analysis indicated that 46 kg N ha-1 gave the highest net benefit of 16024.5 Birr ha-$_1$ with an acceptable MRR of 1056.22% and this might be taken as a profitable rate for the test area. Based on the result of this study, it can be concluded that 46 kg N ha-1 is more economical and recommended for Durum wheat production in the experimental area. However, these finding need to be confirmed through further research across locations and years to ascertain the consistency of the recommendation.

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