Nitrogen Uptake, Recovery and Use-efficiency in forage oat (*Avena sativa* L.)

Aklilu Mekasha [1*], *Y.P. Joshi* [2] *and Alemayehu Mengistu* [3]

[1.] Melkassa Agricultural Research Center; P.O. Box 436; Nazareth, Ethiopia.
[2] G.B. Pant University of Agriculture & Technology, Pantnagar-263145, India
[3] Research and development consultant; Addis Ababa, Ethiopia

Abstract

Study was conducted to investigate effects of different levels of nitrogen on nitrogen content, uptake, recovery and use-efficiency of forage oat. Two-third of five levels of nitrogen (0, 40, 80, 120 and 160 kg ha^{-1}) in the form of urea (CO $(NH_2)_2$), was applied at planting time and the remaining one-third - 30 days after sowing on soils with pH 7.3, 238 kg ha^{-1} available nitrogen, 0.7% organic carbon, 47.3 kg ha^{-1} available phosphorous and 284.37 kg ha^{-1} exchangeable potassium. It was found that total nitrogen uptake by the crop and the nitrogen content in plant tissue significantly increased ($P < 0.05$) with successive levels of nitrogen applied upto 120 kg ha^{-1} ; whereas, the apparent recovery and the use-efficiency declined significantly ($P < 0.05$) with successive levels of the applied nitrogen. The implication is that the efficiency of fertilizer use is inversely related with level of application and that of the uptake and content in plant tissue and dry mater yield of the crop. In the present study optimum level for maximum rate of yield increment could not be more than 120 kg N ha^{-1}. The decrease in recovery and use efficiency was reflected in yield only at a rate higher than the optimum level.

Keywords: *Forage oat; Nitrogen; Recovery; Uptake; Use-efficiency*

Introduction

Among all essential nutrients to plants, nitrogen is the most important essential element in nutrition of almost all plants. It is an important constituent of physiologically important compounds like nucleotides, phosphatides, vitamins, enzymes, hormones and chloroplast that promotes growth and development in plants (Pandey and Sinha, 2006). The nutritional importance of nitrogen probably is higher in forage crops than in grain since ruminant animals relay on low quality protein present in the diet to derive. Most of the protein comes from pasture or cultivated crops that normally constitute the bulk of feed. Efficient use of grasses for higher production of animal protein thus depends upon adequate concentration of nitrogen in the herbage (Hopkins *et al.*, 1994).

Nitrogen is frequently deficient in soils (Havlin *et al.*, 1999) and plants grown on nitrogen deficient soils show stunted growth, yellowish color and reduced yield (Pandey and

*Corresponding Author: aklilumekasha@yahoo.com

Sinha, 2006). Grazing animals also suffer from the deficiency. As a result, forage and pasture agronomists often apply nitrogenous chemical fertilizers at a higher dose based on results of soil test. On the other hand, over application of such nutrients beyond the level of uptake and use by the crop is wastage. The adverse effects could be avoided and the application tuned to economic level by careful selection and development of responsive crops and varieties to high and conversely low levels of nitrogen (Below, 2002). This study was therefore, conducted to see the response of forage oat to different levels of nitrogen in terms of uptake, recovery and use efficiency of the applied nitrogen- as urea.

Materials and Methods

The study site

The study was conducted at Govind Ballbah Pant University of Agriculture and Technology, India. The site is located at 29.5^{o} N latitude and 79.3^{o}E longitude with 243.8 m altitude above mean sea level. It is characterized by subhumid tropical and subtropical climate with shallow water table and gentle slope. The long term meteorological data shows that the mean annual rainfall is about 1385 mm; the maximum temperature of the year occurs in summer, which often exceeds 40^{0}C in May and June with mean monthly minimum temperature below 10^{0}C in January. The soil was generally Beni silty clay loam under the order mollisol. It is slightly alkaline in reaction (pH 7.3), low in available nitrogen (238 kg ha^{-1}), medium in organic carbon (0.7%), available phosphorous (47.3 kg ha^{-1}) and exchangeable potassium (284.37 kg ha^{-1}).

Treatments, design and management practices

The treatments consist of nitrogen fertilizer in the form of urea ($CO(NH_2)_2$) applied at the rate of 0, 40, 80,120 and 160 kg ha^{-1}. Two-third of the level was applied at planting and the remaining one-third 30 days after sowing. The nitrogen level was laid out in a Randomized Complete Block Design with four replications in net plot areas of 4 m^2. The crop was sown at 100 kg ha^{-1} seed rate by drilling in furrows opened 4-5 cm deep at 25 cm spacing in between rows. The plots were irrigated at 20-25 days interval depending on moisture /precipitation status and the need of the crop. A total of 4 irrigations were given to meet water requirement of the crop. Herbicide 2-4, D was also applied to all plots at 1.0 kg a.i. ha^{-1} 25 days after sowing with one supplementary hand weeding 50 days after sowing.

Data collection and analysis

The crop was harvested when it reached 50% heading stage. The harvested green herbage was weighed plot wise and sub samples of about 200g were taken and oven dried at $70^{O}C$ to constant weight. The dried samples were ground by laboratory Willey mill to pass 1 mm sieve and composite samples of 0.5 g were digested with sulfuric acid and analyzed for total nitrogen content by Micro-Kjeldhal method (Jackson, 1973). The nitrogen uptake, apparent recovery, use-efficiencies and dry matter yields of the crop were determined by the following equations:

Nitrogen Uptake (NU)

The nitrogen removed by the crop was determined by multiplying the percentage of total nitrogen content of the plant tissue with the dry matter yield of the crop:

$$\text{Nitrogen uptake (kg/ha)} = \text{DM yield(kg ha}^{-1}) \times \frac{\text{total nitrogen content (\%)}}{100}$$

Apparent Nitrogen Recovery (ANR)

The apparent nitrogen recovery was determined as percentage of the ratio of that portion of the applied nitrogen absorbed by the crop to the total nitrogen applied through urea:

Apparent N recovery (%) =

$$\frac{\text{N uptake from treated plot (kg ha}^{-1}) - \text{N uptake from control plot (kg ha}^{-1})}{\text{Amount of N applied (kg ha}^{-1})} \times 100$$

Nitrogen Use-Efficiency (NUE)

The agronomic nitrogen use-efficiency was determined as the ratio of yield difference between nitrogen treated and untreated plots to the amount of nitrogen applied:

$$\text{NUE} = \frac{\text{DMY from treated plot (kg ha}^{-1}) - \text{DMY from control plot (kg ha}^{-1})}{\text{Amount of N applied (kg ha}^{-1})}$$

Dry Matter Yield (DMY)

The dry matter yield was determined as product of green forage yield multiplied by the dry matter content of the crop:

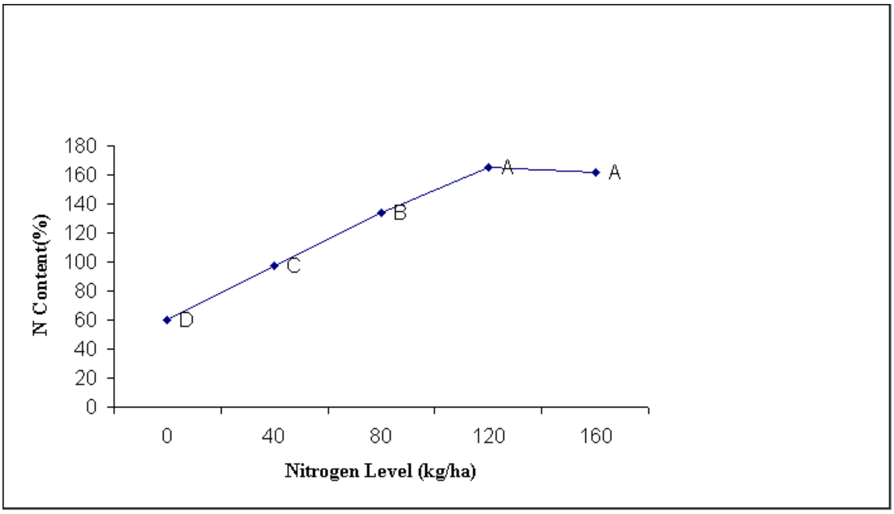
$$\text{Dry matter yield (ton ha}^{-1}) = \frac{\text{Green forage yield (ton ha}^{-1}) \times \text{Dry matter content (\%)}}{100}$$

Finally the data on all parameters were subjected to analyses of variance according to Cochran and Cox (1957) and results were depicted in graph using Microsoft excel spread sheet. On figures levels of nitrogen which did not show significant difference at P > 0.05 were denoted by the same letters.

Results and Discussions

Nitrogen content

Nitrogen content in plant tissue increased significantly ($P<0.05$) with levels of the applied nitrogen (Fig 1). The highest content of 1.71% was recorded at 120 kg N ha^{-1} and further increasing the dose level to 160 kg N ha^{-1} did not show any increment in nitrogen content of the plant tissue. Similar increase in nitrogen content with levels of applied nitrogen was reported by several authors on different crops. Kirkham and Wilkins (1994) noticed consistently higher concentration of nitrogen in plants harvested from plots assigned to the highest dose. The increase in total nitrogen content with dose levels could be due to the fact that availability of more nitrogen enabled the crop to synthesis more cellular organelles to which nitrogen is a building block. The range of total nitrogen content (1.17% to 1.71%) observed, however, is lower when compared to the reports of Aklilu (2005) for the same crop harvested at 30, 60 and 90 days after sowing. The discrepancy could be because of differences in stage of plant growth at harvest. At early stages of growth, plant tissues contain higher amount of total nitrogen. Bloom *et al.* (1985) coined the high nitrogen content at early stages to luxury consumption. The young actively growing roots absorb nitrogen both as ammonium and nitrate ions voracious beyond the capacity of the plant to assimilate. The excessively absorbed nitrate is accumulated in vacuoles and made available for assimilation when the external source is depleted (Below, 1995). This accumulation of nitrate along with more synthesis of protein by young growing leaves could thus result in high percent total nitrogen content regardless of level of applied nitrogen. At later stages of growth, 50% heading observed in present study diminished to 1.17 - 1.71 % perhaps because of depletion of plant reserve, nitrogen supply from the soil, less efficient recovery and dilution of the absorbed nitrogen with high dry matter accumulations. Karlen *et al.* (1988) also accounted the net loss of aerial nitrogen accumulation during the transition from vegetative to reproductive phase, in the absence of sink, to volatilization loss in maize.



Figures with different alphabetical letters are significantly different at p <0.05
Fig 1. Effect of different levels of nitrogen on Nitrogen (N) content (%) of forage oat

Nitrogen uptake

The Nitrogen removed by the crop from soil also increased significantly ($p<0.05$) with successive levels of applied nitrogen from 60 kg uptake recorded at 0 kg N ha^{-1} to 166 kg uptake observed at 120 kg N ha^{-1} and declined to 162 kg uptake noticed at 160 kg N ha^{-1} (Fig 2). The increase in uptake observed in present study is in agreement with the reports of Verma and Joshi (1998) in Teosinte (*Euchlaena maxicana* L.) and Tripati (1994) in oats grown on soils with low fertility. The higher uptake with increased dose level might be due to increased availability of nitrogen in soils with better development of roots of the crop on which nitrogen has positive effect as observed by Chacraborty *et al*. (1999). On the other hand, the decreasing trend observed at above 120 Kg N ha^{-1} was related to the same decrease in nitrogen content since uptake was calculated as a product of nitrogen content and dry matter accumulation in plant tissue. Apart from fertilizer nitrogen (given in the form of urea), the crop also removed about 60 kg from soil available nitrogen which might have made the observed level of uptake (removal) to be at more than the level of applied nitrogen.

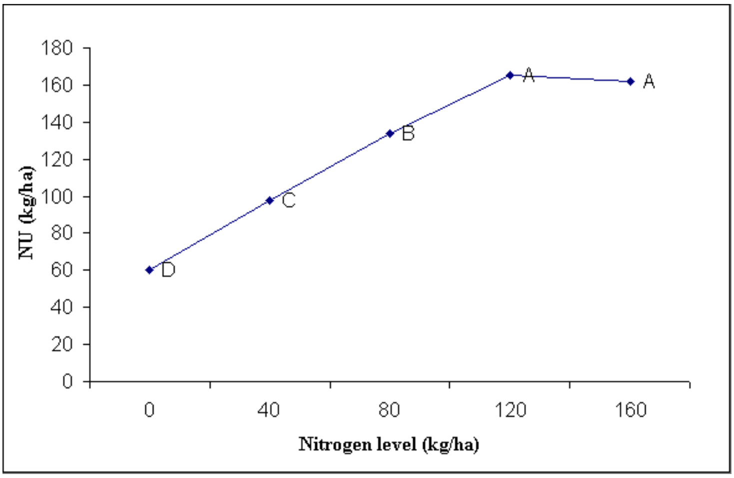


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Fig 2. Effect of different levels of nitrogen on Nitrogen Uptake (NU) of forage oat

Apparent recovery

Unlike the nitrogen content and uptake, the recovery of part of the applied nitrogen explained by the apparent recovery (Fig 3), decreased significantly ($p<0.05$) with successive levels of applied nitrogen from 94 % revealed at 40 kg N ha-1 to 64 % recorded at 160 kg N ha-1. Similar trends have been reported in wheat (Kumar et al., 1995), rice (Shivay and Singh, 2003) and sorghum (Nyamudeza et al., 2003; Ammaji and Suryanaryana, 2003). The decrease in recovery with increased levels of applied nitrogen could be due to genetic limitation of the crop to takeup more nitrogen beyond its capacity to assimilate and also loss of the applied soil nitrogen through denitrification, volatilization, leaching, and immobilization (Havlin et al., 1999; Brady and Weil, 2002). Ammaji and Suryanaryyana (2003) accounted this to the operation of the law of diminishing return in sorghum.

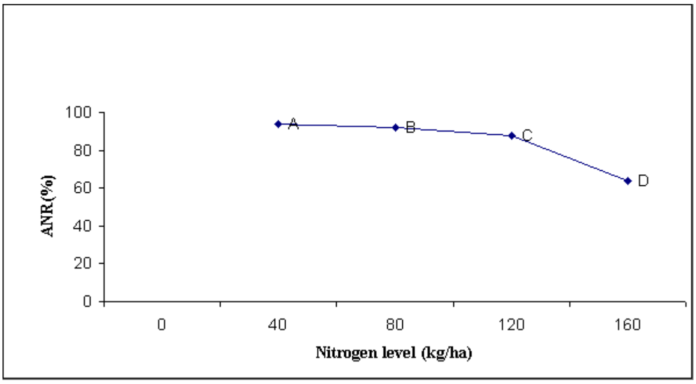

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Fig 3. Effect of different levels of nitrogen on Apparent Nitrogen Recovery (ANR %) of forage oat

Nitrogen use-efficiency

In a similar fashion to recovery, the agronomic nitrogen use-efficiency of the crop decreased significantly ($p<0.05$) with successive levels of applied nitrogen from 60 recorded at 40 kg N ha^{-1} to 26 revealed at 160 Kg N ha^{-1} (Fig 4). The decrease in efficiency of use, i.e the amount of dry matter produced by a unit of the applied nitrogen, was related to the amount of applied nitrogen recovered by the crop. Low recovery of the applied fertilizer nitrogen along with other losses suggested by Karlen *et al.* (1988) might have accounted to the decrease in efficiency of fertilizer use for production of targeted yield.

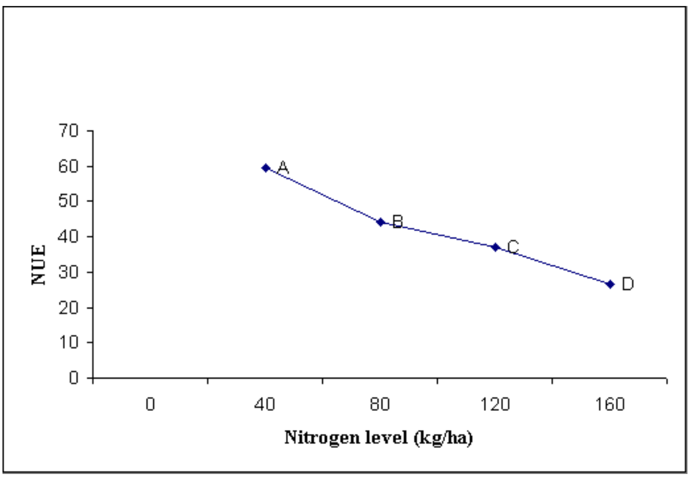

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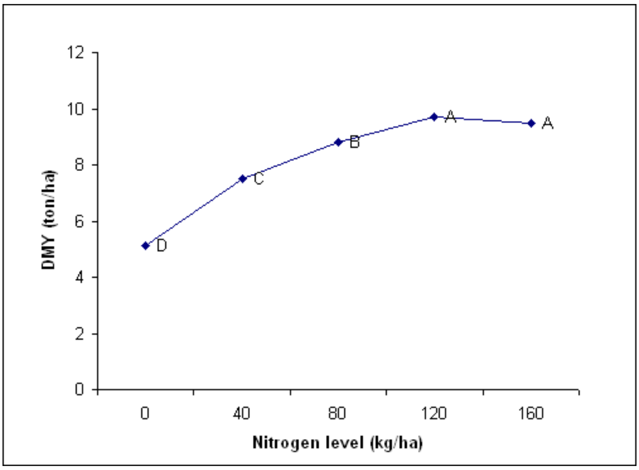
Fig 4. Effect of different levels of nitrogen on Nitrogen Use Efficiency (NUE) of forage oat

Dry matter yield

The dry matter yield of present study increased significantly ($p<0.05$) with levels of applied nitrogen (Fig 5). Maximum dry matter yield of 9.7 ton ha^{-1} was recorded by application of 120 Kg N ha^{-1}. Increasing the dose level to 160 Kg N ha^{-1} however, reduced the dry matter yield to 9.5 ton ha^{-1}. The increase in yield with successive level of nitrogen masked the associated loss of nitrogen explained by both decreasing apparent recovery and use efficiency of the crop. The dry mater yield continued to increase with decreasing recovery and use efficiency till no more yield increment was recorded at above 120 Kg N ha^{-1}. The observation suggests, it might be better to consider efficiency of the crop to improve recovery and use of the applied nitrogen to attain production of both biologically and economically targeted yields.



Figures with different alphabetical letters are significantly different at p <0.05
Fig 5. Effect of different levels of nitrogen on Dry Matter Yield (DMY) of forage oat

Conclusions and Recommendations

Forage yield and quality are the two important aspects for which fertilizer management is required. Nitrogen is by far important for its role in improving yield and quality of the crop. Increasing the amount of fertilizer beyond certain threshold however, did not improve yield and quality of the crop. The dry matter yield of present study increased significantly with successive levels of applied nitrogen and the maximum yield of 9.7 ton ha^{-1} was recorded at 120kg N ha^{-1} and thereafter, there was no yield increment. The total nitrogen content in plant tissue also increased with uptake. The origin of the nitrogen in plant tissue was both from uptake of mineralized soil available nitrogen and the applied nitrogen as urea. Whereas, the recovery of the portion of the applied nitrogen and the efficiency of use for production of dry matter decreased significantly with successive levels of applied nitrogen. The loss in applied nitrogen was reflected in dry matter yield reduction at only above 120 kg N ha^{-1}. From the observation it could be advisable to consider efficiency of the crop to recommend fertilizer rates rather than relying on yield and or soil test *perse.*

Acknowledgement

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