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Agronomic efficiency, yield and yield components of food barley response to nitrogen rates after fababean in Emba Alaje, Northern Ethiopia

Sofonyas Dargie[1*], Bereket Haileselassie[1], Mehretab Haileselassie[1,2], Fisseha Hadgu[1], Hagos Birhane[1] Molla Hadis[1] and Medhn Berhane[1]

[1]Tigray Agricultural Research Institute, Mekelle Soil Research Center, P. O. Box 1070, Mekelle, Ethiopia.
[2]Wageningen University and Research, Soil Biology and Quality, Wageningen, Netherlands.

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This study was initiated to investigate the effect of nitrogen fertilizer on agronomic efficiency, yield and yield components of barley after faba bean precursor crop. A field experiment was carried out in 2015 main cropping season at district at Ayba and Tek'a kebeles in Tigray Regional State, Ethiopia. The experiments were arranged in a randomized complete block design with three replications. Treatments were six levels of nitrogen (0, 11.5, 23, 34.5, 46 and 69 kg N ha-1). Soil samples were collected before planting and analyzed for selected physicochemical properties. Pre-planting soil analysis results revealed that total N was low at Tek'a kebelle (0.09%) and medium at Ayba (0.186%). The organic carbon content of experimental fields was medium at Ayba and low at Tek'a. Application of nitrogen had significantly influenced yield and yield components of barley at Tek'a site but not at Ayba after fababean precursor crop. This is consistent with the initial soil nitrogen and contribution of the precursor crop for nitrogen fixation. The highest agronomic efficiency was recorded from the addition of 23 kg N ha-1 (31.52 kg kg-1) and 34.5 kg N ha-1 (31.44 kg kg-1) at Ayba kebelle and Tek'a, respectively. Both biological and partial budget analysis depicted that application of 34.5 kg N ha-1 was found to be economical. Therefore, application of nitrogen after legume crop should consider initial soil result..

Key words: Barley, Fababean, nitrogen, crop rotation, agronomic efficiency.

INTRODUCTION

Barley is one of the most important cereal crops widely grown by small-scale farmers under rain fed conditions in Ethiopia. For millennia it has been supplying the basic necessities of life (food, feed and beverages) for many in the Ethiopian highlands. Barley ranks fourth in worldwide production of all cereals (FAO, 2004).

In Ethiopia, barley is ranked fifth of all cereals, based on area of production, but fourth based on yield per unit area (CSA, 2014).

The factors constraining the increased production of

*Corresponding author. E-mail: sofifidel97@gmail.com.

barley in the different barley production systems are various (Chilot et al., 1998). The most important abiotic stresses include low soil fertility, low soil pH, poor soil drainage, frost and drought. Soil fertility depletion is a key problem of cereal production in Ethiopia. Low soil nitrogen is often the major factor limiting crop production (Andrews et al., 2004). Application of inorganic nitrogen fertilizer, crop rotation and intercropping are some of the important tools used to increase crop yields and grain quality in intensive agricultural system. Crop rotation is necessary and a desirable management option to restore, maintain, enhance soil fertility, and maximise yield (Tolera et al., 2011). Legumes contribute to increased productivity of other crops when incorporated into cropping systems as intercrops and through crop rotation (Giller, 1991).

Rotations with legumes build up the N status of the soil. Patwary et al. (1989) reported that available soil N was increased by about 32 and 40 kg ha^{-1} following chickpea and lentil crop compared with wheat. The grain yield of barley monoculture with an application of 41/20 kg ha^{-1} N/P was lower than the yield of barley following linseed or faba bean with an application of 18/20 kg ha^{-1} N/P, which saved 23 kg N ha^{-1} in the form of urea (Tolera et al., 2011). Farmers in the mid-highlands and highlands of Ethiopia are well aware of the importance of crop rotation to replenish soil fertility and skill fully used this option for nitrogen management (Bereket et al., 2011). Depending on agro-ecology, farmers grow legumes such as chick pea, faba bean, field pea, grass pea and fenugreek as rotation crop with cereals to improve soil fertility of cereals. Farmers usually reduce the N requirement of next cereal crop after legume. For example, farmers in Ude and Hatsebo reduce their N fertilizer rate for teff after leguminous crops, mostly for one year based on their personal judgments (Bereket et al., 2011). However, the N rate required after a specific legume crop for barley is not well studied in Ethiopia specifically in northern Ethiopia. Therefore, a study was conducted to evaluate agronomic efficiency, yield and yield components of barley response to nitrogen rates after faba bean precursor crop.

METHODOLOGY

On farm field experiments were conducted at district of Emba-Alaje at Te'ka and Ayba Tabias sites in 2014. The experiment consists of six nitrogen treatments that were 0, 11.5, 23, 34.5, 46 and 69 kg N ha^{-1}. Each treatments were supplied with basal application of phosphorous, potassium and sulfur at rates of 69 kg P_2O_5 ha^{-1}, 80 kg K_2O ha^{-1} and 30 kg S ha^{-1}. The design was Randomized Complete Block Design treatments with three replications in a plot size of 3 m by 4 m. Nitrogen, phosphorus, potassium and sulfur were applied in the form of urea, Triple Super Phosphate (TSP), potassium chloride and calcium sulfate, respectively. Phosphorus, potassium, sulfur and half of the nitrogen rates were applied at planting. The remaining half of the nitrogen rates were applied during tillering.

The initial experimental soils (0-20 cm) were analyzed for texture, organic carbon, total nitrogen, CEC, available P, pH and EC. The methods used for samples physicochemical analysis were pH (Jackson, 1967), EC (Bower and Wilcox, 1965), organic carbon [modified Walkley and Black method (Jackson, 1967)], texture [hydrometer method procedure of Bouyoucos (Day, 1965)], available phosphorous (Olsen et al., 1954), total nitrogen [Kjeldehal method (Bremner and Mulvaney, 1982)] and CEC [Neutral ammonium acetate method (Black et al., 1965)]. Agronomic efficiency was calculated following Fageria and Baligar (2001).

$$\text{Agronomic N use efficiency}(\text{kg kg}^{-1}) = \left(\frac{\text{Gf} - \text{GU}}{\text{Na}}\right)$$

Where: Gf is the grain yield in the fertilized plot (kg), Gu is the grain yield in the unfertilized plot (kg), Na is the quantity of N applied (kg).

The barley variety used in this experiment was HB1307 and was planted at a rate of 150 kg ha^{-1} in row planting. Above ground biomass from whole plots were sun-air dried before weighing. The spikes were threshed and cleaned and grain yield was weighed. The straw yield was calculated by subtracting grain yield from the above ground biomass.

Data collection

Soil and agronomic data were collected following the standard procedure.

Data analysis

The collected data were subjected to analysis of variance (ANOVA) using SAS software program version 9.1.3 (SAS, 2002).Significant difference among treatment means were assessed using the least significant difference (LSD) at 0.05 level of probability (Gomez and Gomez, 1984).

RESULTS AND DISCUSSION

Soil properties before planting

The chemical and physical property of the soils of the experimental sites after the precursor legume crops is indicated in Table 1. Textural class of Te'ka and Ayba sites was sandy clay and clay loam, respectively. According to Tekalign (1991) rating of soil pH, the pH of soils of both Te'ka and Ayba was slightly acidic. The organic carbon content of soils of the experimental sites was low at both sites (Tekalign, 1991). According to Birhanu (1980) total nitrogen content at Te'ka was low and medium at Ayba. Available phosphorous (Olsen P) for fababean- barley was medium at Ayba and high at Te'ka (Olsen, 1954). According to Landon (1991) rating, CEC was very high at both sites.

Growth parameters

Application of different nitrogen rates for barley production after faba bean was significantly influenced the plant height at Tek’a kebelle. The reverse was true for increasing nitrogen rate. Application of nitrogen

Table 1. Surface (0-20 cm) soil properties of experimental fields.

Parameter	Tek'a	Ayba
pH_{water} (1:2.5)	6.64	6.31
Organic carbon (%)	0.8	1.37
Total N (%)	0.09	0.186
P-Olsen (mg kg^{-1})	20.27	9.96
CEC (meq/100 gm soil)	50.2	54.4
Clay (%)	48	48
Silt (%)	9	39
Sand (%)	43	13

Table 2. Effect of nitrogen on growth parameters of barley after faba bean in Tek'a and Ayba.

Treatments	PH (cm)		SL (cm)	
	Tek'a	Ayba	Tek'a	Ayba
0 kg N/ha	77.73[b]	87.87	5.6	5.433[b]
11.5 kg N/ha	82[ab]	88.6	5.9	5.3[b]
23 kg N/ha	82.2[ab]	95.8	6.133	5.367[b]
34.5 kg N/ha	88[ab]	93.87	5.8	6.433[a]
46 kg N/ha	87[ab]	93.2	5.867	5.567[ab]
69 kg N/ha	93.07[a]	93.13	5.6	5.767[ab]
LSD	13.66	NS	NS	0.94
CV (%)	9.03	7.07	7.74	9.44

significantly influenced spike length at Ayba kebelle. This study were in line with the findings of Sofonyas et al. (2016) and Bereket et al. (2016).

Effect of nitrogen on barley grain straw yields after fababean

There is a significant difference in grain and straw yields of barley due to application of nitrogen after fababean crop rotation at Te'ka (Table 2) but not at Ayba probably due to the initial moderate level of soil total nitrogen. Grain and straw yields of barley increased with an increase of nitrogen application at Te'ka up to 69 kg N/ha though it was not significant with nitrogen rates of 23, 34.5, and 46 kg N/ha. Although it was not statistically significant, grain and straw yield of barley increased with nitrogen application till 34.5 kg N/ha with further decreasing trend at the higher rates. Most of the farmers at Tek'a and Ayba kebelles reduce the amount of nitrogen for barley production after faba bean. This may be similar with the findings of Bereket et al. (2016) reported that half of the recommended nitrogen rate was optimum for wheat production after legume crops at Emba Alaje. Maadi et al. (2012) reported that the preceding leguminous crop increases the grain yields of wheat significantly. Benefit of legumes insertion in the cropping sequence is the yield advantage associated with extra soil N availability to a cereal crop succeeding a legume; for example, under pea-wheat rotation, approximately 50 kg ha^{-1} more N was accumulated compared to wheat-wheat rotation (Evans et al., 1991) (Table 4)..

Agronomic efficiency of nitrogen

Agronomic efficiency is the amount of additional yield obtained for each additional kg of nutrient applied (Fageria and Baligar, 2001). The highest agronomic efficiency was recorded from the addition of 23 kg N ha^{-1} (31.52 kg kg^{-1}) and the lowest from 11.5 kg N ha^{-1} (3.65 kg kg^{1}), respectively at Ayba kebelle (Table 4). At Tek'a kebelle the highest and lowest agronomic efficiency were obtained at 34.5 kg N ha^{-1} (31.44 kg kg^{-1}) and 11.5 kg N ha^{-1} (8.45 kg ka-1), respectively (Table 4).

Partial budget analysis of nitrogen rates

At Emba Alaje district Tek'a kebelle the highest marginal

Table 3. Effect of nitrogen on barley grain and straw yields after faba bean crop rotation at Emba-Alaje.

Treatments	Grain yield (kg ha^{-1})		Straw yield (kg ha^{-1})	
	Tek'a	Ayba	Tek'a	Ayba
0 kg N/ha	3750^{b}	3317	4717^{b}	4792
11.5 kg N/ha	3792^{b}	3325	4633^{b}	5300
23 kg N/ha	4475^{ab}	3558	5533^{ab}	5308
34.5 kg N/ha	4392^{ab}	4402	5833^{ab}	6833
46 kg N/ha	5052^{a}	4150	6075^{a}	6150
69 kg N/ha	5108^{a}	3133	6592^{a}	4825
P-value	0.038	0.225	0.011	0.40
LSD	952	NS	1034	NS

Table 4. Agronomic efficiency of nitrogen of barley after faba bean.

N rate (kg/ha)	Ayba	Tek'a
	AE (kg/kg)	AE (kg/kg
0		
11.5	3.65	0.69
23	31.52	10.47
34.5	18.60	31.44
46	28.30	18.10
69	19.68	-2.6

Table 5. Partial budget analysis of Nitrogen rates for barley production.

Fertilizer Rate (kg N/ha	Fertilizer Cost (Birr)	Fertilizer Application and Transport Cost [Birr]	Total Variable Cost (TVC) [Birr]	Grain Yield (kg/ha)	Total Revenue (TR) [Grain yield*11]	Net Revenue [TR-TVC]	Marginal Rate of Return (ratio)	Marginal Rate of Return (%)
0	0	0	0	3750	41250 0	41250		
11.5	313	240	553 0	3792	41712 0	41159	D	D
23	626	360	986 0	4475	49225	48239	16.35103926	1635.103926
34.5	939	480	1419	4392	48312	46893	D	D
46	1252	600	1852	5052	55572	53720	6.329099307	632.9099307
69	1565	720	2285	5108	56188	53903	D	D

rate of return was obtained from plots treated with 46kg N ha^{-1}. The identification of a recommendation is based on a change from one treatment to another if the marginal rate of return of that change is greater than the minimum rate of return (100%). According to the marginal rate of return 46 kg N ha^{-1} was found economically profitable compared to other treatments for barley production after faba bean (Table 5).

Conclusion

Grain and straw yields of barley increased significantly with application of nitrogen after faba bean precursor crop at Tek'a. There was no significant effect of nitrogen application for barley after faba bean indicating the precursor crop (faba bean) had contributed for fixation of nitrogen in the soil. This is in-line with the initial soil nitrogen in Ayba kebelle. Partial budget analysis revealed that nitrogen application rate has to be 46 kg N/ha in Tek'a kebelle. But, application of 34 and 46 kg N ha^{-1} was statistically the same, consequently 34.5 kg N ha^{-1} was optimum rate for barley production after faba bean.

CONFLICT OF INTERESTS

The authors have not declared any conflict of interests.

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