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Agronomic and Economic Evaluation of Nitrogen Fertilizer types and levels on Bread Wheat (*Triticum Aestivum L.)* in the *Vertisols* of Northern Highlands of Ethiopia

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ABSTRACT

Optimum nitrogen fertilization from the right source is the most important production factors for higher grain yield of wheat Study on the effect of type and rate of urea fertilizers on yield of wheat was conducted evaluate in northern Ethiopia in 2017 and 2018 main cropping season. The treatments consist four (Prilled urea, granular urea, urea super granule and UREAstabil) different source of nitrogen fertilizer each with three application rates of (46, 69 and 92kg N ha−1), and one control (without any N fertilizer application) laid down in a randomized complete block design. Grain yield of bread wheat showed significantly to the application of different rates and source of nitrogen fertilizer at Adigolo and Mekan districts. At Adigolo districts the highest mean wheat yield of 5.11t ha^{-1} (with MRR=391.48) was obtained from application 92 kg N ha^{-1} of UREAstabil with no statistically significant difference compared to the grain yield obtained from the application of 69 kg ha^{-1} of UREAstabil (5.08 t ha^{-1}), 92 kg N ha^{-1} of prilled urea (4.56 t ha^{-1}) and 92 kg N ha^{-1} of granular urea (4.68 t ha^{-1}). At Mekan distrcts the highest mean wheat grain yield of 4.08 t ha^{-1} (with MRR=733.07) was obtained from application 69 kg N ha^{-1} of UREAstabil with no statistically significant difference compared to the grain yield obtained from the application of 92 kg N ha^{-1} of UREAstabil (4.44 t ha^{-1}). In both Adigolo and Mekan districts grain yield of wheat showed that a linear increase with increasing rate of application of N fertilizer and the grain yield of wheat obtained from all the level of UREAstabil were higher than corresponding levels of either prilled urea, granular urea or urea super granule, while application of 46 kg N ha^{-1} from UREAstabil reaches optimum agronomically and economically for the study areas.

Keywords: prilled urea; super granular urea; granular urea; UREAstabil; wheat

INTRODUCTION

Wheat is one of the most important cereals cultivated in Ethiopia. In area of production, Wheat ranks 4th after Teff, Maize and Sorghum and 3rd in total grain production after Maize and Teff and 2nd in yield to Maize.

It is cultivated by 4.22 million farmers and accounts for more than 14.9% of the total cereal production (CSA, 2017). However, the mean national yield is 2.7 ton ha^{-1}, which is 13 and 32% far below Africa and world average productivity respectively (FAO, 2014). The low yield of wheat in Ethiopia is primarily due to depleted soil fertility (Asnakew *et al*., 1991; Fageria and Baligar, 2005), little or no addition of fertilizers (Asnakew *et al*., 1991; Amsal *et al*., 1997), unavailability of other modern crop management inputs (Asnakew *et al*., 1991), soil degradation (Cambell, 1991; Stahl, 1990), poor rainfall distribution (Lemma *et al*., 2008), and wheat diseases (ICARDA, 2013).

Therefore managing soil fertility is crucial for improving agricultural productivity Ethiopia. Nevertheless, many farmers refrain from using fertilizer due to escalating costs (Kefyalew, 2010), uncertainty about the economic returns to fertilizing food crops and, more often, lack of knowledge as to which kinds and rates of fertilizers are suitable (Hopkins *et al*., 2008). The physical application rates of fertilizer are also well-below those recommended and estimated. Only 30–40 % of Ethiopian smallholders use fertilizer (Spielman *et al*., 2013) and the physical application rates of fertilizer are on average only 37-40 kg ha^{-1}.

Nitrogen is the most limiting factor calling for external inputs in the form of fertilizer for profitable cereal crop production in most agro-ecological zones. However, conventional N fertilizers are highly soluble and, once applied to the soil may be lost from the soil plant system or made unavailable to the plants through the processes of leaching, NH3 volatilization, denitrification and immobilization and fixed in the soil solids as NH4-N form (Block, 1984) particularly on soils that have a relatively high pH. Soil having a pH greater than 7 is considered as alkaline. This high pH content of the vertisols favors gaseous loss of ammonia when urea or ammonium fertilizers are applied to the surface (Terman, 1979). On the other hand, the low infiltration rates of vertisols could also create environment favorable for denitrification since O_2 diffusion rate in water is very low (Russel, 1977). The N recovery by crops from the soluble N fertilizers such as urea is often as low as 30–40%, with a potentially high environmental cost associated with N losses via NH3 volatilization, NO3- leaching and N2O emission to the atmosphere (Zhou *et al*., 2003).

In order to improve urea-N recovery and reduce its loss, many forms of slow-release urea fertilizers have been developed and applied to different plant species under a range of environmental conditions. Application Urea stable (have long release, up to 60 days, and have high N use efficiency) can also lower losses of nitrogen. The products may be coated, chemically and biochemically modified, or are granular (Jiao, 2004).

Such slow-release urea fertilizers can increase the efficiency of applied urea-N and can avoid negative environmental effects because their N release is in synchrony with plant N uptake, and in a single application, can provide sufficient N to satisfy plant N requirements while maintaining very low concentrations of mineral N in soil throughout the growing season (Bacon, 1995). Therefore evaluating these sources of nitrogen fertilizer on wheat is paramount important. To evaluate the comparative efficiency of different Nitrogen fertilizer source and rate on wheat yield & yield components of wheat.

MATERIAL AND METHODS

Description of experimental sites

This study was conducted in 2017 and 2018 main cropping season at Ofla (A/golo) and Ena-Mehoni (Mekan) districts of south Tigray, northern Ethiopia. The study districts are characterized by a bimodal rainfall pattern with the main wet season (‘kiremt’) extending from July to September and the small wet season (‘*Belg’*) which extends from March to May. The area is characterized by heavy and erratic rainfall distribution. Adigolo is located on the geographic coordinates of 39^{o}30'4", 12^{o}31’15" and an altitude of 2435m above sea level. The long-term (1997-2018) mean annual rainfall was 726.3 mm, while the mean annual rain fall for the study period of 2017 and 2018 was 806.5mm and 1070 mm respectively. Similarly, the mean maximum and minimum monthly temperatures were 22.3°C and 7.8°C, respectively. Mekan is located on the geographic coordinates of 39^{o}31'17" and 12^{o}44'31" and altitude of 2450 m.a.s.l (Figure1) The long term (1999-2018) mean annual rain fall was 685.4mm with the mean annual rain fall for the study period of 2017 and 2018 was 477.8 mm and 838.7 mm respectively with the mean maximum and minimum monthly temperatures were 22.4°C and 10.2°C, respectively (Figure 2).

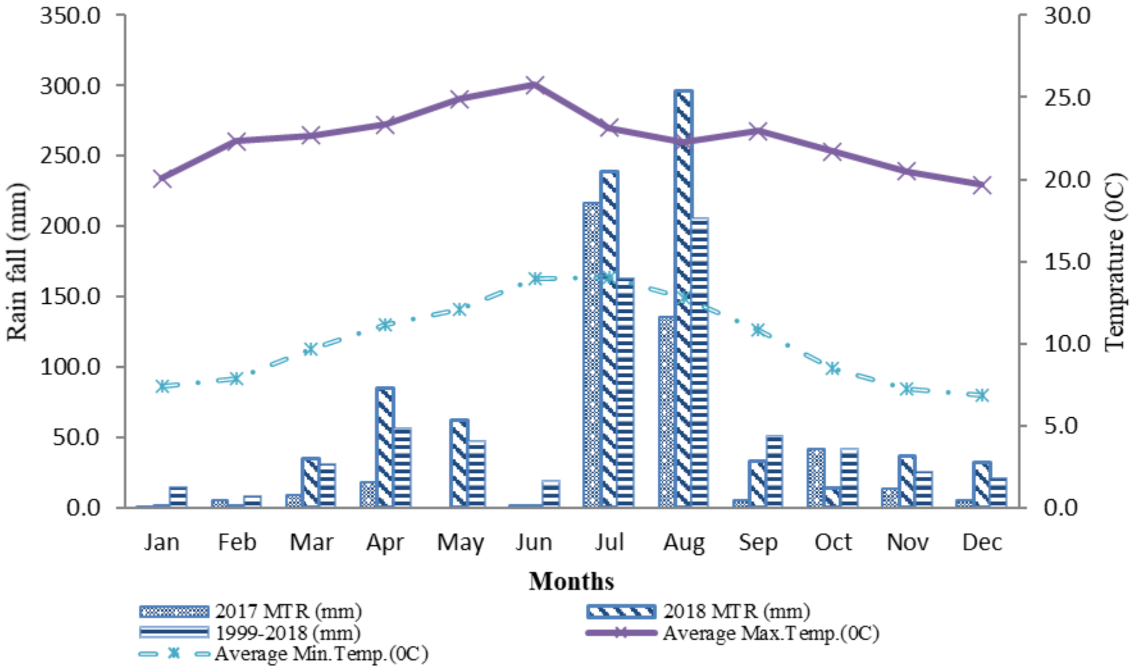

Figure 1 : Monthly total rain fall (MTR) for 2017 and 2018 cropping season, long term (1999-2018) average Monthly rain fall and Average maximum temperature (Average Max.Temp) and Average minimum temperature (average min Temp) of Adigolo district

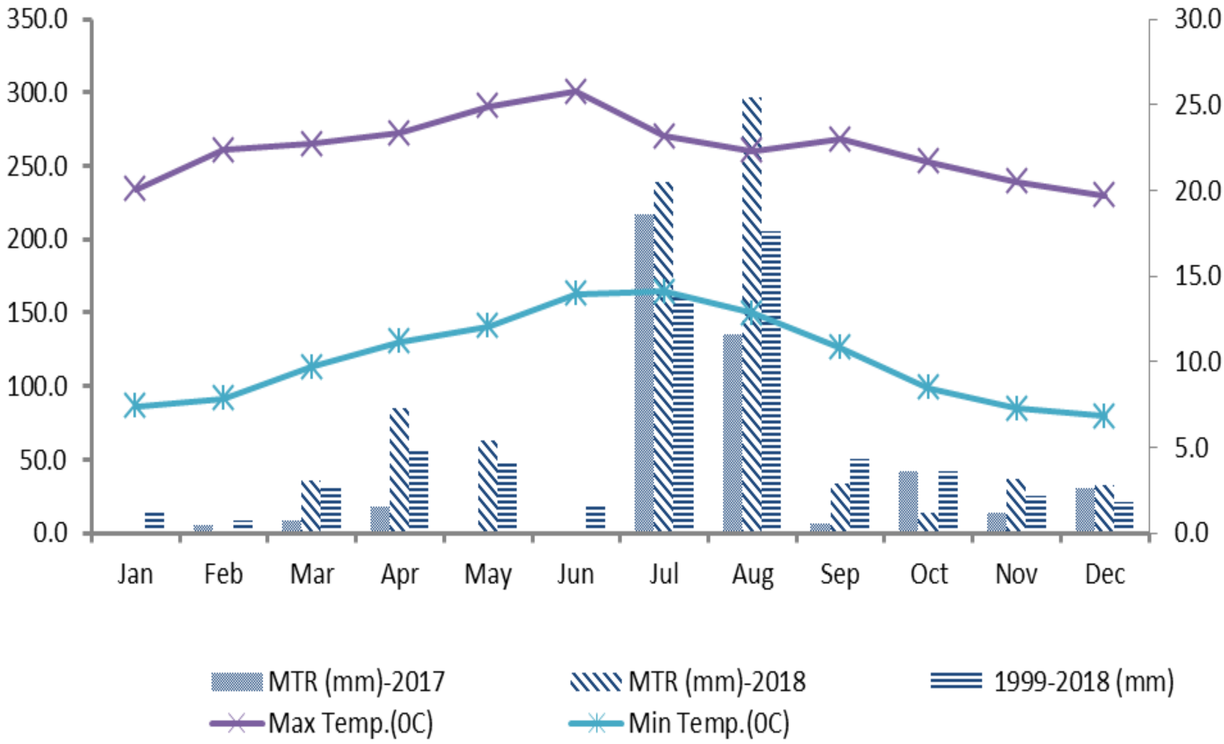

Figure 2 : Monthly total rain fall (MTR) for 2017 and 2018 cropping season, long term (1999-2018) average Monthly rain fall and Average maximum temperature (Average Max.Temp) and Average minimum temperature (average min Temp) of Mekan district.

Experimental materials, procedures and design

The treatments consists four (Prilled urea, granular urea, urea super granule and UREAstabil) different source of nitrogen fertilizer each with three application rates of (46, 69 and 92kg N ha−1), and one control (without any N fertilizer application). The field experiments were laid down in a randomized complete block design with three replications. All experimental unites were treated with a uniform rate of 46 kg P_2O_5 ha^{-1} in the form of triple super phosphate (TSP), 60 kg K_2O ha^{-1} from murite of potash (KCl) and 5 kg S ha^{-1} from CaSO4 at planting time. Nitrogen fertilizer was applied in splits, 33% at planting and 67% after 40 days of planting. Seed rates of 150 kg ha^{-1} were used at row spacing of 30cm for the variety king bird. Furthermore, during the different growth stages of the crop, all the necessary agronomic practices were carried out accordingly.

Data collection

Grain yield: Grain yield (kg/plot) was taken from each plots by excluding the border rows and adjusting to 12.5% moisture level and then converted to hectare basis.

Soil sampling, sample preparation and analysis: Composite surface soil samples were collected using standard Auger from five spots from each experimental block (0-20 cm depth) to form one composite soil sample per block for initial soil fertility evaluation of the experimental fields.

Data analysis

The Analysis of Variance (ANOVA) for the studied variables was computed using the GLM procedure of SAS software version 9.3 (SAS, 2011) following the standard procedures of ANOVA for RCB design (Gomez and Gomez, 1984). The differences fertilizers were considered significant if the P-values were ≤ 0.05. Least significance test (LSD) was used to compare among treatments at 5% probability level. Grain yield data for the fertilizer effect was subjected to economic analysis, using the CIMMYT (1988) partial budget techniques to evaluate the economic profitability of fertilizer options for determination of the economic optimum rate. Wheat yield was adjusted downwards by 10% to more closely approximate yields. N fertilizer rates were analyzed separately by calculating gross benefit (GB), total costs that vary (TCV), net benefit (NB), and the marginal rate of return (MRR) for each treatment (that is, relative to the next lowest cost or non-dominated treatment for the N. Marginal rate of return (MRR) was calculated as the change in net benefit (NB) divided by the change in total variable cost (TVC) of the successive net revenue and total variable cost levels (CIMMYT, 1988). Daily labor costs for fertilizer application were calculated by assuming 100 Birr per person per day and revenue was calculated by considering the prevailing market price. Dominance analysis was used to screen treatments that have higher variable cost and lower net return and dominated treatment removed from further consideration.

RESULTS AND DISCUSSION

Soil physicochemical properties of the study districts

According to the soil pH rating developed by Tekalign *et al*., (1991), the mean pH values of the composite surface soil samples of the experimental sites falls under the slightly neutral soil reaction class. The soil organic matter (SOM) contents were in the range of 1.24 and 1.99 % at Adigolo and Mekan areas respectively (Table 4) thus, these values fall under low to moderate range based on the ratings of soil test values established by Tekalign *et al*., (1991). Total nitrogen (TN) levels of the study sites ranges between 0.101 and 0.15% at Adigolo and Mekan areas respectively which taken as low while those below 0.1% are very low for tropical soils (Beyene, 1988). It, therefore soils of the study areas are low to very low in their total nitrogen status (Table 4). Moreover, according to phosphorus rating developed by Olsen *et al*. (1954), the available phosphorus (Av.P.) contents of the soil of the experimental site fall under the medium for Adigolo and high for Mekan and phosphorus status (Table 1). This indicate the low level of fertility status of the soil aggravated by long term cereal based cultivation, lack of incorporation of organic materials in to the soils through mulching or crop residues retention after harvest and frequent tillage. Continuous mono cropping and inadequate replacement of nutrients removed in harvested materials or lose through erosion and leaching has been the major causes of soil fertility decline (Matson *et al*., 1998). The electrical conductivity (EC) ranged from 0.08 to 0.099 dSm−1 for Adigolo and Mekan areas respectively indicating that these soils have a low content of soluble salts and that there is no danger of salinity in the study areas (Tekalign *et al*., 1991).

Table 1: Soil Physic-Chemical Properties of the Study Sites

Soil properties	Ofla (Adigolo)	E/Mehoni (Mekan)
pH(1:2.5 H2O)	6.74	6.87
Available phosphorus(mg P_2O_5/kg soil)	11	35.10
Total nitrogen (%)	0.101	0.15
OC (%)	1.99	1.24
Electrical conductivity (ds/m)	0.08	0.099
Cation exchange capacity (meq/100g of soil)	41.67	48.85
Exchangeable k (meq k^+/100g of soil)	0.2	0.55
Exchangeable Na (meq Na^+/100g of soil)	0.66	0.96
Exchangeable Ca (meq Ca^{+2}/100g of soil)	25.56	24.17
Exchangeable Mg (meq Mg^{+2}/100g of soil)	8.52	8.9
Silt (%)	15	14.84
Sand (%)	25	30.05
Clay (%)	40	55.11
Textural class	clay	clay

Source: (Amanuel *et al*, 2015)

Table 2: Effect of nitrogen fertilizer application rate (kg N ha−1) & Source on grain yield of bread wheat in 2017 and 2018 cropping season

Nitrogen Source (urea type)	Nitrogen application rate (kg N ha−1)	Grain yield (t/ha)	
		Adigolo	Mekan
0	0	2.01g	1.88f
Prilled urea	46	3.48de	2.945e
Prilled urea	69	4.07bcd	3.594cd
Prilled urea	92	4.561ab	3.99bc
Granular urea	46	3.3ef	2.779e
Granular urea	69	3.74cde	3.2de
Granular urea	92	4.68ab	4.107bc
Urea super granule	46	2.68f	2.174f
Urea super granule	69	3.35e	2.766e
Urea super granule	92	3.66cde	3.147de
UREAstabil	46	4.15bc	3.66cd
UREAstabil	69	5.08a	4.8a
UREAstabil	92	5.11a	4.44ab
LSD (5%)		0.343	0.2798
SEM		0.12	0.096
CV (%)		5.3	5.0

LSD: Least Significant Difference; SE: Standard Error; CV: Coefficient of Variation

Effect of nitrogen fertilizer application rate & Source on grain yield of bread wheat

Grain yield of bread wheat showed significantly ($P < 0.05$) to the application of different rates and source of nitrogen fertilizer (Table 2) at Adigolo and Mekan distrcts.

At Adigolo distrcts of Ofla woreda the highest mean wheat grain yield of 5.11t ha^{-1} was obtained from application 92 kg N ha^{-1} of UREAstabil with no statistically significant difference ($P > 0.05$) compared to the grain yield obtained from the application of 69 kg ha^{-1} of UREAstabil (5.08 t ha^{-1}), 92 kg N ha^{-1} of prilled urea (4.56 t ha^{-1}) and 92 kg N ha^{-1} of granular urea (4.68 t ha^{-1}). The next highest mean wheat grain yield of 4.15 tha^{-1} was obtained from 46 kg N ha^{-1} UREAstabil with no statistically significant difference ($P > 0.05$) compared to the grain yield obtained from the application of 69 kg N ha^{-1} of prilled urea (4.07 t ha^{-1}), 69 kg N ha^{-1} of granular urea (3.74t ha^{-1}) and 92 kg N ha^{-1} (3.66 t ha^{-1}), while the least wheat grain yield 2.01 t ha^{-1}) was obtained from the control plot (0) (Table 2).

Table: 3 Partial budget analysis for Adi-Golo

Nitrogen rate & source	GY.adj ($t\ ha^{-1}$)	TVC (Birr ha^{-1})	GBGY (Birr ha^{-1})	BY (t/ha)	GBBY (Birr ha^{-1})	TR (Birr ha^{-1})	NB (Birr ha^{-1})	MRR-ratio
0 (control)	1.809	0	39906.36	4.64	3618	43524.36	43524.36	
46 (Conventional)	3.132	1800	69091.61	8.03	6264	75355.61	73555.61	16.68
46 (Granular)	2.97	1880	65517.9	7.62	5940	71457.9	69577.9	D
46 (supper granular)	2.412	1910	53208.48	6.18	4824	58032.48	56122.48	D
46 (Stabile)	3.735	1950	82393.73	9.58	7470	89863.73	87913.73	794.78
69 (Conventional)	3.663	2700	80805.41	9.39	7326	88131.41	85431.41	D
69 (Granular)	3.366	2820	74253.62	8.63	6732	80985.62	78165.62	D
69 (supper granular)	3.015	2865	66510.6	7.73	6030	72540.6	69675.6	D
69 (Stabile)	4.572	2925	100857.9	11.72	9144	110001.9	107076.9	623.35
92 (Conventional)	4.1049	3600	90553.68	10.53	8209.8	98763.48	95163.48	D
92 (Granular)	4.212	3760	92916.3	10.80	8424	101340.3	97580.3	15.11
92 (supper granular)	3.294	3820	72665.31	8.45	6588	79253.31	75433.31	D
92 (Stabile)	4.599	3900	101453.5	11.79	9198	110651.5	106751.5	391.48

GY.adj: Adjusted grain yield; TVC: Total variable cost; BY: biomass yield; GBBY: Gross benefit from grain yield; GBBY: Gross benefit from biomass yield; GB: gross benefit; NB: net benefit and MRR: marginal rate of return.

Table 4: Partial budget analysis for Mekan

N rate & source	GY.adj ($t\ ha^{-1}$)	TVC (Birr ha^{-1})	GBGY (Birr ha^{-1})	BY (t/ha)	GBBY (Birr ha^{-1})	GB (Birr ha^{-1})	NB (Birr ha^{-1})	MRR-ratio
0 (control)	1.692	0	37325.35	4.34	3384	40709.35	40709.35	
46 (Conventional)	2.6505	1800	58469.76	6.80	5301	63770.76	61970.76	11.81
46 (Granular)	2.5011	1880	55174.02	6.41	5002.2	60176.22	58296.22	D
46 (supper granular)	1.9566	1910	43162.4	5.02	3913.2	47075.6	45165.6	D
46 (Stabile)	3.294	1950	72665.31	8.45	6588	79253.31	77303.31	803.44
69 (Conventional)	3.2346	2700	71354.95	8.29	6469.2	77824.15	75124.15	D
69 (Granular)	2.88	2820	63532.51	7.38	5760	69292.51	66472.51	D
69 (supper granular)	2.4894	2865	54915.92	6.38	4978.8	59894.72	57029.72	D
69 (Stabile)	4.32	2925	95298.77	11.08	8640	103938.8	101013.8	733.07
92 (Conventional)	3.591	3600	79217.1	9.21	7182	86399.1	82799.1	D
92 (Granular)	3.6963	3760	81540.01	9.48	7392.6	88932.61	85172.61	14.83
92 (supper granular)	2.8323	3820	62480.25	7.26	5664.6	68144.85	64324.85	D
92 (Stabile)	3.996	3900	88151.36	10.25	7992	96143.36	92243.36	348.98

GY.adj: Adjusted grain yield; TVC: Total variable cost; BY: biomass yield; GBBY: Gross benefit from grain yield; GBBY: Gross benefit from biomas yield; GB: gross benefit; NB: net benefit and MRR: marginal rate of return.

At Mekan distrcts of Enda Mehoni woreda the highest mean wheat grain yield of 4.08 t ha^{-1} was obtained from application 69 kg N ha^{-1} of UREAstabil with no statistically significant difference ($P > 0.05$) compared to the grain yield obtained from the application of 92 kg ha^{-1} of UREAstabil (4.44 t ha^{-1}). The next highest mean wheat grain yield of 4.11 tha^{-1} was obtained from 92 kg N ha^{-1} granular urea with no statistically significant difference ($P > 0.05$) compared to the grain yield obtained from the application of 46 kg N ha^{-1} of prilled urea (3.66 t ha^{-1}), 92 kg N ha^{-1} of prilled urea (3.99 t ha^{-1}) while the least wheat grain yield 1.88 t ha^{-1}) was obtained from the control plot (0) (Table 2).

Generally in both Adigolo and Mekan districts grain yield of wheat showed that a linear increase with increasing rate of application of N fertilizer and the grain yield of wheat obtained from all the level of UREAstabil were higher than corresponding levels of either prilled urea, granular urea or urea super granule. In agreement to this finding Sofinas *et al* 2018 reported that highest grain yield (1708.33kg ha-1) was obtained from the application of 64 kg N ha-1 as UREAstabil at Hawzien. Slow-release fertilizers could potentially sustain nitrogen availability during the grain-filling period.

Partial budget Analysis

Partial budget analysis was computed for the nitrogen fertilizer rate and conventional plots (Table 3 and 4). In economic analysis, it is assumed that farmers require a minimal rate of return of 100% (CIMMYT, 1988), representing an increase in net return of at least 1 Birr for every 1Birr invested, to be sufficiently motivated to adopt a new agricultural technology.

Generally the higher marginal rate of returns (MRR) varied from 15.11 to 794.78 in the in Adi-golo and 11.81 to 803.44 in Mekan areas. The highest MRRs (with 794.78 and 803.44) were obtained from applications of 46 kg ha^{-1} UREAstabil in Adi-golo and mekan areas respectively followed by 69 kg ha^{-1} UREAstabil (with MRR, 623.35 and 733.07) from Adi-golo and Mekan areas respectively. Sensitivity analysis was done based on data used in the MRR analysis and with treatment results above 100% minimum rate of return, except for the control. The if-analysis was done with the assumption of an average of 30% rises in all variable costs within 3 years, keeping the prices of the produce constant. The analysis showed that the recommended rates (46 kg N ha UREAstabil and 69 UREAstabil) still hold positive benefit cost ratios.

Conclusion and recommendation

Application of different rates and source of nitrogen fertilizer significantly affected grain yields of bread wheat at Adigolo and Mekan districts of Ofla and Enda Mehoni woredas. The higher grain yields with higher net benefit were obtained from application of 69 UREAstabil both at Adigolo and Mekan districts. However, application of 46 kg N ha-1 sourced from UREAstabil is agronomicaly and economically optimum fertilizer rate for bread wheat production in Adigolo and Mekan study sites.

Hence, slow-release nitrogen fertilizers are fertilizers designed to slowly release nutrients which can be used to maximize nitrogen use efficiency, grain yield and quality of crops, thus providing an economic benefit for growers in the study site and other Wheat AEZs.

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