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Evaluating Nitrogen Use Efficiency and Crop Performance Through Application of Urea Stabil under Balanced Fertilizer for Malt Barley Yield and Quality on Nitisols, in Central Highlands of Ethiopia

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Abstract: A field experiment was carried out during the 2017-2019 cropping season at Holetta Agricultural Research Center to determine evaluating nitrogen use efficiency and crop performance through application of urea Stable under balanced fertilizer for malt barley on nitisols, in central highlands of Ethiopia. The experiments were arranged in a randomized complete block design with three replications on six farmers' fields. Treatments included nine levels of nitrogen fertilizer. The nitrogen source was Urea Stabil, which is slow N releasing fertilizer and conventional urea at recommended rate was included. The results of the study revealed that plant height, spike length, grain and biomass yield, thousand grain weight, moisture content were significantly affected by nitrogen levels, but harvest index and hectoliter weight can't show significance affects at different nitrogen levels. The maximum plant height, spike length, grain and biomass yield (90.42cm, 7.48cm, 4079.0kg ha^{-1} and 9748.3 kg ha^{-1}) respectively were obtained from 69N Urea Stable split application. While the highest thousand grain weight was obtained at 69Nkg ha^{-1} normal Urea in split application and maximum moisture content was recorded from negative control treatment. The highest agronomic efficiency of 54.1 kg kg^{-1} was obtained from 23N Urea Stabil in split form and maximum value of apparent N recovery efficiency of 56.1% was obtained from 69 kg ha^{-1} N Normal Urea in split application. However, the maximum physiological efficiency of 87.03 kg ha^{-1} was recorded from 69 kg ha^{-1}N Urea Stabil split application. The highest agronomic efficiency of 22.2 kg kg^{-1}, physiological efficiency of 87.05 kg kg^{-1} and apparent N recovery of 59.7% was obtained from 64 kg N ha^{-1} as conventional urea. The result also showed that the highest marginal rate of return was obtained from application of 69 kg ha^{-1} N from Urea Stabil in split form application, which is economically the most feasible alternative for malt barley production on nitisols of central Ethiopian highlands. Therefore, based on the marginal return rate application of 69 kg ha^{-1} N from Urea Stabil in split form application is recommended for malt barley production for the study areas. Therefore, this recommendation can use in the areas where the rainfall distribution and soil type is similar with study districts where this experiment was conducted.

Key words: Malt Barley · Nitisols · Nitrogen Use Efficiency · Urea Stabil

INTRODUCTION

Nitrogen (N) is often the most limiting nutrient for crop yield in many regions of the world. Nitrogen fertilizer is one of the main inputs for cereals production systems. The increase of agricultural food production worldwide over the past four decades has been associated with a 7-fold increase in the use of N fertilizers [1]. More than 90% of world industrial production of urea is destined for use as a nitrogen-release fertilizer andurea has the highest nitrogen content of all solid nitrogenous fertilizers in common use [2]. Urea (46% nitrogen content) is currently the most popular nitrogen (N) fertilizer, with about 80% of the world market for straight N-fertilizers and represents the major sectoral growth in the N industry [3]. Urea is an uncharged molecule, which more readily infiltrates into the soil by convection than positively charged ammonium (NH4+) [4]. After application, urea is hydrolyzed in soil to

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NH4+ within a few days. The hydrolysis of urea increases soil pH and this shifts the equilibrium between NH4+ to NH3 towards NH3, which causes emissions from applied urea up to 64% of N and results in allow fertilizer efficiency [5].

Many soil bacteria possess the enzyme urease, which catalyzes conversion of urea to ammonia (NH_3) or ammonium ion (NH_4^+) and bicarbonate ion (HCO_3^-). Thus urea fertilizers rapidly transform to the ammonium in soils. Among the soil bacteria known to carry urease, some ammonia-oxidizing bacteria (AOB), such as species of Nitrosmnas, can also assimilate the carbon dioxide the reaction releases to make biomass via the Calvin cycle and harvest energy by oxidizing ammonia (the other product of urease) to nitrite, a process termed nitrification [6]. Nitrite-oxidizing bacteria, especially Nitrobacteria, oxidize nitrite to nitrate, which is extremely mobile in soils because of its negative charge and is a major cause of water pollution from agriculture. Ammonium and nitrate are readily absorbed by plants and are the dominant sources of nitrogen for plant growth. Urea is also used in many multi-component solid fertilizer formulations and highly soluble in water and is therefore also very suitable for use in fertilizer solutions or in combination with ammonium nitrate. For fertilizer use, granules are preferred over perils because of their narrower particle size distribution, which is an advantage for mechanical application [6].

Availability of nitrogen applied as fertilizer to crop depends not only on the rate but also on the nature of the N fertilizer, soil types, cropping system, management as well as on temperature and precipitation during the growing season [7]. The disadvantage of urea fertilizer is that considerable amounts of N can be lost from through volatilization which may result in very low N fertilizer use efficiency [8, 9], if not incorporated into soil soon after application. There are different mechanisms to improve the nitrogen fertilizer use efficiency. Cropping system, soil and water management, use of appropriate N fertilizer, application rate and time are among the main management options to increase N fertilizer use efficiency. In addition, use of slow N releasing fertilizers, nitrification inhibitor, efficient species or genotypes and control of disease, insects and weeds are also important for improvement of N fertilizer use efficiency [10].

Urea stable is a concentrated nitrogen fertilizer that can be applied as a granular for crops as well as liquid fertilizer through irrigation water for the orchard [11]. Besides, it supposed to have basic advantage of having a combination of rapidly soluble, well absorbable nitrogen with urease inhibitor that helps to improve nitrogen penetrationto plant roots by restraining the sorption and fixation of NH_4^+ in the surface soil layer, which slows the effect to this nitrogen form down and increase nitrogen use efficiency through either slowing the release rate or by altering reactions that lead to losses [12]. Furthermore, effective rate of application for slow N releasing fertilizer for increasing wheat productivity at both districts has not been established. Therefore, the objectives of this study were to: determine optimum urea stable nitrogen fertilizer rate under balanced fertilizer and evaluate nitrogen utilization efficiencies of malt barley and their crop performance to urea stable.

MATERIALS AND METHODS

Location of the Study Areas and Site Characteristics: The trial site was located on two sites (HARC and Welmera) belonging to Holeta Agricultural Research Center. Welmera areas are located in West Shewa highlands of Ethiopia, between 09°03'N latitude and 38°30'E longitude at an altitude of about 2400m above sea level. The rainfall is bimodal with long-term average annual rainfall of 1100mm, about 85% of which from June to September and the rest from January to May and average minimum and maximum air temperatures of 6.1 and 21.9°C, respectively. The environment is seasonally humid and the major soil type of the trial sites is Eutric Nitisols (FAO classification).

Experimental Design and Treatments: The experiment was conducted in 2017, 2018 and 2019 cropping seasons and nine treatments were evaluated under balanced fertilization. The experimental design was randomized complete block design (RCBD) with three replications. The cultivar used was IBON. Nitrogen was applied at the rate of 50% at planting but 50% at top dressing in the form of urea. Recommended fertilizer for malt barley for the area: Nitrogen fertilizer was recommended at the rate of 46 kg N ha^{-1}, Phosphorus fertilizer was applied at the rate of 30 kg P ha^{-1} in the form of triple super phosphate (TSP). Sulfur was applied at the rate of 30 kg S ha^{-1} as CaSO4. Phosphorus and S fertilizers were applied at planting as basal to all plots. Planting was done in the mid of June at the seed rate of 125kg ha^{-1} on plot size 4m x 3m. All other cultural practices were followed as per the recommendation.

Treatments:

T1: Negative control
T2: Rec N from urea(+Ve control)
T3: Rec N from Urea Stabil at planting
T4: Rec N from Urea Stabil in split form
T5: Half of the Rec N from Urea Stabil at once application
T6: Half of the Rec N from Urea Stabil in split form
T7: Half more than Rec N from Urea Stabil split application
T8: Half more than Rec N from normal Urea in split application
T9: Half more than Rec N from Urea Stabil at once application

Data Collection: Composite surface soil samples were collected from experimental fields (0-20 cm depth) before treatment application. Similarly, soil samples were collected after harvest of the crop from each plot and then composited by replication to obtain one representative sample per treatment. The collected samples were analyzed for the determinations of pH, organic carbon (OC), total N and available P. Soil pH was determined with a pH electrode at soil: water of 1:1 (w/v) [13]. Organic carbon was determined by the method of Walkley and Black [14] and total N using Kjeldahl method [15]. Available P was determined following the procedures of Bray and Kurtz [16].

Agronomic data such as grain yield, above-ground total biomass, harvest index, thousand kernel weight, plant height and spike length (average of ten plants). Mature plant height was measured from the ground level to the tip of the spike excluding the awns at physical maturity. Spike length (SL in cm) was measured from the base to the top of the spike excluding awns. Thousand kernel weight (TKW in g) was measured on a sample of 250 seeds. To measure total biomass and grain yields, the entire plot was harvested at maturity in November. After threshing, the seeds were cleaned and weighed and the moisture content was measured. Total biomass (dry matter basis) and grain yields (adjusted to moisture content of 12.5%) recorded on plot basis were converted to kg ha^{-1} for statistical analysis.

Plant Tissue Sampling and Analysis for Nitrogen Content: At maturity, twenty five non-boarder malt barley plant samples were randomly collected from each plot and partitioned into grain and straw. The straw samples were washed with distilled water to clean the samples from contaminants such as dust. The grain and straw samples were oven dried at 70C° to constant weight. After drying, the samples were ground and passed through 0.5 mm sieve. The samples were analyzed for nitrogen concentration following wet digestion method. The nitrogen use efficiencies of wheat such as agronomic efficiency, physiological efficiency and apparent recovery efficiency of N were calculated as describe by Fageria and Baligar [17].

Agronomic Efficiency of Nitrogen:

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

where **Gf** is the grain yield in the fertilized plot (kg); **Gu** is the grain yield in the unfertilized plot (kg); and **Na** is the quantity of N applied (kg).

Physiological Efficiency of Nitrogen:

$$\text{PhysiologicalN use Efficiency (kg ha}^{-1}\text{)} = \left(\frac{Yf - Yu}{Nf - Nu}\right)$$

where **Yf** is the total biological yield (grain plus straw) of the fertilized plot (kg); **Yu** is the total biological yield in the unfertilized plot (kg); **Nf** is the N accumulation in the fertilized plot (kg); and **Nu** is the N accumulation in the unfertilized plot (kg).

Apparent Recovery Efficiency of Nitrogen:

$$\text{Apparent N use Efficiency (kg ha}^{-1}\text{)} = \left(\frac{Nf - Nu}{Na}\right)$$

where **Nf** is the N accumulation by the total biological yield (straw plus grain) in the fertilized plot (kg); **Nu** is the N accumulation by the total biological yield (straw plus grain) in the unfertilized plot (kg); and **Na** is the quantity of N applied (kg).

Data Analysis and Economic Analysis: The collected data were subjected to analysis of variance (ANOVA) using SAS software program version 9.1.3 [18] and SAS was used to test for presence of outliers and normality of residuals. Significant difference among treatment means were assessed using the least significant difference (LSD) at 0.05 level of probability [19]. Partial budget, dominance and marginal analyses following technique as described by CIMMYT [20]. The average yield was adjusted downwards by 10% to reflect the difference between the experimental yield and the expected yield of farmers from the same treatment. This is because, experimental yields even from on-farm experiments under representative conditions, are often higher than the yields that farmers could expect using the same treatments. Daily labor costs were calculated by assuming 60 Birr per person per day and revenue was calculated by considering the prevailing market price, which is 16 Birr kg^{-1} of malt barley grain yield. The prices of conventional urea (13Birr kg^{-1}) and Urea stable (14ETB kg^{-1}).

RESULTS AND DISCUSSION

Effects of Fertilization on Soil Chemical Properties: The laboratory analysis results of soil-chemical properties beforesowing were presented in table1Soil chemical properties such as pH, organic carbon (OC), N and P measured for samples taken after harvesting (Table 1). The pH (H_2O) value of the experimental field soil was 4.84, which shows the acidic soil reaction class andcation exchange capacity of the experimental area before sowing was 15.6$cmol_c$ kg^{-1}. The organic carbon and total nitrogen content of the soil, before planting were found to be 1.46% and 0.18%, respectively. Three years mean ofthe available phosphorus content was 8.29 per millionof the experimental area before sowing.

The collected samples were analyzed for the determinations of organic carbon (OC), total N, available P and sulfur (Table 2). The pH of soils of the experimental sites varied from 4.65 to 5.12 which means acidic soil range .FAO [21] reported that the preferable pH ranges for most crops and productive soils are 4 to 8. However, different crops have different requirements. Thus, the pH of the experimental soil is almost within the range for productive soils. Total Nitrogen (TN %) is rated by Havlin *et al.* [22] as very low (<0.1), low (0.1 to 0.15), medium (0.15 to 0.25) and high (> 0.25). The result showed that the total nitrogen in the soil level was low. Tekalign Mamo *et al.* [23] Described percentage of carbon content C< 0.5, 0.5-1.5, 1.5-3.0, >3.0% as very low, low, moderate and high, respectively. Hence, the result showed that the total amount of carbon level was medium. [23] described soils with available P< 10, 11-31, 32-56, >56 ppm as low, medium, high and very high, respectively. Hence, the result showed that the total amount of available soil P level was medium.

Plant Height: The analysis of variance showed that the response of urea stable fertilizer was significantly affect at ($p<0.05$) on plant height (Table 3). The highest (90.42cm) plant height was recorded from application of half more than Rec N from Urea Stabil in split application, whereas the lowest (68.68cm) plant height was obtained from negative control treatment. There was linear increased in plant height with increased in N fertilizer rate. Such increment of plant height along with increase of N fertilizer rate might be related to the effect of nitrogen which promotes vegetative growth as other growth factors are in conjunction with it. This result is in line with many authors [24, 25] reported that plant height of barely was increase with increasing rates of N fertilizer.

Spike Length: Analysis of variance showed that the response of urea stable fertilizer was significantly affect at ($p<0.05$) on spike length (Table 3). The highest (7.48cm) spike length was recorded from application of half more than Rec N from normal Urea in split application, whereas the lowest (5.73cm) spike length was obtained from control treatments. The increment of spike length along with increase of N rate might be related to the effect of nitrogen which promotes vegetative growth. This result is in line with many authors [25, 26] reported that spike length of barely was increase with increasing rates of nitrogen.

Grain and Biomass Yield: The combined analysis of variance over three years revealed that the effect of urea Stabil was highly significant ($p<0.01$) grain and biomass yield of malt barley. The highest malt barley grain and biomass yield (4079.0 kg ha^{-1} and 9748.3 kg ha^{-1} respectively) were obtained from the application of half more than Rec N from normal Urea in split application followed by Half more than Rec N from normal Urea in split application fertilizer resulting in 3617.2 kg ha^{-1} grain and 9343.8 kg ha^{-1} biomass yields respectively, whereas the lowest (1963.2 kgha^{-1}) grain and 4864.0 kg ha^{-1} biomass yields were obtained on the negative control treatments (Table 3). The current study stated that, as the rate of N fertilizer increased grain yield also increased. The results obtained from this study were in line with the research findings of many previous works [27-29] all of them observed significant increases in grain yields of malt barley crop with increasing levels of N fertilizer. Harvest index shows that the physiological efficiency of plants to convert the fraction of photo-assimilates to grain yield and results of harvest index showed that there was no significance differences observed between nitrogen levels.

Table 1: Physico- chemical properties of the soil before sowing

	Chemical Properties				
Soil depth (cm)	pH (H_20)	TN (%)	CEC ($cmol_ckg^{-1}$)	OC (%)	Av.P (ppm)
0.20	4.84	0.18	15.6	1.46	8.29

CEC=Cation exchange capacity, OC=Organic carbon, TN=Total nitrogen, Av.P=Available phosphorus.

Table 2: Chemical soil characteristics (0-20cm depth) of the experimental site after malt barley harvesting

Treatments	pH	P(ppm)	TN (%)	S(ppm)	OC (%)
0N	5.03	9.13	0.20	1.83	1.72
46N(Conventional urea)	5.08	11.97	0.22	4.57	1.59
46N Urea Stabil at planting	4.97	13.16	0.18	0.91	1.65
46N Urea Stabil in split form	4.74	11.92	0.22	0.91	1.54
23N Urea Stabil at once application	4.82	9.24	0.20	1.83	1.68
23N Urea Stabil in split form	4.89	12.19	0.23	0.91	1.74
69N Urea Stabil split application	5.10	8.16	0.24	1.83	1.62
69NNormal Urea in split application	4.65	14.40	0.20	0.91	1.82
69N Urea Stabil at once application	5.12	13.18	0.22	1.83	1.66
Test method	1:2.5 H_2O	Bray II	Kjeldhal	Turbidity & Calorimetric	Wakely & Black wet digestion

Table 3: Mean plant height, spike length, grain yield, biomass yield and harvest index of malt barley as affected by conventional Urea and Urea Stabil fertilizers

Treatments	Plant height (cm)	Spike length (cm)	Grain yield (kg ha^{-1})	Biomass yield (kg ha^{-1})	Harvest index
0N	68.68^{e}	5.73^{c}	1963.2^{d}	4864.0^{e}	42.39
46N(Conventional urea)	86.23^{bc}	7.07^{ab}	3396.3^{b}	8657.4^{ab}	39.3
46N Urea Stabil at planting	82.86^{cd}	6.52^{b}	3305.9^{b}	8492.5^{ab}	39.58
46N Urea Stabil in split form	84.68^{c}	7.18^{a}	3308.9^{b}	8414.4^{bc}	39.76
23N Urea Stabil at once application	80.17^{d}	6.48^{b}	2724.7^{c}	6522.0^{d}	43.08
23N Urea Stabil in split form	80.43^{d}	6.57^{b}	2679.0^{c}	7156.2^{cd}	39.06
69N Urea Stabil split application	90.42^{a}	7.38^{a}	4079.0^{a}	9748.3^{a}	42.32
69NNormal Urea in split application	88.75^{ab}	7.48^{a}	3617.2^{ab}	9343.8^{ab}	38.86
69N Urea Stabil at once application	88.55^{ab}	7.18^{a}	3409.9^{b}	9036.5^{ab}	38.30
Mean	83.41	6.84	3164.9	8026.1	40.29
LSD (0.05)	3.79	0.615	485.88	1273.8	Ns
CV (5%)	5.6	11.1	18.9	19.6	19.67

Quality Parameters

Thousand Grain Weight: Thousand grain weightswas highly significant ($P<0.001$) to different nitrogen rate application (Table 4). The highest thousand grain weight (46.38g) was obtained from the half more than recommended N from normal Urea in split application treatment and the lowest (43.75 g) obtained from half of the recommended N from Urea Stabil in split form. Thousand grain weight should be >45 g for 2-rowed barley and > 42 g for 6-rowed barley [30]. The standards set for thousand kernel weight by National Standard Authority ranged from 35 to 45 gram [31]. The acceptable thousand grain weights for barley are in the range 44.8–52.8 g [32]. The results of this experiment showed that an acceptable mean of thousand grain weight for nitrogen fertilizer application rate (Table 4).

Hectoliter Weight: Hectoliter weight was non-significant affect at ($P<0.05$) to different N levels (Table 4). The standards set for hectoliter weight by National Standard Authority ranged from 60 to 65 kg hl^{-1} [31]. The results of this experiment revealed that an acceptable hectoliter weight for all nitrogen application rate.

Moisture Content: The result showed that the moisture content was significantly different ($P<0.05$) among thenitrogen fertilizer rate (Table 4). The highest (12.9%) value moisture content was obtained from negative control treatment. Moisture levels need to be low enough to inactivate the enzymes involved in seed germination as well as to prevent heat damage and the growth of disease microorganisms. Fox *et al.* [33] reported that the maximum reasonable industrial specification of malt barley moisture content for safe storage is12.5%, whereas, the EBC standard, a moisture content of 12-13.5 % is accepted. In this study the moisture content were in the acceptable ranges for all N application rates.

Table 4: Mean of over year effect of nitrogen levels on malt barley quality parameter

Treatments	TGW(g)	HLW(kg L^{-1})	MC (%)	GS (%)	GPC (%)	GE (%)
0N	44.79^{bcd}	62.21	12.9^{a}	88.3^{c}	10.2^{c}	96.2
46N(Conventional urea)	44.83^{bcd}	62.31	12.78^{ab}	94.6^{a}	10.8^{b}	95.4
46N Urea Stabil at planting	44.19^{cd}	62.57	12.75^{ab}	91.8^{ab}	11.02^{b}	95.6
46N Urea Stabil in split form	46.28^{ab}	62.28	12.88^{ab}	89.4^{bc}	10.6^{bc}	96.5
23N Urea Stabil at once application	45.07^{abcd}	60.94	12.62^{ab}	90.6^{ab}	11.1^{b}	95.4
23N Urea Stabil in split form	43.75^{d}	61.17	12.60^{b}	91.2^{ab}	10.4^{c}	95.2
69N Urea Stabil split application	45.77^{ab}	60.81	12.79^{ab}	96.4^{a}	12.6^{a}	95.03
69NNormal Urea in split application	46.38^{a}	61.21	12.86^{ab}	95.6^{a}	12.8^{a}	96.1
69N Urea Stabil at once application	45.53^{abc}	60.77	12.66^{ab}	94.2^{ab}	13.4^{a}	96.6
Mean	45.18	61.59	12.76	92.4	11.435	95.78
LSD (0.05)	1.589	Ns	0.287	1.428	0.46	Ns
CV (5%)	4.16	4.11	2.78	4.2	3.6	2.4

Means followed by the same letters are not significantly different at ($P < 0.05$). TGW=Thousand grain weight, HLW=Hectoliter weight, MC=Moisture content, GS=Grain size, GPC=Grain protein content, GE=Germination energy and ns= non-significant

Grain Size: The analysis of variance for grain size was highly significant ($P<0.001$) different among nitrogen fertilizer rate (Table 4). Sieve test analysis results using 2.8 mm and 2.5 mm sieve size responded significantly ($p <0.001$ and $p =0.05$) to N fertilizer rate. Highest (96.4%) mean grain size percentage was obtained from 69N Urea Stabil split application, while the lowest (88.3%) grain size from negative control treatment. Dejene Kassahun Mengistu and Fetien Abay Abera [28] and McKenzie *et al*. [34] reported that grain size was reduced by increasing rates of applied nitrogen. The grain size percentage should be >90% for 2-rowed barley and >80% for barley [30]. In this current study the mean grain size fulfill the standard requirement of the industry according to EBC and Ethiopia malt factory.

Grain Protein Content and Germination Energy: Grain protein content was highly significant ($P<0.001$) affected to different applied N fertilizer (Table 4). The highest grain protein content (13.4%) was recorded from 69N Urea Stable at once application and the lowest grain protein (10.2%) from control treatment. The results of the current study similar research findings with many authors [34, 35] reported that with low available nitrogen in the soil, malt barley responds well to applied fertilizer, showing increases in both yield and protein content. However, too much nitrogen can increase protein beyond levels set by the maltsters. This increase in protein may increase steep times, cause uneven water uptake during steeping, make germination more erratic/not uniform, create undesirable qualities in the malt, increased malt loss due to abnormal growth, excessive enzymatic activity, low extract yield, excessive nitrogenous compounds in the wort during brewing and chill haze formation in beer [36]. According to the Ethiopian standard authority and Asella malt factory (AMF), the protein level of the raw barley quality standard for malt should be between 9–12% [37]. The result showed that the germination energy were not significance differences among nitrogen levels but, the germination energya little bit varied from 95.2-96.6 percent.

Nitrogen Use Efficiency Indications: Agronomic and physiological efficiencies Agronomic efficiency is the amount of additional yield obtained for each additional kg of nutrient applied, whereas physiological efficiency is the biological yield obtained per unit of nutrient uptake [18, 38]. The highest agronomic efficiency (54.1 kg ha^{-1}) was recorded from application of 23N Urea Stabil in split form and the lowest (24.8 kg ha^{-1}) from 69NUrea Stable at once application (Table 5). Similarly, the highest PE (87.03 kg ha^{-1}) was recorded from plots fertilized with 69N Urea Stabil split application and the lowest (72.8 kg ha^{-1}) from 46N Urea Stable in split form. Craswell and Godwin [39] asserted that high agronomic efficiency could be obtained if the yield increment per unit N applied is high because of reduced losses and increased N uptake.

Apparent nitrogen recovery efficiency is a measure of the ability of the crop to extract N from the soil [18]. Both nitrogen fertilizer sources and rates of application influenced apparent nitrogen recovery. The highest N recovery was obtained from 69N Normal Urea in split application (56.1%) (Table 5). Marcelo Curitiba Espindula *et al*. [40] reported that cereal crops fertilized with urea+NBPT had higher apparent nitrogen recovery, total shoot N accumulation and NUE than plants fertilized only with urea. Zaman *et al.* [41] and Xu *et al.* [42] also reported that the use of urease and nitrification inhibitors reduced N losses and increased N use efficiency by different crops.

Table 5: Agronomic, physiological and apparent recovery efficiency as affected by Urea and Urea Stabil fertilizers on malt barley

Levels of N (kg ha^{-1})	AE (kg ha^{-1})	PE(kg ha^{-1})	ARE (%)
0N	-	-	-
46N(Conventional urea)	38.2	76.2	42.3
46N Urea Stabil at planting	40.4	82.4	36.4
46N Urea Stabil in split form	34.8	72.8	45.5
23N Urea Stabil at once application	52.5	78.5	33.4
23N Urea Stabil in split form	54.1	85.4	38.1
69N Urea Stabil split application	26.2	87.03	52.6
69NNormal Urea in split application	28.6	79.8	56.1
69N Urea Stabil at once application	24.8	80.6	47.2

AE- Agronomic Efficiency, PE- Physiological Efficiency, ARE- Apparent Recovery efficiency

Table 6: Partial budget and dominance analysis for malt barley

Treatments	Urea (kg/ha)	NPS (kg/ha)	AV.GY (kg/ha)	Adj.GY (kg/ha)	GB (EB/ha)	Urea (cost)	NPS (cost)	Labour	TVC (EB/ha)	NB (ET/ha)	MRR (%)
0N	0	0	1963.2	1766.9	28270.1	0	0	0	0	28270.1	
46N(Conventional urea)	50	130	2724.7	2452.2	39235.7	700	300	1940	2940	36295.7	272.9
46N Urea Stabil at planting	50	130	2679	2411.1	38577.6	700	300	1950	2950	35627.6	D
46N Urea Stabil in split form	100	130	3396.3	3056.7	48906.7	1400	600	1945	3945	44961.7	938.1
23N Urea Stabil at once application	100	130	3305.9	2975.3	47604.9	1400	600	1950	3950	43654.9	D
23N Urea Stabil in split form	100	130	3308.9	2978.0	47648.2	1400	600	1955	3955	43693.2	764
69N Urea Stabil split application	150	130	4079	3671.1	58737.6	2100	900	1950	4950	53787.6	1014.5
69N Normal Urea in split application	150	130	3617.2	3255.5	52087.7	2100	900	1960	4960	47127.7	D
69N Urea Stabil at once application	150	130	3409.9	3068.9	49102.6	2100	900	1965	4965	44137.6	D

Ave GY=Average yield; Adj GY=Adjusted yield; GB= Growth benefit; TCV=Total cost varies; NB= Net benefit; MRR=Marginal rate of return

Partial Budget Analysis: The economic analysis showed that the application of 69 kg ha^{-1} N from Urea Stabil in split form application provided the highest marginal rate of the return (MRR) of 1014.5% (Table 6) suggesting for one birr invested in malt barley production, the producer would collect birr 10.14 after recovering his investment. The negative marginal rate of returns values obtained were rejected. Since the MRR assumed in this study was 100%, the treatment with application of 69kg ha^{-1}N from Urea Stabil in split form application gave an acceptable MRR. Therefore, the application 69kg ha^{-1}N from Urea Stabil in split form application mentioned above is found economical to be recommended on Nitisols of the study area and similar locations in the central highlands of Ethiopia.

CONCLUSION

Application of different rates of Urea Stabil and conventional urea significantly affected plant height, spike length, grain and biomass yields of malt barley. The highest malt barley grain and biomass yield (4079.0 kg ha^{-1} and 9748.3 kg ha^{-1} respectively) were obtained from the application of half more than Rec N from Urea Stabil in split application followed by Half more than Rec N from normal Urea in split application fertilizer resulting in 3617.2 kg ha^{-1} grain and 9343.8 kg ha^{-1} biomass yields respectively, whereas the lowest (1963.2 kg ha^{-1}) grain and 4864.0 kg ha^{-1} biomass yields were obtained on the negative control treatments. Maximum value of thousand grain weight and grain size was obtained from 69 N Urea Stabil split application. However, the highest (12.9%) value moisture content was obtained from negative control treatment and the highest grain protein content (13.4%) was recorded from 69N Urea Stable at once application and the lowest grain protein (10.2%) from control treatment. The highest agronomic efficiency (54.1 kg ha^{-1}) was recorded from application of 23N Urea Stabil in split form and the lowest (24.8 kg ha^{-1}) from 69NUrea Stable at once application. Similarly, the highest PE (87.03 kg ha^{-1}) was recorded from plots fertilized with 69N Urea Stabil split application and the lowest (72.8 kg ha^{-1}) from 46N Urea Stable in split form. Similarly, the highest (56.1%) N recovery was obtained from 69N Normal Urea in split application. Generally, the study revealed that the malt barley responded more to 69 kg ha^{-1} nitrogen from urea stable in split application method was the best alternative option. Therefore, taking the finding of the present study into consideration and concluded that 69 kg ha^{-1} urea Stabil in split application to improve the grain yield of malt barley for the area. Further study should be conducted on slow releasing nitrogen fertilizer with basal application of micro nutrients and degradability of Urea Stabil.

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