**Yield and quality response of malt barley (*Hordeumdistichon* L.) to nitrogen and phosphorus fertilizer under irrigation in North West Amhara, Ethiopia**

Erkihun Aemu\*, Beamlaku Alemayehu, Tadele Amare, Abere Tenagne, Abriham Awoke,
Atakiltie Abebe, Zerefu Baize and Bitewlign Kerebih

Erkihun Aemu\*\_Associate researcher\_erkiew21@gmail.com \_Bahir Dar, Ethiopia

 Beamlaku Alemayehu\_Associate researcher\_amlakalema@gmail.com \_ Bahir Dar, Ethiopia

Tadele Amare\_Lead researcher\_Tadele17B@yahoo.com \_ Bahir Dar, Ethiopia

Abere Tenagne\_Assistant researcher\_aberetenagne@gmail.com \_ Bahir Dar, Ethiopia

Abraham Awoke\_ Assistant researcher\_abuye466@gmail.com \_ Bahir Dar, Ethiopia

Atakiltie Abebe\_Associate researcher\_atklte24@gmail.com \_ Bahir Dar, Ethiopia

Zerefu Baize\_Associate researcher\_zerfubazie@gmail.com \_ Bahir Dar, Ethiopia

Bitewlign Kerebih\_Assistant researcher\_bitewkerebih3@gmail.com \_ Bahir Dar, Ethiopia

\*Corresponding author: Erkihun Alemu: E-mail-erkiew21@gmail.com, ORCID- [0000-0001-8704-074X](https://orcid.org/0000-0001-8704-074X).

# Acknowledgments

We would like to acknowledge Adet Agricultural Research Centre (AARC) and Amhara Agricultural Research Institute (ARARI) for providing financial and logistic support for the field and laboratory works.

# Abstract

Two years on-farm research was conducted to determine economical and biological optimum rates of nitrogen (N) and phosphorus (P) fertilizers on grain yield and quality of malt barley (*Hordeumdistichon* L.) production under irrigation in North West Amhara. The experiment was conducted from 2019-2020 at two districts (Mecha and Gugusashekudad) using 5 rates of N (0, 46, 69, 92 and 115) kg ha-1 and 3 rates of P (23, 46 and 69) P2O5 kg ha-1 arranged factorially including one satellite treatment (0,0). The experiment was laid out using randomized complete block design (RCBD) with three replications. As test crop improved malt barley variety which is called IBON [174/03] was used. Urea and triple super phosphate (TSP) fertilizers were also used for N and P source, respectively. All P fertilizer was applied at planting; Whereas N was applied at planting, tillering and booting stages of the crop. Grain and biomass yields of malt barley showed a significant response for N fertilization at both districts. Nitrogen showed significant difference on protein contents at Gugusashekudad. However, sole P and its interaction with N didn’t show any statistical significance difference on yields or protein contents of barley. The maximum grain yields was attend on 92/23 N/P2O5 kg ha-1 and 115/23 N/P2O5 kg ha-1 with magnitudes of 3337 and 2284.3 kg ha-1 at Mecha and Gugusashekudad districts, respectively. Application of 92/23 N/P2O5 kg ha-1 and 115/23 N/P2O5 kg ha-1 gave the highest net benefits (66,839 ETB ha-1) and (44,285 ETB ha-1) in Mecha and Gugusashekudad districts, respectively and takes as optimum economical profitable rates with yield advantages of 64% and 194.5% from the control treatment. However, for malt purpose 69/23 N/P2O5 kg ha-1 and 46/23 N/P2O5 kg ha-1 are recommended at Mecha and Gugusashekudad districts, respectively.

**Keywords:** Nitrogen, phosphorus, Fertilizer, Malt barley, Protein content

# Introduction

Ethiopia is the second largest barley producer in Africa, next to Morocco, accounting for about 25% of the total barley production in the continent (FAO, 2014). It is the fifth important cereal crop next to tef, maize, sorghum and wheat in the country with a mean productivity of2.1 ton ha-1 (CSA, 2017). More than 4 million smallholder farmers involved barley production (CSA, 2016). Malt barley *(Hordeumdistichon L.)* in Ethiopia is predominantly grown between 2200-3000 m a.s.l (Asmare *et al.*, 1998). It is one of the most important crops for food, feed, malt and income generation for many smallholder in the highlands of Ethiopia (Bayeh and Berhane, 2011).

However, the productivity is about 2 ton ha-1. ORDA, 2008b estimated that about 15,945 ton of malt barley produced annually in Ethiopia. However, the combined annual malt barley consumption of the six breweries in the country is estimated about 48,330 ton and is more than threefold which demand to increase the production capacity of malt barely. Accordingly, about 60% of the malt demand of factories is met through imports (ORDA, 2008a). Low soil fertility and poor agronomic practices are among the major constraints responsible for the low productivity of malting barley in Ethiopia (Gete *et al.,* 2010).

Most Ethiopian soils are N and P deficient (Taye *et al.,* 2002). Synthetic N and P fertilizer application is one the options to improve the productivity of malt barley and hence satisfy the demands of factories with local production than importing. Nitrogen is critically important to plants since it is a fundamental part of the chlorophyll molecule and is essential in the formation of amino acids and proteins. Phosphorus is an essential structural constituent of various bio chemicals such as nucleic acid (DNA and RNA enzymes and coenzymes). Deficiency of N and P are still one of the factors accountable for low malt yield production in Ethiopia (Khan *et al.,* 2017). Hence, good soil fertility management practices is paramount important for all barley production systems (Bayeh and Berhane, 2011). Therefore, this research was initiated to determine the economical and biological optimum N and P fertilizer rates for seed and malt production under irrigation in North West Amhara, Ethiopia.

# Materials and methods

## Study area description

The study was conducted at two districts (Mecha and Gugusashekudad) which are 525 km and 435 km far away from capital city of Ethiopia, Addiss Ababa; in the north-west direction (Figure 1). According to Ethiopian traditional agro-ecological classification, Mecha district is classified under WeyinaDega and Gugusashekudad under Dega (Mekonnen, 2015).

## Experimental methods and design

The experiment was conducted for two consecutive years (2019-2020). Improved malt barley variety which is called IBON [174/03] with 100 kg ha-1 seed rate was used as a test crop. Urea (46-0-0) and TSP (0-46-0) were used as a source of N and P, respectively. All amount of P was applied at planting and N fertilizer was applied in three splits that was at planting (1/3), tillering (1/3) and booting (1/3) stages. The water was applied in furrows with 40cm furrow width at7 days irrigation interval.

The experiment laid out in randomized complete block design (RCBD) with three replications. In the experiment 5 rates of N (0, 46, 69, 92 and 115 kg ha-1) and 3 rates of P (23, 46 and 69 kg P2O5 ha-1) was used using factorial arrangement. For partial budget analysis purpose, one satellite [control (0, 0)] treatment was also used. The spacing was 1.5m, 0.5m and 0.2m between blocks, plots and rows, respectively. Gross plot size was 3.2 m width and 2m length (6.4m2).



Figure 1. Map of the study areas

## Soil sampling, Preparation and Analysis

One composite soil sample before planting was taken from five points following the Non-Systematic pattern (X-pattern sampling) technique at the depth of 0-20 cm for each site. The sampled soils were air dried and sieved (≤2 mm) for analysis of soil pH, Organic carbon (OC), Cation Exchange Capacity (CEC), Available phosphorus (AP), and total nitrogen (TN). The soil analysis was conducted at Adet Agricultural Research Center's Soil Laboratory. From this, soil pH-H2O was determined in soil-water suspensions of 1:2.5 ratios according to Sahilemedihin and Taye (2002). AP was analyzed following Olsen method (Olsen, 1954); while TN was analyzed following the Kjeldahl method (Bremner and Mulvaney, 1982). Wet oxidation method was used to determine soil OC while cation exchanges capacity (CEC) was determined using ammonium acetate method. Following this, at Table 1 indicated parameter values were obtained.

As shown in Table 1, the soil pH at all experimental sites ranges from strongly acidic (4.5-5.2) to moderately acidic (5.3-5.9) according to the scale of Tekalign (1991). Soil OC values was also ranged from moderate to high (1.5-3%) according to Tekalign (1991), whereas CEC readings ranged from moderate to high (12-40 Cmol(+)/kg) (Hazelton and Murphy, 2007). The TN found to be in high ranges (0.12-0.25%) according to Tekalign (1991). On the other hand, AP at two sites ranged from (5-10ppm) which is medium range while at other sites it was >10 Ppm which is at high rating range (Olsen, 1954).

Table 1.Selected soil properties for the experimental sites before plant

|  |  |  |
| --- | --- | --- |
| Soil parameters  | Mecha  | Gugusashekudad  |
| 2019 | 2020 | 2019 | 2020 |
| Farm 1 | Farm 2 | Farm1 | Farm 2 | Farm 1 | Farm 2 | Farm 1 | Farm 2 |
| pH (H2O) | 5.29 | 5.54 | 5.12 | 5.09 | 5.95 | 5.29 | 5.32 | 5.68 |
| OC (%) | 2.49 | 2.63 | 2.07 | 1.96 | 2.63 | 2.76 | 2.25 | 2.37 |
| CEC (mg/100g) | 15.54 | 19.42 | 26.28 | 27.22 | 21.7 | 15.06 | 28.02 | 27.16 |
| Total N (%) | 0.175 | 0.258 | 0.190 | 0.185 | 0.247 | 0.161 | 0.171 | 0.188 |
| AP (Ppm)  | 10.17 | 7.79 | 6.80 | 14.44 | 10.28 | 12.26 | 10.84 | 11.01 |

## Data collection and analysis

Agronomic data like plant height, spike length, harvest index (HI) and all biological yields (grain + above ground biomass) were collected at harvest. The grain yield was adjusted to 12.5% of moisture content. SAS software version 9.0 was used to analyze all collected agronomic data (SAS Institute, 2002). Least significant difference (LSD) was used for mean separation comparison at 5% probability. The partial budget analysis was done following CIMMYT( 1988) procedure. For the partial budget analysis, farm gate prices of the malt barley and the cost of fertilizers were considered to their specific area. Based on this, 1kg malt barley grain, 1 ton straw, 1 kg Urea and 1 kg NPS fertilizers were considered as 20 ETB, 1000 ETB, 14 ETB and 14.5 ETB, respectively.

# Results and Discussion

## Yield response to applied N and P fertilizers

At Mecha both grain and biomass yields of malt barley linearly increased as N level increased for both two consecutive cropping seasons (Table 2) which is in line with the findings of Snežana *et al. (*2011) and Meharie and Kindie (2019). Although both yields (grain + biomass) in two cropping seasons showed an incremental trend with N levels, this increment showed a decreasing incremental rate after 46 kg N ha-1. In this district, only in 2019, both grain and biomass yields showed a highly significant difference (p<0.0001) among treatments due to N fertilization. But, there was no significant difference between P-rates for both grain and biomass yields. This might be due to existing of enough available P in the natural soil.

Both N and P fertilizer applications didn’t show statistical significant differences and showed irregular trends on protein contents of malt barley in both experimentation periods as shown in Table 4. But from malt quality perspective, all readings in the first cropping season were above critical level (>11.5%) whereas, in the second cropping season it was below critical level of 11.5% based on Atherton (1984) standardization (Table 4).

Table 2.Yield response of malt barley to N and P at Mecha district

|  |  |
| --- | --- |
| Grain yield (kg ha-1) | Biomass yield (kg ha-1) |
| N Levels | 2019 | 2020 | Combined | 2019 | 2020 | Combined |
| 0 | 1241.4 | 2087.2 | 1579.7 | 2707.9 | 5868.5 | 3972.6 |
| 46 | 2619.2 | 2347.4 | 2510.7 | 4746.1 | 7153.0 | 5708.7 |
| 69 | 2805.9 | 2730.1 | 2775.6 | 4907.1 | 7448.2 | 5923.3 |
| 92 | 2889.9 | 2868.9 | 2881.7 | 5092.6 | 7917.2 | 6222.0 |
| 115 | 2885.2 | 2975.1 | 2921.4 | 5463.7 | 8091.1 | 6513.7 |
| LSD  | 496.7 | 811.2 | 430.2 | 952.6 | 1990.9 | 1171.0 |
| Pro.  | \*\* | NS | \*\* | \*\* | NS | \*\* |
| P2O5 levels |
| 23 | 2598.2 | 2685.7 | 2633.2 | 4777.6 | 7312.9 | 5791.5 |
| 46 | 2339.2 | 2566.7 | 2430.2 | 4431.1 | 7562.5 | 5683.0 |
| 69 | 2528.2 | 2553.9 | 2538.7 | 4542.0 | 7010.7 | 5529.0 |
| LSD  | 384.7 | 628.5 | 333.2 | 737.9 | 1542.1 | 907.1 |
| Pro. | NS | NS | NS | NS | NS | NS |
| Pro. (N\*P) | NS | NS | NS | NS | NS | NS |
| CV | 30.1 | 37.9 | 33.2 | 31.3 | 33.2 | 40.5 |

**Note:** \*\*=Highly significant, \*= Significant, NS= Non significant

In Gugusashekudad district, both grain and biomass yields of showed a highly significant difference (P<0.0001) among treatments with linear increment in both cropping season due to N fertilizer application and this result was in line with the findings of Ruiter (1999) and Sainju *et al.* (2013). Similar to Mecha district, at Gugusashekudad, P as well as interaction of the two nutrients (N and P) didn’t show any significant difference among treatments on the yield and protein contents (Table 3). In this district increment of both grain and biomass yields due to N fertilization showed a decreasing rate after 46 kg N ha-1.

In this district similar to biological yields, protein content of malt grain showed highly significant difference (P<0.0001) among treatments due to N fertilization with linear increment in 2019 cropping season (Table 4). In this cropping season, all protein contents of grain showed above the critical level (>11.5) based on Atherton (1984).

Table 3.Yield response of malt barley to N and P at Gugusashekudad district

|  |  |
| --- | --- |
| Grain yield (kg ha-1) | Biomass yield (kg ha-1) |
| N Levels | 2019 | 2020 | Combined | 2019 | 2020 | Combined |
| 0 | 1304.4 | 907.9 | 1106.4 | 3055.6 | 2199.2 | 2627.4 |
| 46 | 1752.4 | 1508.5 | 1631.0 | 3634.3 | 2824.6 | 3229.4 |
| 69 | 1982.2 | 1617.0 | 1799.1 | 4236.3 | 3309.9 | 3773.1 |
| 92 | 2154.9 | 1514.4 | 1835.2 | 4537.3 | 3726.4 | 4132.5 |
| 115 | 2381.2 | 1757.1 | 2068.6 | 5000.5 | 4455.6 | 4728.6 |
| LSD  | 439.8 | 508.1 | 342.9 | 751.2 | 965.0 | 624.7 |
| Pro. | \*\* | \*\* | \*\* | \* | \*\* | \*\* |
| P2O5 levels  |
| 23 | 1864.4 | 1538.9 | 1701.0 | 3902.6 | 3465.1 | 3684.4 |
| 46 | 1838.7 | 1314.9 | 1576.2 | 4083.5 | 3278.4 | 3680.9 |
| 69 | 2041.7 | 1530.7 | 1786.2 | 4292.3 | 3166.4 | 3728.8 |
| LSD  | 340.8 | 393.6 | 265.6 | 580.0 | 747.5 | 483.8 |
| Pro. | NS | NS | NS | NS | NS | NS |
| Pro. (N\*P) | NS | NS | NS | NS | NS | NS |
| CV | 34.6 | 52.4 | 43.6 | 27.6 | 44.0 | 36.3 |

However, in the second cropping season the protein content didn’t show any significant response for both N and P rates and below the critical protein content. Even though the two fertilizers had no significant response on the protein content of the grain in the cropping season, all readings showed below the critical protein content value (<11.5) which is at acceptable range of malt quality (Atherton, 1984).

Demisie *et al.* (2015) and Derebe *et al.* (2018) reported similar result with our finding. Nitrogen fertilizer resulted a highly significant difference (p<0.0001) among treatments on both grain and biomass yields of malt barley from the two years combined analysis result at each district with a linear increment (Table 2 and 3). But this increment is in a decreasing rate as N rate increase on both biological yields. Similar to in a separate year result; sole P and interaction of N and P fertilizers didn’t show any statistical significant difference of grain and biomass yields (Table 2 and 3). The non responsiveness of P fertilizers on biological yields of barley may be due to existing of P nutrient accumulation in the natural soil. The accumulation may be occurred due to continuously P application as fertilizer sources for the last 50 and more than years. By its nature, lose of P from soil system is too low relative to N nutrient due to any mechanism. That is why, our P soil data found from medium to high ranges and supporting our result. In contrast of this, whatever the N level is high in the soil, application of N as synthetic fertilizer sources showed a significant response on biological yields of malt barley. This may be indicated, the amount of N found in the soil is not fully available for plant nutrition during plant growth period.

As shown in combined ANOVA result, protein content showed a significant difference among treatments due to N fertilization only at Gugusashekudad district. Beside of this, application of N up to 92 kg N ha-1 at Mecha and 46 kg N ha-1 at Gugusashekudad district, protein values found less than the critical level (11.5%) which is under acceptable malt quality rage (Atherton, 1984) (Table 4). From yield potential perspective, both grain and biomass yields showed nearly a 20% yield penalty per hectare due to furrow spacing in both districts compared to the rainy season.

Table 4. Response of protein contents (%) of malt barley to N and P

|  |  |
| --- | --- |
| Mecha | Gugusashekudad |
| N Levels | 2019 | 2020 | Combined | 2019 | 2020 | Combined |
| 0 | 10.8 | 9.7 | 10.4 | 11.9 | 10.0 | 10.9 |
| 46 | 11.6 | 10.1 | 11.0 | 12.0 | 10.2 | 11.1 |
| 69 | 11.8 | 10.3 | 11.2 | 12.5 | 10.6 | 11.6 |
| 92 | 11.7 | 9.7 | 10.9 | 13.0 | 10.3 | 11.6 |
| 115 | 12.5 | 10.0 | 11.5 | 13.5 | 10.4 | 11.9 |
| LSD  | 1.4 | 1.5 | 1.1 | 0.5 | 0.8 | 0.7 |
| Pro. | NS | NS | NS | \*\* | NS | \* |
| P2O5 levels  |
| 23 | 11.5 | 9.6 | 10.8 | 12.5 | 10.2 | 11.3 |
| 46 | 11.8 | 10.3 | 11.2 | 12.8 | 10.4 | 11.6 |
| 69 | 11.6 | 10.0 | 10.9 | 12.4 | 10.3 | 11.4 |
| LSD  | 1.1 | 1.2 | 0.8 | 0.4 | 0.6 | 0.6 |
| Pro. | NS | NS | NS | NS | NS | NS |
| Pro. (N\*P) | NS | NS | NS | NS | NS | NS |
| CV | 18.2 | 18.6 | 19.4 | 6.2 | 11.8 | 13.7 |

##  Partial budget analysis

All biological yields (grain and biomass) of malt barley showed a highly significant difference (p<0.0001) among location/districts, which subjects to the analysis of the partial budget for each district separately. Based on CIMMYT (1988) partial budget analysis principle as shown in (Table 5 and 6), 92 kg N with 23kg P2O5 and 115 kg N with 23 kg P2O5 ha-1showed the highest net benefit values (66,839and 44,285 Birr/ha) and takes as the first optimum economical profitable rates for Mecha and Gugusashekudad districts, respectively. The above combined fertilizer rates gave 64% and 194.5% yield advantages over the control (zero input) at Mecha and Gugusashekudad districts, respectively.

Table 5.Partial budget analysis for Mecha district

|  |  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| N kg ha-1 | P2O5 kg ha-1 | NPS kg ha-1 | Urea kg ha-1 | GY(kg ha-1) | STY (t ha-1) | GI | N Fertilizer cost | P fertilizer cost | TVC | NB | Dominance |
| 0 | 0 | 0 | 0 | 1862 | 3.6 | 40851 | 0 | 0 | 0 | 40851 |   |
| 0 | 23 | 60.5 | 0 | 1936 | 2.9 | 41575 | 0 | 878 | 878 | 40697 | D |
| 0 | 46 | 121.1 | 0 | 1465 | 2.6 | 31861 | 0 | 1755 | 1755 | 30106 | D |
| 46 | 23 | 60.5 | 75 | 2518 | 3.2 | 53551 | 1050 | 878 | 1928 | 51624 |   |
| 46 | 46 | 121.1 | 50 | 2539 | 3.5 | 54330 | 700 | 1755 | 2455 | 51875 |   |
| 69 | 23 | 60.5 | 125 | 2695 | 3.2 | 57128 | 1750 | 878 | 2628 | 54500 |   |
| 0 | 69 | 181.6 | 0 | 1474 | 2.0 | 31443 | 0 | 2633 | 2633 | 28810 | D |
| 46 | 69 | 181.6 | 25 | 2690 | 3.1 | 56939 | 350 | 2633 | 2983 | 53956 | D |
| 69 | 46 | 121.1 | 100 | 2957 | 3.6 | 62789 | 1400 | 1755 | 3155 | 59634 |   |
| 92 | 23 | 60.5 | 175 | 3337 | 3.4 | 70167 | 2450 | 878 | 3328 | 66839 |   |
| 69 | 69 | 181.6 | 75 | 2911 | 2.9 | 61077 | 1050 | 2633 | 3683 | 57394 | D |
| 92 | 46 | 121.1 | 150 | 2641 | 3.3 | 56144 | 2100 | 1755 | 3855 | 52288 | D |
| 115 | 23 | 60.5 | 225 | 3055 | 3.5 | 64643 | 3150 | 878 | 4028 | 60616 | D |
| 92 | 69 | 181.6 | 125 | 2913 | 3.6 | 61826 | 1750 | 2633 | 4383 | 57443 | D |
| 115 | 46 | 121.1 | 200 | 2893 | 3.7 | 61524 | 2800 | 1755 | 4555 | 56969 | D |
| 115 | 69 | 181.6 | 175 | 3066 | 3.9 | 65205 | 2450 | 2633 | 5083 | 60123 | D |
| N | P2O5 | TVC (ETB ha-1) | NB (ETB ha-1) | MRR (%) |  |  |  |  |
| 0 | 0 | 0 | 40851 |   |  |  |  |  |
| 46 | 23 | 1928 | 51624 | 559 |  |  |  |  |
| 46 | 46 | 2455 | 51875 | 48 |  |  |  |  |
| 69 | 23 | 2628 | 54500 | 1523 |  |  |  |  |
| 69 | 46 | 3155 | 59634 | 973 |  |  |  |  |
| 92 | 23 | 3328 | 66839 | 4180 |  |  |  |  |
| 1kg grain=20 ETB, 1t straw=1000 ETB, 1kg Urea=14 ETB, 1kg NPS=14.5 ETB |

**Note:** GY=grain yield, STY= straw yield, GI=gross income, TVC=total variable costs, NB=net benefits, MRR=marginal rate of return, ETB= Ethiopian birr

Table 6. Table 6.Partial budget analysis for Gugusashekudad district

|  |  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| N kg ha-1 | P2O5 kg ha-1 | NPS kg ha-1 | Urea kg ha-1 | GY(kg ha-1) | STY (t ha-1) | GI | N Fertilizer cost | P fertilizer cost | TVC | NB | Dominance |
| 0 | 0 | 0 | 0 | 652.3 | 2.0 | 15037 | 0 | 0 | 0 | 15037 |   |
| 0 | 23 | 60.5 | 0 | 1073.8 | 1.4 | 22903 | 0 | 878 | 878 | 22025 |   |
| 0 | 46 | 121.1 | 0 | 1129.3 | 1.7 | 24243 | 0 | 1755 | 1755 | 22488 |   |
| 46 | 23 | 60.5 | 75 | 1560.6 | 1.6 | 32795 | 1050 | 878 | 1928 | 30867 |   |
| 46 | 46 | 121.1 | 50 | 1694.9 | 1.9 | 35774 | 700 | 1755 | 2455 | 33319 |   |
| 69 | 23 | 60.5 | 125 | 1921.3 | 2.2 | 40611 | 1750 | 878 | 2628 | 37984 |   |
| 0 | 69 | 181.6 | 0 | 1210.8 | 1.6 | 25826 | 0 | 2633 | 2633 | 23193 | D |
| 46 | 69 | 181.6 | 25 | 1775.4 | 1.5 | 36982 | 350 | 2633 | 2983 | 33999 | D |
| 69 | 46 | 121.1 | 100 | 1892.6 | 2.0 | 39817 | 1400 | 1755 | 3155 | 36661 | D |
| 92 | 23 | 60.5 | 175 | 1908.7 | 2.4 | 40551 | 2450 | 878 | 3328 | 37223 | D |
| 69 | 69 | 181.6 | 75 | 1738.0 | 1.9 | 36700 | 1050 | 2633 | 3683 | 33017 | D |
| 92 | 46 | 121.1 | 150 | 1593.3 | 2.4 | 34272 | 2100 | 1755 | 3855 | 30417 | D |
| 115 | 23 | 60.5 | 225 | 2284.3 | 2.6 | 48313 | 3150 | 878 | 4028 | 44285 |   |
| 92 | 69 | 181.6 | 125 | 2159.5 | 2.3 | 45495 | 1750 | 2633 | 4383 | 41112 | D |
| 115 | 46 | 121.1 | 200 | 1798.2 | 2.9 | 38879 | 2800 | 1755 | 4555 | 34324 | D |
| 115 | 69 | 181.6 | 175 | 2301.8 | 2.7 | 48698 | 2450 | 2633 | 5083 | 43615 | D |
| N | P2O5 | TVC (ETB ha-1) | NB (ETB ha-1) | MRR (%) |  |  |  |  |
| 0 | 0 | 0 | 15037 |   |  |  |  |  |
| 0 | 23 | 878 | 22025 | 796 |  |  |  |  |
| 0 | 46 | 1755 | 22488 | 53 |  |  |  |  |
| 46 | 23 | 1928 | 30867 | 4861 |  |  |  |  |
| 46 | 46 | 2455 | 33319 | 465 |  |  |  |  |
| 69 | 23 | 2628 | 37984 | 2706 |  |  |  |  |
| 115 | 23 | 4028 | 44285 | 450 |  |  |  |  |
| 1kg grain=20 ETB, 1t straw=1000 ETB, 1kg Urea=14 ETB, 1kg NPS=14.5 ETB |

**Note:** GY=grain yield, STY= straw yield, GI=gross income, TVC=total variable costs, NB=net benefits, MRR=marginal rate of return, ETB=Ethiopian birr

# Conclusions and recommendations

In this study, application of N fertilizer showed a significant response on biological yields (grain + biomass) at both districts with linear increment. However, sole P and interaction of N and P fertilizers didn’t show any statistical significant difference on biological yields (grain + biomass) and malt qualities of malt barley among treatments at each district. Application of 92/23 N/P2O5 kg ha-1 and 115/23 N/P2O5 kg ha-1 gave the highest net benefits (66,839 ETB ha-1) and (44,285 ETB ha-1) in Mecha and Gugusashekudad districts, respectively and takes as optimum economical profitable rates with yield advantages of 64% and 194.5% from the control treatment. However, for malt purpose 69/23 N/P2O5 kg ha-1 and 46/23 N/P2O5 kg ha-1 are recommended at Mecha and Gugusashekudad districts, respectively.

# References

Asmare Yallew, Alemu Hailiye, Alemayehu Assefa, Melkamu Ayalew, Tessema Zewudu, B. A. and H. H. (1998) Barley based farming system in the high lands of Ethiopia. Ethiopian Agricultural Research Organisation. Addis Ababa, Ethiopia. In F. A. & W. S. (eds. ). In: Chilot Yirga (Ed.), Barley production practices in Gojam and Gondar (pp. 67–89) Addis Ababa, Ethiopia.

Atherton MJ. (1984) Quality requirements: malting barley, In: EJ Gallagher, Cereal Production. Butter worths in association with Royal Dublin Society, Dublin. pp 113-130.

Bayeh M. and Berhane. L. (2011) Barley research and development in Ethiopia—an overview. In G. S. (eds). In: Mulatu B (Ed.), Barley research and development in Ethiopia. Holleta Ethiopia.

Bremner, J. M. and C. S. Mulvaney (1982) Nitrogen-total, In A. L. Page ed. Methods of Soil Analysis, Part 2: Chemical and Microbiological Properties. *Agronomy 9.* Madison, Wisconsin. 595-624.

CIMMYT (1988) From agronomic data to farmer recommendations. An economic training manual . *Compeletly revised Edition.* Mexico.

CSA (2016) Agricultural sample survey report on area and production of major crops. Addis Ababa, Ethiopia.

CSA (Central statistical agency). (2017) Agricultural sample survey. Report on area and production of major crops (private peasant holdings, Meher season). Volume I, Statistical bulletin. Addis Ababa, Ethiopia.

De Ruiter, J. M. (1999) Yield and quality of malting barley (Hordeum vulgare L. ‘Valetta’) in response to irrigation and nitrogen fertilisation. *New Zealand Journal of Crop and Horticultural Science*, 27(4), 307–317. https://doi.org/10.1080/01140671.1999.9514110

Demisie Ejigu, Tamado Tana, and Firdissa Etich (2015) Effect of Nitrogen Fertilizer Levels on Yield Components and Grain Yield of Effect of Nitrogen Fertilizer Levels on Yield Components and Grain Yield of Malt Barley ( Hordeum vulgare L .) Varieties at Kulumsa , Central Ethiopia. *Journal of Crop Science and Technology, (January).*

Derebe Terefe, Temesgen Desalegn and Habtamu Ashagre (2018) Effect of Nitrogen Fertilizer Levels on Grain Yield and Quality of Malt Barley ( Hordeum Vulgare L .) Varieties at Wolmera District , Central Highland of Ethiopia. *International Journal of Research Studies in Agricultural Sciences, 4(4), 29–43.*

FAO (2014) Food and Agriculture Organization (FAO) : Rome, Italy.

Gete Zelleke, Getachew Agegnehu, Dejene Abera and Shahidur (2010) Fertilizer and soil fertility potential in Ethiopia: Constraints and opportunities for enhancing the system. Addis Ababa, Ethiopia.

Hazelton P. and Murphy B. (2007) Interpreting soil test results: What do all the numbers mean? (2nd Editio). CSIRO. 152.

Khan K., Sharif, M., Azeem I., Ibadullah, Khan A.A., Ali S., K. I. and K. A. (2017) phosphorus solubility from rock phosphate mixed compost with sulphur application and its effect on yield and phosphorus uptake of wheat crop. *Open Journal of Soil Science*, 7, 401-429.

Meharie Kassie and Kindie Tesfaye (2019) Malting Barley Grain Quality and Yield Response to Nitrogen Fertilization in the Arsi Highlands of Ethiopia. *J. Crop Sci. Biotech*, 2019(10), 225–234.

Olsen, Sterling Robertson, C.V. Cole, F. S. W. and L. A. D (1954) Estimation of available phosphorus in soils by extraction with sodium carbonate.

ORDA (Organization for Rehabilitation and Development in Amhara) (2008) Malt barley value chain study. Options for growing a new channel in Amhara region.Bahir Dar, Ethiopia.

ORDA (Organization for Rehabilitation and Development in Amhara) (2008) Baseline survey of six malt barley potential woredas of north and south Gondar zones of the Amhara region, Ethiopia. Bahir Dar Ethiopia.

Sainju, U. M., Lenssen, A. W., & Barsotti, Joy L. (2013) Dryland malt barley yield and quality affected by tillage, cropping sequence, and nitrogen fertilization. *Agronomy Journal*, 105(2), 329–340. https://doi.org/10.2134/agronj2012.0343

SAS Institute (2002) A Business Unit of SAS. SAS Institute Inc, Cary, NC. 2751. USA.

Snežana J., Đorđe G., Radojka, Sveto R., Nikola and Ik. J (2011) Effects of nitrogen fertilization on yield and grain quality in malting barley 10(84), 19534–19541. https://doi.org/10.5897/AJB11.2633

Taye Bekele, Yesuf Assen, Sahlemedhin Sertsu, Amanuel Gorfu, Mohammed Hassena, D.G. Tanner, Tesfaye Tesemma, and Takele Gebre (2002) Optimizing fertilizer use in Ethiopia: Correlation of soil analysis with fertilizer response in Hetosa Wereda, Arsi Zone. Addis Ababa. Sasakawa-Global, 2000.

Tekalign Tadese 1991) Soil, plant, water, fertilizer, animal manure and compost analysis. Working Document No. 13. Addis Ababa, Ethiopia. (No. 13).

# Statements and Declarations

**Conflict of interest**

We declared that there is no conflict of interest to the best of our knowledge.

**Author Contributions**

Erkihun Alemu, Beamlaku Alemayehu, and Tadele Amare designed the research, implemented the research, collected data, analyzed the data, and wrote and approved the manuscript. While, Abere Tenagne, Abraham Awoke, Atakiltie Abebe, Zerefu Baize and Bitewlign Kerebih participated on data collection, executing the field work, and input preparation during experimentation.