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Original Paper

Enhancing Yield and Yield Components of Food Barley (*Hordeum Vulgare L.*) Through Optimum Nitrogen and Phosphorus Levels in Eastern Amhara, Ethiopia

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***Abstract*— fertility management plays a crucial role in optimizing crop productivity by ensuring an adequate supply of essential nutrients. The appropriate application of plant nutrients requires an understanding of both crop nutrient requirements and soil nutrient supply capacity. This study was conducted during the main cropping seasons of 2019 and 2020 to determine the economically optimum nitrogen and phosphorus fertilizer rates for enhancing food barley production. A factorial experiment was designed using three nitrogen rates (46, 69, and 92 kg N ha^{-1}) and three phosphorus rates (46, 69, and 92 kg P_2O_5 ha^{-1}) in a randomized complete block design with three replications. Before planting the soil samples were collected to know the fertility status of the experimental sites. Data on plant height, biomass yield, and adjusted grain yield were collected and all the collected data were subjected to Analysis of Variance (ANOVA) at the 0.05 significance level using SAS software (version 9.0). Means were separated by the Duncan multiple range test. The results showed that nitrogen and phosphorus fertilization significantly increased both grain and biomass yields of food barley. Yield and yield-related parameters improved with increasing nitrogen and phosphorus rates. The highest above-ground biomass yield (5,466.2 kg ha^{-1}) and maximum grain yield (2,884.6 kg ha^{-1}) were achieved with the application of 92 kg N ha^{-1} and 92 kg P_2O_5 ha^{-1}, significantly outperforming all other treatments. However, the most economically viable treatment was 92 kg N ha^{-1} combined with 69 kg P_2O_5 ha^{-1}, which resulted in the highest net benefit (53,592.3 ETB) and a marginal rate of return of 1,597.1%. Therefore, the application of 92 kg N ha^{-1} and 69 kg P_2O_5 ha^{-1} is recommended for food barley production in the study area and similar agro-ecological zones, and Future research should be conducted site-specific nutrient recommendations while assessing the sustainability and environmental impacts of high fertilizer applications.**

Keywords*— biomass yield, grain yield, plant nutrients, soil fertility, yield-related parameters

I. INTRODUCTION

Maintaining soil fertility and boosting crop yields in agricultural productivity is a key challenge for Ethiopia's agriculture [1]. Different types of plants have different nutritional requirements depending on their biological traits, developmental stages, and environmental circumstances. Because various species need varying amounts of particular nutrients, it is essential to customize nutrition management for each type of plant to maximize yields and optimize health [2]. The way plants use nutrients can greatly affect their overall performance and yield [3, 4]. For farmers who want to increase crop yields and reduce input costs, it is important to understand the nutritional needs of crops. Application of balanced fertilizers is an important practice that can increase crop yields on existing arable land. As well as maximizing the efficiency of nutrient use, implementing precision agriculture techniques can further enhance this process. By utilizing advanced technologies such as soil sensors and data analytics, farmers can tailor their management strategies to ensure that each plant receives the optimal amount of nutrients at the right time. The nutrient requirements of crops according to their physiological needs and expected yields [5]. The correct application of plant nutrients depends on the understanding of the nutrient requirements of crops and the nutrient supply capacity of the soil [6, 2]. Soils in the highlands of Ethiopia usually have low levels of essential plant nutrients, especially low availability of nitrogen, and it is the main constraint to cereal crop production [7].

Nitrogen is an essential nutrient for crops and is consumed by the roots of crops during the growing season [8]. Nitrogen is an extremely vital component for the synthesis of amino acids, proteins, and nucleic acids, which are crucial for plant growth and development. Therefore, improving nitrogen availability in these soils can significantly enhance crop yields and overall agricultural productivity in the region. Phytonutrients and their supply can be controlled through proper management practices [9]. Due to its mountainous terrain and an intensive agricultural system based on small grains, Ethiopia is considered one of the countries most affected by soil fertility depletion. The national average nutrient balance is estimated to be -41 kg N, -6 kg P, and -26 kg K ha^{-1} year^{-1}, which are the maximum nutrient consumption rates [10]. However, the soil nutrient balance between different crops, agricultural systems, and agroecological zones may vary greatly [11]. Therefore, reestablishing soil fertility and increasing crop yields is a key priority for researchers by applying balanced nutrients for each crop and location-specific fertilization recommendations and better management practices to increase crop yields and maintain soil sustainability.

Barley is the most important crop for the production of food, feed, and income for numerous small farmers in the Ethiopian highlands [12,13]. In Ethiopia, barley is the fifth most stable crop after tef, maize, wheat, and sorghum [14]. Barley is a cool-season crop adapted to high altitudes. Barley grows in a wide range of agro-climatic areas under various production systems. However, it grows in Ethiopia, mainly between 2200 and 3000 masl [15,16]. Since barley is an early harvest crop, it is a popular hunger nemesis during the lean season in some parts of the country [17]. It also has the advantage of dual crop production. Ethiopia is the second-largest producer of barley in Africa, only surpassed by Morocco, and represents approximately 25% of the total barley production on the African continent [18]. The land area allocated for barley production in 2015/16 was approximately 1 million hectares, with an average national productivity of 25 qt ha-1 (more than 23 million quintals of production) and more than 4 million smallholder farmers producing it [19]. It also covers a considerable amount of cultivated land in the Amhara region (321,515.21 ha) and in the North Wollo zone (35,222.50 ha), with 23.3 and 17.4 qt/ha productivity, respectively [14].

Nutrient management (agronomic trial) for barley began in the late 1960s [20]. However, food barley was grown in Ethiopia, particularly in the Amhara region, mostly on steep slopes and in degraded areas, with little to no fertilizer application [21]. Therefore, its national average yield (2.11 t ha^{-1}) is very low [22]. Low soil fertility and low input (fertilizer) application are the major constraints for barley production in Ethiopia [21,23]. Poor soil fertility, water logging, drought, cold, low soil pH, diseases, insects, poor crop management techniques, a lack of better varieties, and weed competition are the main reasons for lowering barley production in Ethiopia [24]. From the macro, nutrients nitrogen and phosphorus are the nutrients that most limit barley performance [25,26]. However, there is no updated nutrient management package for barley production in the rainy season for the study area. Reducing the massive application of chemical fertilizers and establishing a balance between crop nutrient requirements and fertilizer inputs, preserving soil fertility, increasing yield, boosting profitability, and ultimately lowering pollution levels. Therefore, this research was designed to determine the economic optimum rates of nitrogen and phosphorus nutrients for barley production in the Gazo district of the North Wollo Zone.

II. Materials And Methods

A. Description of the Study Area

The Gazo district is characterized by a mixed farming system that integrates both crop cultivation and livestock production. The major crops grown in the area include food barley (Hordeum vulgare L.), potato (Solanum tuberosum L.), and wheat (Triticum aestivum L.), which serve as staple food sources for the local farming communities. Additionally, pulse crops such as faba bean (Vicia faba L.) and lentil (Lens culinaris Medik.) are widely cultivated, contributing to household food security and soil fertility improvement through biological nitrogen fixation.

The district experiences a bimodal rainfall pattern, with two distinct rainy seasons. The primary rainy season, known as the Kiremt, occurs from June to September, providing the main source of moisture for crop production. The secondary rainy season, called the Belg, takes place between February and May, supporting the cultivation of short-cycle crops and early land preparation for the main cropping season. The total annual rainfall varies from year to year, but it generally provides adequate moisture for highland crop production.

The agroecology of the Gazo district is predominantly highland, characterized by a cool and humid climate that is favorable for the production of highland crops. The soil in the area varies in fertility levels and texture, with the dominant soil types being Andosols, and Cambisols, each with distinct physical and chemical properties:

Given these agroecological conditions, farmers in the Gazo district practice integrated soil fertility management, including the application of organic and inorganic fertilizers, soil conservation techniques, and crop rotation, to maintain soil productivity and sustain agricultural output. Livestock production is also a key component of the farming system, with cattle, sheep, goats, and poultry raised for draft power, manure, milk, and meat production. The integration of crop and livestock farming enhances nutrient cycling and contributes to farm resilience.

Overall, the Gazo district serves as an important agricultural zone where research and development efforts focus on improving soil fertility, optimizing fertilizer use, and enhancing crop productivity to support the livelihoods of smallholder farmers.

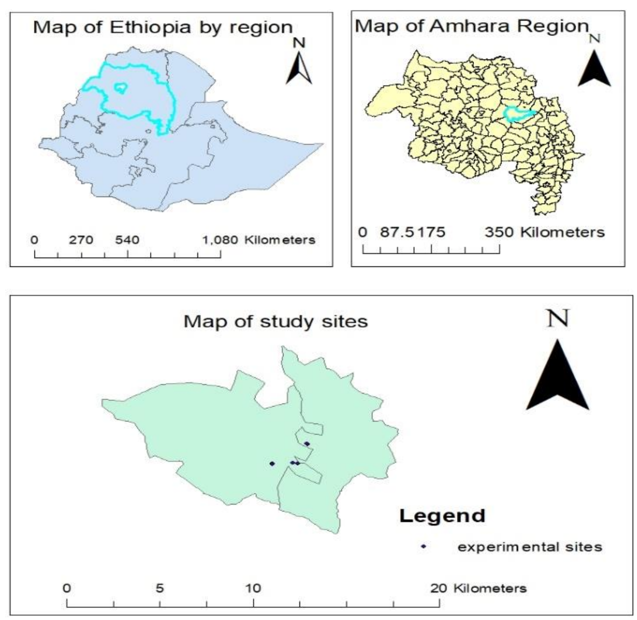

Fig. 1. Location map of the study district

B. Experimental procedures

The trial sites were carefully prepared using standard cultivation practices to ensure uniformity and suitability for planting. Land preparation involved plowing with traditional oxen-drawn equipment, a widely used method among local farmers in the Gazo district. This approach was selected to align with the prevailing farming systems in the area, thereby enhancing the practical relevance of the study's findings to smallholder farmers who rely on traditional tillage methods. The fields were plowed at least twice before planting to achieve a fine seedbed, facilitating proper seed germination, root development, and nutrient availability.

The experiment was designed as a factorial randomized complete block design (RCBD) with three replications to account for variability in soil conditions and ensure statistical reliability. The factorial arrangement consisted of three levels of nitrogen (46, 69, and 92 kg ha^{-1} N) and three levels of phosphorus (46, 69, and 92 kg ha^{-1} P_2O_5), resulting in nine treatment combinations. This setup allowed for an in-depth evaluation of both the individual and interactive effects of nitrogen and phosphorus fertilizers on Barley growth, yield components, and overall productivity.

The factorial Combination of the treatments used were

1. Control
2. (46,46) N, P2O5
3. (46,69) N, P2O5
4. (46,92) N, P2O5
5. (69,46) N, P2O5
6. (69,69) N, P2O5
7. (69,92) N, P2O5
8. (92,46) N, P2O5
9. (92,69) N, P2O5
10. (92,92) N, P2O5

Control treatment (0, 0) was for negative control for doing partial budget analysis.

The treatments were randomly assigned to plots using a Randomized Complete Block Design (RCBD). Each plot measured 3m × 3m (9m²) and was replicated three times at each site. The trial was carried out across three different sites within the location and extended over two consecutive years to account for seasonal variability. This design ensured robust comparisons and allowed for the evaluation of treatment effects under different environmental conditions and over multiple growing seasons.

The plots were arranged with a spacing of 0.5 meters between each plot and 1 meter between blocks to minimize the potential for interference between treatments. Within each plot, the spacing between rows was set at 20 cm to ensure optimal plant growth and development. Sowing of the crops was carried out during the first week of July, allowing for timely planting and ensuring appropriate environmental conditions for germination and early growth stages. This planting schedule was aimed at maximizing the yield potential while minimizing the effects of climatic variability.

Phosphorus was applied in the form of triple superphosphate (TSP), while nitrogen was applied using urea. To optimize nitrogen utilization and minimize losses, the nitrogen was applied in two split doses: half of the total nitrogen was applied at planting, and the remaining half was applied shortly after the first weeding, ensuring the presence of adequate moisture in the soil. This split application approach aims to synchronize nitrogen availability with the crop's growth stages, improving nitrogen use efficiency and promoting better crop development. Phosphorus, on the other hand, was applied in full during planting to ensure its availability for early root development and overall plant growth.

Recommended agronomic practices, including weeding, cultivation, and fertilizer application, were carried out uniformly according to the specified treatment rates during the growing season of the barley, except for the negative control treatment. Regular weeding was carried out to reduce competition from weeds, ensuring that barley plants had sufficient access to necessary nutrients, water, and sunlight. Cultivation was carried out as required to maintain proper soil aeration, enhance water infiltration, and prevent soil crusting. Fertilizer application was implemented in line with the prescribed rates for each treatment, ensuring that each plot received the intended amount of nutrients at the appropriate times. This consistent application of agronomic practices helped maintain uniformity across all treatments, ensuring that any differences in crop performance could be attributed to the fertilizer treatments rather than variations in management. The negative control treatment, which received no fertilizer, helped as a control to evaluate the impact of fertilization on barley growth and yield.

C. *Methods of Data Collection*

1) *Growth, Yield, and yield Component*

The plant height (cm): The heights of five randomly selected plants, grown within a net plot area, were measured from the ground level to the end of the spike at maturity using a meter excluding awns. The average height of the plants was calculated and used for further analysis.

The aboveground biomass yield (kg ha-1): The total air-dried aboveground biomass collected from the rows of net plot areas was weighed to calculate the aboveground biomass, and the aboveground biomass yield per plot and per hectare was noted or recorded.

The Grain yield (kg ha-1): The weight of grains was separated from the straw by threshing, and seeds/grains were cleaned, weighed, and corrected to a moisture level of 12.5% using a grain moisture tester. The plot base grain yield was converted to hectare-based.

The Straw yield (kg ha-1); was converted by subtracting the grain yield from the biomass yield. This method assumes that the aboveground biomass consists primarily of the grain and straw components. By determining the total air-dried biomass and deducting the weight of the harvested grain, the remaining portion was considered the straw yield. This approach provides an indirect yet practical estimate of straw production per plot and it converts to a hectare.

2) *Soil Sample Collection and Analysis*

The Surface soil samples were taken randomly in a cross manner before planting from the 0 to 20 cm deep plow layer using an auger across the completely experimental field of each site and composited. The soil sample was first air-dried, then carefully ground with a pestle and mortar, and finally passed with a 2 mm sieve to prepare it for analysis. A 1:2.5 soil-to-water suspension was used to calculate the pH of the soil using the method described by [27].

Organic carbon of the soil content was quantified by the wet digestion method using the Walkley and Black procedure [28] and total N using Kjeldhal's method [29]. The available phosphorus was determined following the Olsen procedure [30].

3) Data analysis

The treatments' effects were statistically examined using SAS Version 9.0 computer software and Analysis of Variance (ANOVA) for Randomized Complete Block Design (RCBD). Duncan's Multiple Range Test (DMRT) was used to identify particular significant differences between treatment means.

4) Partial budget analysis

A partial budget analysis was calculated to evaluate the economic trade-offs between different treatments by comparing their respective gains and losses. This analysis involved calculating key economic indicators, including:

Gross Benefit (GB): The total revenue generated from the yield produced under each treatment, based on the market value of the grain and straw.

The total Variable Cost (TVC): The sum of all costs directly relayed with implementing each treatment, such as expenses for fertilizers and labor.

Net Benefit (NB): Derived by subtracting the total variable cost from the gross benefit, this represents the economic return for each treatment.

Additionally, the Marginal Rate of Return (MRR) was analyzed to assess the incremental financial return from investing in one treatment compared to another. This metric was expressed as a percentage, providing a measure of profitability for each additional unit of cost incurred. Together, these parameters enabled a comprehensive comparison of the economic performance of the various treatments.

Variable costs (Birr/kg): Nitrogen (Urea) 14 birr per kg, Phosphorus (TSP) fertilizer 12birr per kg, costs were the price of fertilizer at the time of the experiment conducted.

The farmer gate price of straw and grain was 2.5 birr per kg and 20 birr per kg, respectively.

III. Results And Discussion

A. Physicochemical Properties of the Soil

The trial site analysis results indicated that particle size distribution of the experimental sites was in proportions of 29.2% sand, 40.8% silt, and 30% clay with the textural class of clay loam. According to [31], the pH of the study site (5.5) was moderately acidic. The analysis result shows that the mean available P content was 13.93 ppm (Table 1.) which is rated as medium to adequate according to [32]. The mean total nitrogen content was 0.28 %, which ranged high according to [31] classification. Similarly, organic carbon content was 1.54%, which ranged at a low level according to [31] classification.

TABLE I. Laboratory Result Of Soil Parameters Taken At Planting

pH	**OC**	**T.N (%)**	**Avail P (ppm)**	**%clay**	**%silt**	**%sand**
				30	**40.8**	**29.2**
5.5	1.54	0.28	13.93	Clay loam		

Note: pH=Power of Hydrogen; OM=Organic matter; OC= Organic carbon T.N= Total nitrogen; P Avail P =Phosphorus;

B. The Yield and Yield Components of Food Barley

1) Response of Nitrogen and Phosphorus Application on Plant Height

The combined statistical analysis revealed that the interaction effect of nitrogen and phosphorus rates affected significantly ($p<0.05$) the plant height (Table 2.). The maximum plant height (98.3) obtained from applications of 92 kgha-1 N and 69 kgha-1 P2O5 and the lowest plant height (85.8cm) observed in plots receiving 46kgha-1N and 92 kgha-1 P2O5 (Table 2.). Such an increase in plant height in conjunction with an increase in N and P rate is attributed to the action of nitrogen and phosphorus synergetic effects, which increase vegetative growth when other growth factors are present. The application of nitrogen and phosphors contributed to an increase in plant height, with levels ranging from 46 kg ha-1 to 92 kg ha-1 for both fertilizer sources. The combination of 92 kg N ha-1 and 69 kg P ha-1 increased plant height by 12.48% beyond the baseline (46 kg N ha-1, 46 kg ha-1). These results are consistent with those of [33, 34, 35], who observed that plant height while growing linearly with increasing amounts of N and P fertilization and that increasing nitrogen fertilizer rates improved barley plant height. Similarly, this finding is consistent with the findings of [36], and [35], who conclude that the rate of fertilization increases the plant height also increased linearly. Additionally, [37] concluded that the role of macronutrients, primarily nitrogen and phosphorus, in chlorophyll formation, and nutrient movement within the plant boosts vegetative growth, increasing plant height. The plant heights recorded from all NP fertilized plots were considerably greater than the baseline treatments. This is because the use of NP fertilizers plays a significant influence on plant growth. This finding is consistent with [25], who found that by increasing nitrogen and phosphorus rates from 0, 0 to 69,30 kg ha^{-1} the plant height of barley also enhanced.

TABLE II. Effect Of Nitrogen And Phosphorus Fertilizer Rate On Plant Height (Cm) Of Food Barley Combined Over Years (2019 And 2020)

Nitrogen rate (kg ha^{-1})	**Phosphorus rate (kg ha^{-1})**		
	46	**69**	**92**
46	87.4^{cd}	86.0^{d}	85.8^{d}
69	88.3^{cd}	89.4^{bcd}	94.1^{abc}
92	89.9^{bcd}	98.347^{a}	96.2^{ab}
Sig.	**		
CV (%)	10.4		

2) The Interaction Effects of Nitrogen and Phosphorus Fertilizer Rate on Biomass Yield of Barley

The combined statistical analysis showed that the interaction effect of nitrogen and phosphorus rates affected aboveground biomass significantly ($p<0.05$) to the plant height (table 3.).The greatest biomass yield (5466.2kgha-1) was obtained from the application of 92Kgha-1 N and 92 Kgha-1 P2O5 which was significantly superior over other treatments (but not with 92-69). The last biomass yield (2969.5kgha-1) was recorded from the plots, which received 46, Kgha-1 N and 46 Kg ha-1 P2O5 (Table 3.). The maximum biomass yield recorded with the application of a higher rate of nitrogen and phosphorus was due to cumulative increase measured in different yield contributing characters (plant height and thousand seed weight). The maximum biomass yield might have been the result of overall improvement in the vegetative growth of the plant due to the application of a higher rate of nitrogen and phosphorus. This finding is in line with that of, [38], who observed that balanced nitrogen and phosphorus fertilization considerably boosted wheat plant height and overall biomass output, indicating the need for targeted nutrient management. Additionally, this result aligned with [39] who observed that total aboveground dry mass barely increased significantly, when nitrogen and phosphorus rates increased up to 69 kg ha-1 N with the combination of 30Kgha-1 P2O5. The finding shows that with the increment of nitrogen and phosphorus rates from 46kg ha-1 to 92 kg ha-1 the biomass yield increased by 54%. Similarly, furthermore, [40], they observed the rate of nitrogen and phosphorus increased the biomass and straw yield also increased.

The results of this study contrasted with those of [25], and [41], who reported that the interaction between nitrogen and phosphorus was not significant in barley biomass production.

TABLE III. THE INTERACTION EFFECT OF NITROGEN AND PHOSPHORUS FERTILIZER RATES ON BIOMASS (KG HA^{-1}) OF FOOD BARLEY COMBINED OVER YEARS

Nitrogen rate (kg ha-1)	Phosphorus rate (kg ha-1)		
	46	69	92
46	2969.5^{d}	2978.6^{d}	3696.5^{bcd}
69	3569.7^{bc}	4096.3^{bc}	4398.6^{b}
92)	4410.7^{b}	5420.3^{a}	5466.2^{a}
Sig.	**		
CV (%)	26.1		

3) The Interaction Effect of Nitrogen and Phosphorus Fertilizer Rate on Grain Yield of Barley

Grain yield is the outcome of numerous intricate physiological and morphological processes that take place throughout crop growth and development [42]. The combined analysis shows that differing nitrogen and phosphorus rates significantly affect barley grain yield ($p < 0.05$) (Table 4). Accordingly, the application of 92 kg ha^{-1} N and 92 kg ha^{-1} P2O5 obtained the maximum grain yield (2884.6 kg ha^{-1}) of barely, without statistically significant difference between 92 kg ha^{-1} N and 69 kg ha-1 P2O5 (table 4). The huge gains in grain yield observed with higher nitrogen and phosphorus rates demonstrate that delivering both nutrients at optimum levels can result in significant yield advantages The findings indicate that applying relatively high levels of nitrogen (N) and phosphorus (P), such as 92 kg N ha^{-1} and 69 kg P ha^{-1}, results in a 75.21% increase in barley production. Furthermore, the maximum yield response was obtained with 92 kg N ha^{-1} and 92 kg P ha^{-1}, resulting in a remarkable 84.85% higher yield than with the lower fertilizer treatment of 46 kg N ha^{-1} and 46 kg P $ha^{-1.}$ This shows that the levels of N and P increase the yield of barley also increases. This is consistent with [40], who found that applying 23–92 kg ha^{-1} of nitrogen ha^{-1} increased grain yield by 11–92% and that applying 10–40 kg ha-1 of phosphorus increased yields by 12–33% in comparison to the control group in various kinds of agro ecological zones. Additionally,[43] who found significant increases in barley yields with increased fertilizer application rate.

Furthermore, [44] observed that sorghum grain yield significantly increased with higher rates of nitrogen and phosphorus fertilizer. Due to the nutrient's synergistic effects, barley yield increases linearly as nitrogen and phosphorus fertilizers increase. This finding aligns with Otieno *et al*. [45], who found that while the application of inorganic phosphorus fertilizer increased the plants' efficient utilization of inorganic N fertilizer in grain yield, increasing N and P rates significantly increased the production of grain and total dry biomass.

On the other hand the application of 46 Kg ha^{-1} N with 46 Kg ha^{-1} P_2O_5 recorded in lowest grain yield (1560.1 kg ha^{-1})(Table 4) than others. As observed in Table 4 below when nitrogen and phosphorus rates increased from 46 kg ha^{-1}, 46 kg ha^{-1} to 92 kg ha^{-1},92 kg ha^{-1} except 69 kg ha^{-1} 92 kg ha^{-1} the grain yield of barely was increase with the mean of 11.7% (table 4.). This finding is in contrast with [46], who stated that the increase in the levels of nitrogen and phosphorus fertilizer from the control (0,0 N, P) to 46 kg N ha^{-1} along with 10 kg P ha^{-1}, increased the grain yield of tef but decreased with further increase in applied N and P fertilizer. As indicated in the result, grain yield increases when the Nitrogen and Phosphorus rates increase. These findings generally indicate that the yield of food barley increases with the use of fertilizer containing nitrogen and phosphate. The increased availability of the nutrient in the root zone throughout the growth stages may have allowed the plants to absorb adequate amounts of phosphorous and nitrogen throughout the main growth stages.) This result was in agreement with the findings of [47], who found that nitrogen and phosphorus fertilizers play significant roles in the production of wheat maize, and barley. According to [25], nitrogen and phosphorus fertilizers are crucial nutrients in limiting crop growth and development, which directly affects the productivity of barley.

TABLE IV. THE INTERACTION EFFECTS OF NITROGEN AND PHOSPHORUS ON GRAIN YIELD (KG HA-1) OF BARLEY COMBINED OVER YEAR AND LOCATION

N rate	P rate (Kg ha^{-1})		
	46	69	92
46	1560.1^{d}	1564.7^{d}	1720.1^{d}
69	1788.8^{cd}	2168.1^{bc}	2144.3^{bc}
92)	2241.0^{b}	2733.7^{a}	2884.6^{a}
Sig.	**		
CV (%)	27.5		

4) Partial Budget Analysis

The partial budget analysis was done to investigate the economic feasibility of the treatments with an acceptable marginal rate of return by assuming total variable cost (TVC), which was a cost incurred due to the application of inputs (fertilizers). In doing the partial budget analysis, the average grain yield was adjusted to 10% downwards to reflect, the difference between the experimental plot yield and the yield expected from farmers with the same treatment. The average open market price (Birr kg^{-1}) for barley and the prices of nitrogen and phosphorus-containing fertilizers were used for analysis. For a treatment to be considered a worthwhile option for farmers, MRR should be 100% [48], which is suggested to be realistic. Accordingly, when all the comparable treatments showed more than 100% MRR value in the experiment, the treatment having the highest NB value can be taken as economically profitable and recommendable to the users. The current result revealed that 46-46, 69-46, 46-92, 69-69, 69-92, and 92-69 kg ha^{-1} N and P_2O_5 respectively gave more than 100% MRR values than others which were more than the minimum acceptable value (Table 5). Therefore, from those treatments that had MRR values more than 100%, the treatment that received 92 kg N ha^{-1} and 69 kg P_2O_5 ha^{-1} (Table 5.) gave the highest net benefit (NB) which can be taken as economically acceptable and recommendable for the users.

TABLE V. THE PARTIAL BUDGET ANALYSIS OF MEAN GRAIN AND STRAW YIELDS OF BARLEY

Trt	AGY	GYP	ASY	SYP	TR	TVC	NB	D	MRR (%)
0,0	631.8	20	1614..3	2.5	16671.8	0	14171.8		0
46, 46	1404.09	20	3077.8	2.5	34763.2	5500	28553.2		2187.2
46, 69	1408.23	20	2576.6	2.5	34866.5	6190	28521.5	D	
69, 46	1548.09	20	3501.9	2.5	39278.9	6310	32968.9		753.1
46, 92	1609.92	20	2834.4	2.5	40230.2	6880	33350.2		317.7
69, 69	1951.29	20	3817.9	2.5	48242.5	7000	41242.5		6576.9
92, 46	1929.87	20	3926.2	2.5	48494.3	7120	41374.3		23.1
69, 92	2016.9	20	4210.9	2.5	50262.1	7690	42572.1		998.2
92, 69	2460.33	20	4387.1	2.5	61402.3	7810	53592.3		1597.1
92, 92	2596.14	20	4725.1	2.5	64221.8	8500	55721.8	D	

Where: - All costs are expressed in Ethiopian birr (ETB); AGY=Adjusted grain yield (kg ha-1), GYP=Grain yield price kg-1 (ETB), ASY=Adjusted straw yield (kg ha-1), SYP=Straw yield pricekg-1 (ETB), TR=Total revenue (ETB), TVC=Total variable cost, NB=Net benefit (ETB); DA = Dominance Analysis, MRR=Marginal rate of return

CONCLUSION AND RECOMMENDATION

The study demonstrated that varying nitrogen (N) and phosphorus (P) application rates significantly influenced barley growth and productivity, particularly affecting plant height, aboveground biomass, and grain yield. The findings indicated that grain yield and yield-related traits responded positively to N and P fertilization, with the highest productivity observed at an application rate of 92 kg N ha^{-1} paired with 92 kg P ha^{-1}.

However, the application of 92 kg N ha^{-1} combined with 69 kg P ha^{-1} delivered the attainable yields but also resulted in the greatest net economic benefit compared to lower fertilizer rates or alternative treatments. Statistical analysis confirmed that the interaction between nitrogen and phosphorus had a significant impact on most measured parameters, including grain yield. Furthermore, yield and yield-related traits exhibited a linear increase with rising fertilizer application rates, highlighting the crucial role of balanced nutrient management in optimizing barley productivity. Based on partial budget analysis and biological yield, the application of 92 kg N and 69 kg P_2O_5 ha^{-1} resulted in the highest net benefit of 53,592.3 ETB ha^{-1}, with a marginal rate of return (MRR) of 1,597.1% and a grain yield of 2,460.33 kg ha^{-1} is recommended in the study area.

For future research and agricultural practices, it is essential to explore site-specific nutrient recommendations by considering variations in soil fertility, climatic conditions, and barley varieties. Long-term studies should also assess the sustainability of high fertilizer applications, their residual effects on soil health, and potential environmental impacts. Additionally, integrating organic amendments or precision nutrient management strategies could further enhance nutrient use efficiency while maintaining soil fertility. Farmers should consider these insights to refine fertilization practices and ensure sustainable and economically viable barley production in the study area and similar agro ecological zones.

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