



Response of food barley (*Hordeum vulgare* L.) grain yield to the application of integrated farmyard manure and nitrogen fertilizer rates at Gesha Woreda, Kaffa Zone, Southwest Ethiopia

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Abstract

Barley is produced mainly for human consumption and is one of the most important staple food crops. Lack of integrated nutrient management is one of the limiting factors for barley production. This experiment was conducted at Daniti kebele in Gesha Woreda of Kaffa zone during the 2017 main cropping season to determine the effect of integrated application of Farmyard Manure with N fertilizers on growth, yield components, and yield of food barley and its economic feasibility. Fifteen treatments comprising five levels of N (0, 23, 46, 69, and 92 Kg ha⁻¹) combined with three levels of FYM (0, 0.5, and 1 ton ha⁻¹) were used in a randomized complete block design (RCBD) in factorial arrangement with three replications. Days to heading and physiological maturity were not significantly affected by the integrated application of farmyard manure and nitrogen fertilizer. The interaction effect of farmyard manure with nitrogen fertilizer showed a significant increase in the number of the productive tiller, seed/spike, and thousand-grain weight with the increase in nitrogen levels under all treatments over the control. It was observed that the highest grain/spike (33.67) thousand-grain weight (43.00 g) and productive tiller (177.00 m⁻²) and grain yield of (3233.00 Kg/ha) was obtained from the combined application of 1 Kg/ha FYM with 92 Kg/ha N fertilizer. The application of this treatment has resulted in the highest net return of Birr 23188.5 ha⁻¹.

Keywords: barley, FYM, n rate, economic feasibility, the net return, productivity

Introduction

Barley (*Hordeum vulgare* L.) is one of the most important cereal crops in the world. It is widely grown fourth cereal and among the top ten crop plants in the world. Barley was mainly cultivated and used for human food supply in the last century but nowadays it is significantly grown as animal feed, malt products, and human food respectively. In addition, barley is very well known as a model crop for plant breeding methodology, genetics, Cytogenetics, pathology, virology, and biotechnology studies [1].

Barley is an annual monocotyledonous herb belonging to the tribe Triticeae and the family *Poaceae*. It is evolutionarily closely related to two other small-grain cereal species, wheat, and rye, although the genus *Hordeum* is known to have diverged c. 12 million years ago [2]. The first signs of the pre-agricultural gathering of wild barley are found in the region of Fertile Crescent in south-western Asia 22 000 years ago, and domestication of barley has occurred independently also in Central Asia. The early selection by environmental factors and man and continued with modern breeding has resulted in hundreds of landraces and cultivars, which are grown from semi-arid subtropical to temperate climates, from equatorial to nearly circumpolar latitudes, and from sea-level to high altitudes.

Barley is a fast-growing, cool-season, annual grain crop, that could be used as forage as well as, cover crop to improve soil fertility [3]. It ranks fifth among crops in grain production in the world after maize, wheat, rice, and soybean. On the other hand, Ethiopia is the second-largest barley producer in Africa, next to Morocco, accounting for about 25 percent of the total barley production in the continent [4]. Ethiopia is also recognized as a center of

diversity, as its barley germplasms have global significance because of improved Traits, including disease resistance.

Its grain is used for the preparation of different foodstuffs, such as Injera, Kolo, and local alcoholic drinks like Tela. The straw is used as animal feed, especially during the dry season. In most developing countries, it is often considered as a poor man's crop, and the only crop able to give some yield in environments unsuitable to other crops at higher elevations. It is a cool-season crop, the most dependable, early maturing cereal grain with relatively high-yield potential including in marginal areas where other cereal crops are not adapted [5]. It is the world's fourth important cereal crop after wheat, maize, and rice in production.

The national area coverage of barley was estimated to be 1,047,000 ha with the productivity of 1.63 tons ha⁻¹ while the regional area coverage and average productivity were estimated to be 328,000 ha 1.3 tons ha⁻¹, 1,019,477.93 ha with the productivity of 18.72 qt/ha⁻¹ and 174489.3 ha with the productivity of 18.75 qt ha⁻¹ 29078.18 ha with the productivity of 9.96qt/ ha⁻¹ respectively [6]. Similarly, the total area coverage for the Kafa zone was 12459.07 ha with the productivity of 1.4 tons ha⁻¹, while Gesha woreda was 2,649 ha with the productivity of 1.3 tons ha⁻¹ [7].

Among other factors contributing to the low productivity of the crop, the low yielding ability of farmers' cultivars and soil acidity problems are the major bottlenecks. Unlike in industrialized countries where barley is mainly used for animal feed and malting, it is one of the staple food crops in Ethiopia, accounting for 6 percent of the per capita calorie consumption. Barley is one of the commonly grown food security crops in high-altitude areas of CASCAPE intervention areas. The total number of households

cultivating barley at the national level was estimated to be 4,148,000^[6].

Although barley is not among the top cereal crops in Ethiopia, its importance is rapidly growing in terms of production, the potential for poverty reduction, as well as for the country's coffers and the current balance of payment situation. Between 2003/04 and 2013/14, the number of smallholders growing barley increased from 3.5 million to 4.5 million; yields increased from 1.17 metric tons/ha to 1.87 metric tons/ha; and total production grew from 1.0 million tons in 2005 to about 1.9 million tons in 2014^[8, 9]. However, Ethiopia produces mostly food barley, with its share estimated to be 90 %^[10], and remains significantly deficient in malt barley.

The continuous use of fertilizers containing only a few essential elements like those being used in Ethiopia, Urea and DAP, aggravate the depletion of other essential nutrients in the soil, acidify soil, and have an adverse effect on the environment and generally, they are unsustainable. Reduced fertilizer use efficiency or recovery efficiency by crops is the most important problem associated with the use of chemical fertilizers. In a developed country like the USA, only 50% of the applied fertilizers are used by crops in the season. The situation is very severe in the tropics where only between 25 – 40% of the applied fertilizers are utilized by crops in the season. In the case of N-fertilizers, leaching and denitrification are the main causes that reduce recovery efficiency. However, we cannot avoid the use of chemical fertilizers for crop production for the plenty of beneficial effects of these inputs. Thus, there is a need to mitigate the adverse effects of fertilizers and maximize the fertilizer use efficiency of crops.

Therefore, the integrated application of organic and inorganic nutrients sources to soil is very crucial to counteract the negative aspects of chemical fertilizers. Organic nutrients that could be applied as biomass transfer, green manure, FYM, compost, etc serve as source nutrients for the growth and productivity of plants. In addition, they help to increase the organic matter content of the soil which in turn improves the physicochemical characteristics of the soil. Besides, they increase the fertilizer use efficiency of crops. TSBF-CIAT^[11] states that "both organic and inorganic inputs are necessary to enhance crop yields without deteriorating the soil resource base emphasizing the integrated application of both inputs for either of them are hardly available in sufficient quantities to small scale farmers and the multiple benefits of combined applications of organic and inorganic inputs". Therefore, this research was initiated to determine the effect of integrated application of farmyard manure with N fertilizers management on growth, yield components, and yield of food barley and also to determine the economically feasible methods of their application.

Materials and Methods

Description of the Study Area

The experiment was conducted in Gesha districts namely, at Daniti Kebele, Southwestern Ethiopia, during the 2017 main cropping season. The study site was located at 9° 05' N, 42° 33' E, 2350 m.a.s.l. The rainfall pattern of this area is characterized by bimodal distribution with a small rainy season *belg* (March-June) and a main rainy season *Meher* (July-November)^[12]. The annual total rainfall was 1467 mm with a respective mean annual temperature of 19.7°C. The

soil physicochemical analysis of the study areas revealed that the soils of the experimental field were clay loam in texture. The results also indicated that the soil of the study site was slightly acidic with a pH of 5.72. The soils have low organic carbon (1.20) and total N (0.09%). Available P is low (7.12 ppm) (Table 1).

Table 1: Physico-chemical characteristics of the soil of the experimental sites

| Soil parameter | Laboratory Result |
|----------------------|-------------------|
| Textural Composition | |
| Sand | 18.9 |
| Silt | 25.90 |
| Clay | 55.20 |
| Textural class | Clay loam |
| Ph | 5.72 |
| Organic carbon | 1.20 |
| Total N (%) | 0.09 |
| Available P (ppm) | 7.12 |

Treatments and Experimental Design

The treatment consisted of five levels of N (0, 23, 46, 69, and 92 Kg ha⁻¹) and three levels of FYM (0, 0.5, 1 tone ha⁻¹) fertilizers arranged in a factorial combination. The treatments were laid out in a randomized complete block design with three replications. The spacing between blocks was 1 m and between was 0.5 m. Each plot had a size of 1 m × 2 m and consists of ten rows. The gross plot size of the study area was 37.5 m x 6 m (225 m²).

Experimental Procedures

The land was ploughed three times through local farmers' practice using pair of oxen until the land become fine to sow the crop. Before planting, surface (0 - 30 cm) soil samples, from five spots across the experimental fields, were collected in a zigzag pattern, composited, and analyzed for soil Physico-chemical properties and the results are depicted in Table 1.

Soil texture was determined using Bouyoucos hydrometer method^[13]; soil pH at 1:2.5 soils to water ratio by pH digital meter^[14]; (Page, 1982); soil organic carbon by wet digestion method^[15], and total N by Kjeldahl method^[16]. Available phosphorus was determined by the Olsen method^[17]; the cation exchange capacity (CEC) using 1M-neutral ammonium acetate^[16].

A food barley variety called 'HB-1307' was used as a test crop. The variety was released in 2006 by Holetta Agricultural Research Center, Ethiopia, for its high yield and promising agronomic performances. The variety matures in 97 days and has an average height of 100 cm^[18]. The barley seeds were sown in rows spaced 20 cm apart by hand drilling at the seed rate of 120 Kg ha⁻¹. The source of N was urea (46% N). FYM was applied one week before sowing the crop. All P and half of the N fertilizer sources for the respective inorganic N and P₂O₅ treatments were applied at planting. The remaining half of the inorganic N fertilizer was applied at the tillering stage by side drilling. Weeds were removed manually three times *i.e.* at early tillering, maximum tillering, and booting stages. No insecticide or fungicide was applied as there was no serious incidence of insect pests or diseases. Harvesting was done manually using hand sickles. The harvested product was sun-dried to a constant weight and threshing and winnowing were done subsequently.

Data Collection

Days to heading were recorded when the ears or panicles were fully visible on 50% of the plants from each plot by visual observation and days to physiological maturity were recorded when 90% of the plants reached maturity in each plot, *i.e.* when grains were difficult to break with the thumbnail. The number of productive tillers m^{-2} was counted from two random 1m X 1m areas (5 rows of 1m length) within the net plot area at physiological maturity and the average was recorded as the number of productive tiller m^{-2} . Plant height (cm) was determined from measurements of 10 randomly pre-tagged mother shoots from ground level to the top of the spike excluding the awns at physiological maturity. Likewise, the spikes in the pre-tagged 10 plants were collected and the total grains were counted to record the number of grains per spike. A thousand grains were counted in each plot using an electronic seed counter from a bulk of threshed grain and their weight was measured using a sensitive balance at harvest and the weight was adjusted to 12.5% moisture content.

The total aboveground dry biomass yield including straw and spikes of plants in a net plot area was measured using spring balance after sun drying to a constant weight. Then threshed and the grain yield per net plot was weighed and adjusted to 12.5% moisture content. Harvest index was calculated as the ratio of grain yield to total aboveground dry biomass and expressed in percentage.

Statistical Data Analysis

The agronomic data were subjected to analysis of variance (GLM procedure) using SAS software program version 9.2 [19]. Homogeneity of variances was evaluated using the F-test as described by [20] and since the F-test has shown

heterogeneity of the variances of the two locations for most of the agronomic parameters, a separate analysis was used for the two locations. The Fisher's protected least significant difference (LSD) test at 0.05 probability level was employed to separate treatment means where significant treatment differences existed.

Partial Budget Analysis

The partial budget analysis as described by [21] was done to determine the economic feasibility of the fertilizer application. It was calculated by taking into account the additional input cost (variable cost) involved and the gross returns obtained from different treatments. The variable cost also included the labor cost involved for harvesting, threshing, and winnowing of the product as this varied according to the yield obtained from a particular treatment. For determining gross returns, the prevailing local market price at the harvest of barley (8.50 Ethiopian Birr Kg^{-1}) was used for computation. The net returns were calculated by subtracting the cost of treatment from its gross returns, *i.e.* $RNR = GR - VC$ where, RNR = Relative net returns, GR = Gross returns, and VC = Variable cost.

Results and Discussion

Phenological and growth parameters

Observation on the phenological parameters of this study showed that the application of different rates of farmyard manures and N fertilizer had no significant effect on days to 50% heading and physiological maturity at the study site (Table 2). However, it was observed that the application of both organic fertilizers, irrespective of doses hastened days to heading and maturity as compared to no fertilizer application.

Table 2: The interaction effect of FYM and Nitrogen on the phenological and growth parameters of Barley at Danity in 2017 cropping season

| FYM rates ($Kg\ ha^{-1}$) | Nitrogen rates ($Kg\ ha^{-1}$) | Days to 50% Emergence | Days to 90% Maturity | Plant height (cm) | Number of effective tillers/ m^2 |
|-----------------------------|----------------------------------|-----------------------|----------------------|-----------------------|------------------------------------|
| 0 | 0 | 51.0 | 98.3 | 96.67 ^h | 81.00 ^k |
| 0 | 23 | 51.1 | 100.2 | 98.00 ^{gh} | 86.00 ^k |
| 0 | 46 | 52.7 | 102.1 | 100.33 ^{def} | 107.00 ^j |
| 0 | 69 | 52.8 | 104.7 | 101.33 ^{b-e} | 107.00 ^{ij} |
| 0 | 92 | 52.8 | 107.7 | 101.33 ^{fg} | 109.00 ^{ij} |
| 0.5 | 0 | 53.7 | 98.4 | 98.33 ^{gh} | 120.00 ^{sh} |
| 0.5 | 23 | 54.1 | 99.6 | 100.33 ^{def} | 140.00 ^e |
| 0.5 | 46 | 54.2 | 99.9 | 100.66 ^{cde} | 142.00 ^{de} |
| 0.5 | 69 | 54.3 | 100.6 | 100.00 ^{efg} | 145.00 ^{hi} |
| 0.5 | 92 | 54.6 | 100.8 | 100.00 ^{efg} | 150.00 ^f |
| 1 | 0 | 53.6 | 99.5 | 100.33 ^{def} | 143.00 ^{de} |
| 1 | 23 | 54.2 | 100.5 | 100.66 ^{cde} | 176.00 ^b |
| 1 | 46 | 55.5 | 100.2 | 102.00 ^{b-e} | 174.00 ^{ef} |
| 1 | 69 | 55.9 | 100.3 | 102.33 ^{a-d} | 153.00 ^{cd} |
| 1 | 92 | 55.9 | 101.5 | 102.67 ^{abc} | 177.00 ^a |
| LSD | | NS | NS | 2.0 | 5.3 |
| CV | | 3.7 | 9.8 | 7.8 | 13.5 |

CV=coefficient of variation, LSD= least significant difference at alpha 5% level, Numerals in each column superscripted by the same letter(s) are not statistically different

On the other hand, it was observed that plant height was significantly ($P < 0.05$) affected by the interaction effect of different rates of Farmyard manure and N fertilizers at the study site. The interaction effect of Farmyard manure and N fertilizers revealed that the maximum plant height of 102.67 cm was recorded from the combined application of 1 $Kg\ FYM\ ha^{-1}$ and 92 $Kg\ N\ ha^{-1}$ at the study site. The shortest plant height of 96.67 cm was observed from the control (Table 2). Generally, it was observed that plots that received FYM and N fertilizer had increased plant height

significantly as compared to the control plot. This increment in plant height due to the increased rate of FYM and N fertilization might be attributed due to an increase in internode length resulted from an increase in cell elongation. In line with this result, [22] reported that the plant height of barley increased linearly with the increasing level of N fertilizer from 0 to 90 $Kg\ ha^{-1}$.

Commonly adequate integrated supply of FYM with N is associated with high photosynthetic activity and vigorous vegetative growth thereby increasing plant height.

Successful vegetative growth of any crop is a prerequisite for better crop production and productivity. This can be greatly influenced by the interaction of cultivar, climate, seedbed preparation, and rate of fertilizers used. In this regard, [23] reported that the biomass-related trait of plant height of barley was increased by the application of an increased rate of N (90 Kg ha⁻¹) fertilizer.

Yield components

The analysis of variance showed that the interaction of FYM and with N fertilizer had a highly significant ($P < 0.01$) effect on the number of productive tillers at the study site (Table 2). Accordingly, the highest number of productive tillers (177.00 m⁻²) was obtained when the highest (92 Kg ha⁻¹) level of nitrogen was applied in combination with the 1 Kg FYM ha⁻¹ level, while the lowest number of productive tillers (81.00 m⁻²) was obtained from unfertilized plots (Table 1). It was observed that the number of productive tillers m⁻² increased with increasing rate of both applied FYM and N fertilizer rates. The application of the highest (92 Kg ha⁻¹) with 1 Kg FYM ha⁻¹ has the advantage of 118.51% over the control. The increase in the number of productive tillers m⁻² as the fertilizer levels increased could be due to enhancement of plant growth as a result of FYM and N fertilizers. This indicates that both organic and inorganic fertilizer was one of the limiting factors for the production of a high number of productive tillers of barley in these areas. Similar results were reported by [24] which implies that the interaction of increased rate of N (92 Kg ha⁻¹) fertilizer increases the number of productive tillers (202 m⁻²) of barley. Similarly, the results of [25] indicated that the increase in tillering with an increase in the rate of FYM combined with inorganic NP might be due to the immediate availability of nutrients from the inorganic sources and the

steady and increased availability of nutrients from organic sources (FYM) which resulted in increased uptake of nutrients by the plants.

Similarly, [26] reported that the application of N at the rate of 160 Kg ha⁻¹ produced a higher number of productive tillers per unit area as compared to the nil N (no N) treatment in wheat. This is attributed to proper vegetative and reproductive growth, which ultimately increases the number of productive tillers m⁻². Also in agreement with these results, [27] reported a 29% increase in the number of productive/effective tillers of barley with increased application of N fertilizer rates from 0 to 72 Kg ha⁻¹. The application of FYM and N fertilizers, on the other hand, showed a significant ($P < 0.05$) interaction effect on the number of grain spike⁻¹ of barley at the study site. The application of 1 Kg FYM ha⁻¹ in combination with 92 Kg N ha⁻¹ resulted in the highest (34.33) number of grains spike⁻¹. On the other hand, the lowest number of grains spike⁻¹ (24.00) was obtained from the control (Table 3).

From this experiment, it was observed that the number of grains spike⁻¹ of barley increased as the rate of both FYM and N fertilizers increased. The possible reason could be due to the proper availability of applied FYM and N, which helped the plants to utilize the nutrients hence more grains spike⁻¹ were obtained or might be due to increased photosynthesis translocation of assimilates to the spike. This result is consistent with the investigations of [28] where they reported the highest number of fertile grains spikes⁻¹ per unit area with increasing rates of N fertilizer application of wheat. Similarly, [29] reported that the N fertilized treatments doubled the grain yield of the wheat crop as compared with control plots due to significantly more and heavier grains spikes⁻¹ produced.

Table 3: The interaction effect of FYM and Nitrogen on the yield and yield components of Barley at Danity in 2017 cropping season

| FYM rates (Kg ha ⁻¹) | Nitrogen rates (Kg ha ⁻¹) | Thousand-grain weight (g) | Grains spike ⁻¹ | Grain Yield (Kg ha ⁻¹) | Above-ground dry matter yield | Harvest index |
|----------------------------------|---------------------------------------|---------------------------|----------------------------|------------------------------------|-------------------------------|---------------------|
| 0 | 0 | 30.00 ^e | 24.00 ^c | 478.00 ⁱ | 4151.7 ⁱ | 35.61 ^{ab} |
| 0 | 23 | 36.00 ^d | 27.00 ^c | 1044.67 ^{ef} | 4420.3 ^{efg} | 37.72 ^a |
| 0 | 46 | 36.00 ^d | 28.00 ^{bc} | 1049.67 ^{ef} | 4517.0 ^{ef} | 37.15 ^a |
| 0 | 69 | 37.020 ^d | 28.00 ^{bc} | 1269.67 ^h | 4860.0 ^h | 33.68 ^{bs} |
| 0 | 92 | 38.01 ^d | 27.00 ^c | 1437.67 ^g | 4982.0 ^g | 28.51 ^e |
| 0.5 | 0 | 38.00 ^d | 28.00 ^{bc} | 1911.67 ^e | 5007.7 ^e | 37.66 ^a |
| 0.5 | 23 | 40.00 ^{bc} | 31.00 ^{ab} | 2404.00 ^c | 5250.3 ^{bc} | 30.83 ^{de} |
| 0.5 | 46 | 41.00 ^{ab} | 31.00 ^a | 1713.67 ^f | 6006.3 ^d | 30.11 ^{de} |
| 0.5 | 69 | 40.67 ^{cd} | 31.00 ^{ab} | 2137.67 ^d | 6061.3 ^d | 37.34 ^a |
| 0.5 | 92 | 41.00 ^{ab} | 31.00 ^{ab} | 2232.33 ^d | 6356.7 ^d | 37.09 ^a |
| 1 | 0 | 40.00 ^{ab} | 32.00 ^a | 2942.67 ^b | 8033.7 ^c | 37.71 ^a |
| 1 | 23 | 40.00 ^{ab} | 33.00 ^a | 3055.67 ^{ef} | 8063.3 ^{fg} | 37.16 ^c |
| 1 | 46 | 42.00 ^{ab} | 31.00 ^{ab} | 3061.33 ^{ab} | 8521.7 ^b | 37.53 ^a |
| 1 | 69 | 42.00 ^{ab} | 32.00 ^a | 3073.33 ^{ab} | 8681.0 ^b | 37.57 ^a |
| 1 | 92 | 43.00 ^a | 33.67 ^a | 3233.00 ^a | 8845.0 ^a | 37.95 ^a |
| LSD | | 2.45 | 3.73 | 168.23 | 348.37 | 1.70 |
| CV | | 13.64 | 12.8 | 17.8 | 13.5 | 16.33 |

CV=coefficient of variation, LSD= least significant difference at alpha 5% level, Numerals in each column superscripted by the same letter(s) are not statistically different

There was a highly significant ($P < 0.01$) interaction effect of FYM and N on thousand-grain weights at the study site. The application of 1 Kg FYM ha⁻¹ in combination with 1 Kg N ha⁻¹ resulted in the highest (43.33 g) thousand-grain weight (Table 3). On the other hand, the lowest thousand-grain weight (30.00 g) was obtained from the control. This could be due to more and vigorous leaves under high FYM and N-

supplied treatments that improved the supply of assimilating to be stored in the grains than in the control; hence, the weight of thousand grains increased over the control. Similarly, [25] reported that the increment in thousand-grain weight in response to increased rates of both organic and inorganic fertilizers might be attributed to the availability of optimum nitrogen, phosphorus, and other nutrients in FYM

that might lead to high mean thousand-grain weight through facilitating leaf growth and photosynthetic activities, thereby increasing partitioning of assimilating to the storage organ. Contrary to the current result, [30] reported decreased thousand-grain weight of bread wheat due to increased rates of N application that resulted in an increased number of grains m^{-2} and stated that this implies the grain number, rather than size, increases as the rates of N fertilizer increase and results in low thousand-grain weight.

Grain yield, Above-ground dry biomass yield, and Harvest index

In the current study, the application of FYM and N fertilizers revealed highly significant ($P < 0.001$) interaction effects on the yield of barley at the study site. Accordingly, the highest grain yield (3233.00 $Kg\ ha^{-1}$) was obtained from the application of the highest rate (1 $Kg\ ha^{-1}$) FYM rate combined with 92 $Kg\ N\ ha^{-1}$. The lowest grain yield (478.00 $Kg\ ha^{-1}$) was obtained from the control. The significant increase of grain yield with increased rates of FYM and N might have resulted from the increase in the number of grains spike $^{-1}$, productive tillers m^{-2} , and thousand-grain weights. On the other hand, the lowest yield obtained from control plots could be due to the unavailability of balanced nutrients in the soil due to many physiochemical reactions that hindered mass growth of crown roots to harvest plant nutrients and at the end of the growing season simultaneously might affect their positive (synergetic) effect on yield and yield components of barley.

Generally, the result of this experiment showed that an increase in the rates of FYM fertilizer from 0 to 1 $Kg\ ha^{-1}$ and N from 0 to 92 $Kg\ ha^{-1}$ showed an increase in grain yield at the study site. This result was confirmed with the finding of [31] who reported that the grain yield of triticale increased in line with the N rate increase from 0 to 120 $Kg\ ha^{-1}$. The decreased yield at the lower rate of N fertilizer could be due to the rapid nitrification at a low rate of N fertilizer subjected to leaching or de-nitrification soon after application.

On the other hand, this finding strengthens the finding of [32] who reported that the overall effect of N application is to increase the resource capture of the plant as well as to increase the sink capacity, which is determined by the number and size of grains and their rates of growth that increases grain yield of barley. Nitrogen is a key factor in achieving optimum cereal grain yield. It increases chlorophyll contents, leaf size, affects crop performance due to its effect on photosynthetic ability and delays senescence; stimulates tillering, plant height, and grain formation [33].

Moreover, nitrogen is important in determining the final grain yield of cereals during the rapid phase of crop development because it is required for high rates of spikelet initiation, improvement of spikelet fertility, increasing grains per fertile spikelet, and biomass formation. Similarly, [34] reported that among the most significant functions of plants on which phosphorus has an important effect are reproduction, photosynthesis, N-fixation, crop maturation (flowering and fruiting, including seed formation), root development (particularly of the lateral and fibrous rootlets), the strength of straw in cereals crops; thus helping to prevent lodging and finally, quality and quantity of yield products improvement. In line with the result of this experiment, [35] reported that increased phosphorus rate promoted the development of the root system, seed

formation, hastened to ripen, and finally increases yield per unit area of barley.

Such a judicious use and management of nutrients is claimed to improve and maintain soil fertility while sustaining economically viable and environmentally friendly agriculture that would meet the requirements of the future [36]. Being the essential constituent of protein, N is involved in all the major processes of development, and a good supply of N to the plant stimulated root growth and development as well as uptake of other nutrients, which, in turn, increased the grain yield by increasing the magnitude of yield attributes on rice [37].

The aboveground dry biomass of barley showed a significant ($P < 0.05$) difference among treatments by the interaction effect of FYM and N fertilizers at the study site. The highest total biomass yield (8845.0 $Kg\ ha^{-1}$) was obtained from the application of the highest (1 $Kg\ N\ ha^{-1}$) FYM rate combined with 92 $Kg\ N\ ha^{-1}$. In line with this result, [32] indicated that the increased N fertilizer rate has increased the dry matter and yield of barley due to its positive effect on yield components and growth parameters. The harvest index indicates the efficiency of the crop to the dry matter biomass (assimilation) translocation or mobilization to the seed. The harvest index of barley in this experiment was significantly ($P < 0.05$) affected by the interaction of FYM and N at the study site. The highest harvest index (37.95%) was recorded from the combined application of 1 $Kg\ FYM\ ha^{-1}$ with 92 $Kg\ N\ ha^{-1}$. This indicates that the application of different rates of FYM and N fertilizers affected the translocations and assimilation processes of barley crops during the grain-filling period. This lowest harvest index of the crop could be due to the lower number of productive tillers m^{-2} , the number of grains spike $^{-1}$, and thousand-grain weights that might have contributed to low yield that narrowed the overall ratio between the grain yield and aboveground dry biomass.

Therefore, from this harvest index as a measure of increasing crop yield potential, the efficiency of the partitioning of the net accumulated plant nutrients from the vegetative part to the grain was numerically increased due to the application of FYM fertilizer and slightly increased due to the application of N fertilizer at the study site. In line with this, the optimum amount of rainfall in the experimental sites during the growth period (especially at the grain-filling period) might have enhanced absorption and assimilation of nutrients to the grain (sink). Similarly, [38] reported that post-anthesis N uptake can be limited by lack of moisture. This is because, under field conditions, grain filling is usually associated with hot, dry weather in which available N diminishes.

Economic Evaluation

In this study, the combined application of 1 $Kg\ FYM\ ha^{-1}$ with 92 $Kg\ N\ ha^{-1}$ had the highest total variable cost 4292 of Birr ha^{-1} at the study site. This was followed by the application of the combined application of 1 $Kg\ FYM\ ha^{-1}$ with 69 $Kg\ N\ ha^{-1}$ that resulted in the cost of 4197 of Birr ha^{-1} . In these treatments, the cost of the increased rate of FYM and N fertilizer contributed to higher input costs while, in addition, the higher yield in these treatments increased proportionally as the total variable cost for the production of the crop. In contrast, the highest gross return 27480.5 Birr ha^{-1} was recorded by the combined application of 1 $Kg\ FYM\ ha^{-1}$ with 92 $Kg\ N\ ha^{-1}$. The higher gross

return in these treatments over the other treatments was due to the higher yield.

Table 4: Partial budget analysis to estimate net benefit as influenced by the interaction of FYM and N fertilizers at Daniti, Southwestern Ethiopia

| FYM rate (Kg ha ⁻¹) | P ₂ O ₅ rate (Kg ha ⁻¹) | Grain Yield (Kg ha ⁻¹) | Gross return (ETB ha ⁻¹) | Total cost (ETB ha ⁻¹) | Net return (ETB ha ⁻¹) |
|---------------------------------|-----------------------------------------------------------|------------------------------------|--------------------------------------|------------------------------------|------------------------------------|
| 0 | 0 | 478.00 | 4063.3 | 2875 | 1686.7 |
| | 23 | 1044.67 | 8879.695 | 2898 | 5981.695 |
| | 46 | 1049.67 | 8922.195 | 2932 | 5990.195 |
| | 69 | 1269.67 | 10792.2 | 2950 | 7842.2 |
| | 92 | 1437.67 | 12220.2 | 3260 | 8960.2 |
| 0.5 | 0 | 1911.67 | 16249.2 | 3425 | 12824.2 |
| | 23 | 2404.00 | 20434 | 3640 | 16794 |
| | 46 | 1713.67 | 14566.2 | 3842 | 10724.2 |
| | 69 | 2137.67 | 18170.2 | 3370 | 14800.2 |
| | 92 | 2232.33 | 18974.81 | 3523 | 15451.81 |
| 1 | 0 | 2942.67 | 25012.7 | 3667 | 21345.7 |
| | 23 | 3055.67 | 25973.2 | 3811 | 22162.2 |
| | 46 | 3061.33 | 26021.31 | 4122 | 21899.31 |
| | 69 | 3073.33 | 26123.31 | 4197 | 21926.31 |
| | 92 | 3233.00 | 27480.5 | 4292 | 23188.5 |

ETB= Ethiopian Birr and the local market price of food barley at harvesting time at Daniti was 850.00 birrs/100Kg and gross return was the product of market price and grain yield.

Based on variable input cost, the data (Table 4) further depicted the highest net return of Birr 23188.5 ha⁻¹ was obtained with the combined application of 1 Kg FYM ha⁻¹ with 92 Kg N ha⁻¹. The lowest net return Birr 1686.7 ha⁻¹ was from the control treatment. Generally, it was observed that the net return increased as the rate of both FYM and N fertilizer rates increased from control to the highest levels. This might be due to the increased fertilizer level enhanced the yield to such an extent that benefited the net return. As a result, the farmers may be interested in the net benefit rather than the benefit per birr spent. Therefore, the combined use of 1 Kg FYM ha⁻¹ with 92 Kg N ha⁻¹ can be recommended for these study areas and similar agro-ecologies.

Summary and Conclusion

Integrated soil fertility management has great promise for fighting hangers, increasing income, and improving soil fertility. While productions are constrained by several biotic and abiotic factors, which lowers the yield of barley under the attainable yield from which poor soil fertility is the serious problem in the barley production area of SNNP in Ethiopia in general and at Daniti in particular. The farmers are less aware of the integrated nutrient management in their fields even they cannot properly utilize the natural organic fertilizers like FYM; when the problem of soil fertility reaches peak period of agricultural activities due to shortage of continuous supply of organic fertilizer. Therefore this study was conducted at Daniti kebele in Gesha Woreda Southwest Ethiopia, during the main cropping season of 2017 to investigating the effect of integrated application of FYM with N fertilizer on yield and yield components of barley. The experiment comprise of 15 treatments: FYM (0, 0.5 and 1.0 tone ha⁻¹) combined with N (0, 23, 46, 69 and 92 Kg ha⁻¹). The treatments were arranged in randomized complete block design in a factorial arrangement with three replications. The barley variety 'HB-1307' was used as a testing crop for this study.

The results of this study indicated that the phenological parameters of this study showed that the application of different rates of farmyard manures and N fertilizer had no significant effect on days to 50% heading and physiological maturity at the study site. However, it was observed that the

application of both organic fertilizers, irrespective of doses hastened days to heading and maturity as compared to no fertilizer application. On the other hand, it was observed that plant height was significantly (P<0.05) affected by the interaction effect of different rates of Farmyard manure and N fertilizers at the study site. The interaction effect of Farmyard manure and N fertilizers revealed that the maximum plant height of 102.67 cm was recorded from the combined application of 1 Kg FYM ha⁻¹ and 92 Kg N ha⁻¹ at the study site. The shortest plant height of 96.67 cm was observed from the control. Generally, it was observed that plots that received FYM and N fertilizer had increased plant height significantly as compared to the control plot.

On the other hand, the analysis of variance showed that the interaction of FYM and with N fertilizer had a highly significant (P<0.01) effect on the number of productive tillers at the study site. Accordingly, the highest number of productive tillers (177.00 m⁻²) was obtained when the highest (92 Kg ha⁻¹) level of nitrogen was applied in combination with the 1 Kg FYM ha⁻¹ level, while the lowest number of productive tillers (81.00 m⁻²) was obtained from unfertilized plots. It was observed that the number of productive tillers m⁻² increased with increasing rate of both applied FYM and N fertilizer rates. The application of the highest (92 Kg N ha⁻¹) with 1 Kg FYM ha⁻¹ has the advantage of 118.51% over the control. The increase in the number of productive tillers m⁻² as the fertilizer levels increased could be due to enhancement of plant growth as a result of FYM and N fertilizers. This indicates that both organic and inorganic fertilizer was one of the limiting factors for the production of the high number of productive tillers of barley in these areas.

On the other hand, the application of FYM and N fertilizers had shown a significant (P≤0.05) interaction effect on the number of grain spike⁻¹ of barley at the study site. The application of 1 Kg FYM ha⁻¹ in combination with 92 Kg N ha⁻¹ has resulted in the highest (34.33) number of grains spike⁻¹. On the other hand, the lowest number of grains spike⁻¹ (24.00) was obtained from the control. From this experiment, it was observed that the number of grains spike⁻¹ of barley increased as the rate of both FYM and N fertilizers increased. There was also a highly significant

($P < 0.01$) interaction effect of FYM and N on thousand-grain weights at the study site. The application of 1 Kg FYM ha⁻¹ in combination with 1 Kg N ha⁻¹ resulted in the highest (43.33 g) thousand-grain weight. On the other hand, the lowest thousand-grain weight (30.00 g) was obtained from the control. This could be due to more and vigorous leaves under high FYM and N-supplied treatments that improved the supply of assimilating to be stored in the grains than in the control; hence, the weight of thousand grains increased over the control.

In the current study, the application of FYM and N fertilizers revealed highly significant ($p < 0.001$) interaction effects on the yield of barley at the study site. Accordingly, the highest grain yield (3233.00 Kg ha⁻¹) was obtained from the application of the highest rate (1 Kg ha⁻¹) FYM rate combined with 92 Kg N ha⁻¹. The lowest grain yield (478.00 Kg ha⁻¹) was obtained from the control. The significant increase of grain yield with increased rates of FYM and N might have resulted from the increase in the number of grains spike⁻¹, productive tillers m⁻² and thousand-grain weights. On the other hand, the lowest yield obtained from control plots could be due to the unavailability of balanced nutrients in the soil due to many physiochemical reactions that hindered mass growth of crown roots to harvest plant nutrients and at the end of the growing season simultaneously might affect their positive (synergetic) effect on yield and yield components of barley.

The aboveground dry biomass of barley showed a significant ($P < 0.05$) difference among treatments by the interaction effect of FYM and N fertilizers at the study site. The highest total biomass yield (8845.0 Kg ha⁻¹) was obtained from the application of the highest (1 Kg N ha⁻¹) FYM rate combined with 92 Kg N ha⁻¹. The highest harvest index (37.95%) was recorded from the combined application of 1 Kg FYM ha⁻¹ with 92 Kg N ha⁻¹. This indicates that the application of different rates of FYM and N fertilizers affected the translocations and assimilation processes of barley crops during the grain-filling period. This lowest harvest index of the crop could be due to the lower number of productive tillers m⁻², the number of grains spike⁻¹ and thousand-grain weights that might have contributed to low yield that narrowed the overall ratio between the grain yield and aboveground dry biomass.

In this study, the combined application of 1 Kg FYM ha⁻¹ with 92 Kg N ha⁻¹ had the highest total variable cost 4292 of Birr ha⁻¹ at the study site. This was followed by the application of the combined application of 1 Kg FYM ha⁻¹ with 69 Kg N ha⁻¹ that resulted in the cost of 4197 of Birr ha⁻¹. In these treatments, the cost of the increased rate of FYM and N fertilizer contributed to higher input costs while, in addition, the higher yield in these treatments increased proportionally as the total variable cost for the production of the crop. In contrast, the highest gross return 27480.5 Birr ha⁻¹ was recorded by the combined application of 1 Kg FYM ha⁻¹ with 92 Kg N ha⁻¹. The higher gross return in these treatments over the other treatments was due to the higher yield. Based on variable input cost, the data further depicted the highest net return of Birr 23188.5 ha⁻¹ was obtained with the combined application of 1 Kg FYM ha⁻¹ with 92 Kg N ha⁻¹. The lowest net return Birr 1686.7 ha⁻¹ was from the control treatment. It was observed that the net return increased as the rate of both FYM and N fertilizer rates increased from control to the highest levels. This was due to the that the increased fertilizer level enhanced the

yield to such an extent that benefited the net return. As a result, the farmers may be interested in the net benefit rather than the benefit per birr spent. Therefore, the combined use of 1 Kg FYM ha⁻¹ with 92 Kg N ha⁻¹ can be recommended for these study areas and similar agro-ecologies.

Generally, the application of different rates of FYM and N fertilizers combination significantly affected the yield and yield components of the barley at the study site. The number of productive tillers m⁻² grains spike⁻¹ and thousand-grain weights were increased with levels of FYM and N fertilizer. The application of 1 Kg FYM ha⁻¹ in combination with 92 Kg N ha⁻¹ gave the highest grain and above-ground dries biomass at the study site. Likewise, the partial budget analysis revealed that the application of 1 Kg N ha⁻¹ with 92 Kg N ha⁻¹ resulted in the highest net return of Birr 23188.5 ha⁻¹ at the study site. Therefore, the application of 1 Kg FYM ha⁻¹ in combination with 92 Kg N ha⁻¹ could be recommended to achieve a high grain yield and to get a high economic return of the barley variety 'HB-1307 in the study area.

Conflicts of Interest

The authors have declared that there is no conflict of interest exists.

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