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Research Article

Effects of Weeding Frequency and NPS Fertilizer Rates on Barley (*Hordeum vulgare* L.) Yield performance, Western Ethiopia

Jaleta Mendera, Zerihun Jalata* and Alemayehu Wagari

Department of Plant Sciences, Wallaga University, Ethiopia

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***Corresponding author:** Zerihun Jalata, Department of Plant Sciences, Wallaga University, Ethiopia,
E-mail: jaluu_z@yahoo.com

ORCiD: https://orcid.org/0000-0001-7881-9284

Keywords: Barley; Economic benefits; Weed; Soil analysis

Abstract

Background: Food barley is one of the main staple crops in Ethiopia, however, its production is influenced by several factors including the effect of weeds and low soil fertility.

Purpose: An experiment was conducted with the objective of investigating the combined impact of weeding frequencies and NPS fertilizer rates on barley growth and yield performance.

Methodology: Three levels of weeding frequencies (designated as W1, W2, and W3 for one-time, two-time, and three-time weeding, respectively), and five levels of NPS fertilizers (50, 100, 150, and 200 kg ha^{-1}) were applied in an RCB and replicated three times. HB1307 was used as the test material.

Results: The results indicated that NPS fertilizer rates and weeding frequency had a significant ($p < 0.01$) main influence on barley phenology. The interaction between NPS fertilizer rates and weeding frequency resulted in a highly significant ($p < 0.01$) impact on food barley production, grain yield, and other yield component metrics. Maximum straw yield (5476 kg ha^{-1}) was obtained from the application of 200 kg NPS ha^{-1} with three weeding frequencies. Moreover, the highest grain output (4726 kg ha^{-1}) and highest net return (106,889.8 ETB (Ethiopian Birr ha^{-1}) with a marginal rate of return (47430.8%) were achieved by applying 200kg NPS ha^{-1} and weeding three times.

Conclusion: Barley yield performance was greatly influenced by the application of 200 kg NPS ha^{-1} with three times weeding, resulting in the maximum grain yield (4726 kg ha^{-1}) and straw yield (5476 kg ha^{-1}) that was determined to be cost-effective. However, further research is required to achieve optimum rates of treatment.

Introduction

Barley (*Hordeum vulgare* L.) is one of the most important cereal crops produced in the world, and it is believed to have originated from the wild progenitor *Hordeum spontaneum* in the Fertile Hemispherical region of the Middle East [1]. Most barley that Ethiopian farmers produce is food barley, and it is the main component for several dishes such as injera, porridge, and bread [2]. Consuming barley foods gives the body strength, has medicinal purposes for gastric and headache pain, and can heal broken bones [3]. Additionally, in Ethiopia, barley straw is also increasingly useful for animal feed which creates competition between the two uses [4]. However, in the highlands of Ethiopia, barley is mainly cultivated in altitudinal ranges of 2000 to 3000 m.a.s.l. (meters above sea level) [5].

Globally, 141.7 million tons of barley are produced. With 20.5 million tons produced, the European Union leads the world in barley production. The Russian Federation follows with 8 million tons. Morocco, Ethiopia, Algeria, Tunisia, and South Africa are the top five African countries that grow food barley, with estimated totals of 2.1 million tons, 1.85 million tons, 1.3 million tons, 0.5 million tons, and 0.307 million tons, respectively [6]. In Ethiopia, food barley is the fifth cereal crop produced in the country [7]. Ethiopia is Africa's second-largest barley producer after Morocco, accounting for 25% of

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the continent's total barley production [8]. Compared to other cereal crops like teff, maize, wheat, and sorghum, barley's percentage of the total farmed area has declined [9].

Furthermore, when food barley has inadequate weed control, the crop produces less because it is particularly susceptible to weed competition [10]. Weeds negatively affect the number and quality of agricultural products produced when barley is included, which significantly lowers farmers' profitability [11]. Crop plants and weeds fight for the same resources, such as sunlight, moisture, space, and nutrients. They can also compete by secreting substances called allelochemicals, which have a negative effect on crop plant development and seed germination [12]. In certain barley-growing regions, weeds can cause yield losses of up to 60% when minimum weed management measures are taken [7]. NPS fertilizer is the main essential nutrient in cereal crop production. However, the use of inorganic fertilizers like NPS on barley is low as compared with teff, wheat, and maize which received 25.13, 25.60, and 17.74%, respectively; barley received only 6.92% of fertilizer in the same year may be why the production of barley is reduced [13]. Application N, P and S uptake in barley produces, heavier grains, higher biological yield and consequently maximized grain yield by increasing the levels of fertilizer on food barely [14].

In areas where barley is grown, weeds are a major problem, and most farmers rely mostly on using 2.4.D herbicides. However, research findings indicate that hand weeding is a more effective weed control approach than applying 2,4-D in terms of slowing down weed development [15]. Barley productivity can occasionally decrease due to inadequate use of inputs, such as the appropriate amount of fertilizers and management techniques [16]. Farmers in the study region use various management techniques, most of which aren't backed by research. Therefore, to increase food barley output, for optimal yield performance, it is imperative to ascertain the optimal NPS mixed fertilizer rate and frequency of weeding. Therefore, the objective was to determine the ideal NPS fertilizer rate and weeding frequency in order to assess the economic viability of food barley and maximize yield performance.

Materials and methods

Experimental field

The experiment was conducted under rain-feed conditions in the 2022 main cropping season, at Shambu Site, Horro Guduru Wallaga Zone. The study site is located 315 km away from Addis Ababa, Ethiopia. The soil of the study area is characterized by sandy clay loam. The experimental site is located at 9° 34' 0'' North latitude (Figure 1) and 37° 6' 0'' East longitude, 2600 meters above sea level. At the experimental location, the main rainy season lasts from June to October, with 10°C on average for minimum and 24°C for maximum temperatures. Rainfall averages are usually between 1700 and 2000 mm per year. The three primary cereal crops farmed in the research region are tef (*Eragrostis tef*), wheat (*Triticum species*), and barley (*Hordeum vulgare*) [13].

Description of experimental material

The food barley (HB-1307) variety, which was released by the Holeta Agricultural Research Center in 2006 was used as experimental materials. Due to its higher grain yield performance, disease resistance, and wider adaptation, this variety has been selected in the mid and high-altitude range of 2000–3000 m.a.s.l. It matures in 130 to 135 days and produces grain yields of 3500 to 4000 kg ha^{-1} on station and 2500 to 3000 kg ha^{-1} on farm.

Experimental treatments and design

Fifteen treatment combinations in total were set up using an RCB design with three replications. The factorial experiment included three levels of weeding frequencies (W1, W2, and W3 as one-time, two-time, and three-time weeding, respectively) and five rates of NPS fertilizer (0, 50, 100, 150, and 200 kg ha^{-1}). Every plot had dimensions of 1.6 m wide by 2 m long. Each plot and block had a row spacing of 0.2, 0.5, and 1 meters, respectively. The gross experimental area was 251.6 m^2 (37 m*6.8 m). Therefore, the total number of plots in this experiment was 45 (15x3). Each plot has 8 rows with a length of 2 m. The remaining six middle rows were used for data collection from a net plot area of 2.4 m^2 (1.2m x 2m).

Experimental procedures

An oxen plow was used three times between May and July to plow the experimental field. The clods were broken, and the land was manually leveled. Lastly, spades were used to prepare the seed bed plots. Food barley (HB-1307) was seeded at the customary rate of 100 kg ha^{-1} and hand-drilled to a soil depth of 5 cm in July 2022. The appropriate rate of UREA was applied to each plot in two splits—half during sowing and the other half 28 days later—but the entire amount of NPS fertilizer was applied in compliance with the regulations during planting. Additionally, weeding frequencies (W1, W2, and W3) were carried out as per the treatments.

Soil sampling and analysis

An augur was used to plant after a zigzag pattern of entry into the experimental location, where a soil sample of fifteen plots was taken at a depth of 0–20 cm. The combined soil sample prior to planting. One kilogram of this mixture was taken as a sample. Using a pestle and mortar, an air-dried soil sample was pulverized and dried in the shade. At the Nekemte Soil Laboratory, the material was first put through a 2-mm filter to ascertain its physicochemical characteristics before analysis. Using a 1:2.5 soil and water mixture, the pH of the soil in the supernatant suspension was determined using a pH meter. According to Rowell's [17] description, the USDA textural triangle methodology [18] was applied to determine the soil texture using the Bouyoucos hydrometer method. The soil organic matter content was calculated using a factor of 1.724 and the soil organic carbon content was ascertained using the wet digestion method [19]. Furthermore, Jackson [20] determined the soil's total nitrogen concentration using the Kjeld Hals Method. The soil's available sulfur concentration was determined turbidly metrically using a spectrophotometer

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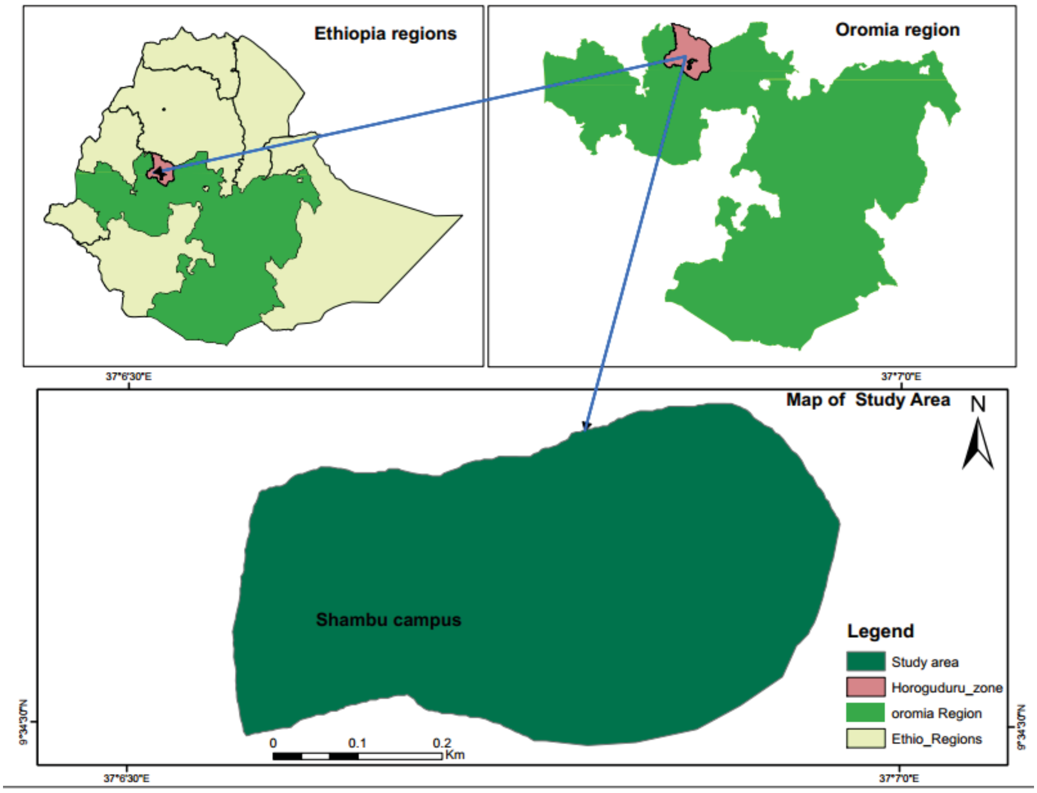

Figure 1: Geographical map of experimental site.

[21]. Bray and Kurtz [22] determined the available phosphorus using the Bray II method. The Ammonium Acetate Method was used to calculate Cation Exchangeable Capacity (CEC) [23].

Data collection

Number of days to 50% heading: Was determined as the number of days taken from the date of sowing to the date of 50% heading of the plants from each plot by visual observation.

Days to 90% physiological maturity: Based on visual inspection, this was the point at which 90% of the plants in each plot flag left and the spike turned yellow.

Plant height: Was measured from the soil surface to the tip of the spike (awns excluded) at the average of 10 randomly tagged plants from the net plot area at physiological maturity.

Spike length: Was measured from the bottom of the spike to the tip of the spike, excluding the awns from 10 randomly tagged spikes from the net plot at maturity.

Total tillers/plant: Both productive and non-productive tillers were determined at grain filling by counting all the tillers by considering 10 randomly selected plants in each net plot area.

Effective tillers/plants: Were counted during grain filling considering 10 randomly selected plants in each net plot area to determine the total number of productive (head-bearing) tillers.

Kernels per spike: Ten randomly selected plants were taken from the net plot area of each plot. Each spike's kernel count was carefully recorded, and the mean was subsequently determined.

A thousand kernels weight: Was determined by weighing a thousand kernels sampled from the net plot using a sensitive balance and expressed in grams.

Biomass yield: All above-ground parts of each plant, including the leaves, stems, and seeds, were taken from the net plot area after the plant reached maturity. After that, the seeds were sun-dried until they attained a stable weight, the above-ground biomass was calculated and expressed in kilograms per hectare.

Grain yield: This was taken by harvesting and threshing the grain yield from the net plot area. Finally, the yield per net plot was converted to kg ha^{-1}. A 12.5% moisture level was used when measuring the grain yield.

Straw yield: Was measured by subtracting the grain yield from the above-ground biomass yield and expressed in kg ha^{-1}.

Harvest index: It refers to the ratio of grain yield to the above-ground biomass yield, i.e.

$$HI(\%) = \frac{GY}{AGBY} x100$$

Where HI = harvest index, GY = grain yield, and AGBY = Above ground biomass yield.

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Economic analysis: The method outlined by CIMMYT [24], which uses the going rates for inputs at planting and outputs at harvesting, was used for the partial budget analysis. Every benefit and outlay was calculated on a ha^{-1} basis in Birr. The concepts used in the partial budget analysis were the average grain yield for each treatment, the Gross Field Benefit (GFB) ha^{-1}, the Total Variable Cost (TVC) per hectare, and the net benefit for each treatment.

Adjusted yield (kg ha^{-1}): The average yield was deducted by 10% to account for the fact that experimental yield differences are frequently greater than what farmers could anticipate when applying the same treatments. As a result, farmers' yields are adjusted in economic calculations by 10% less than those of the research findings [24].

Gross Field Benefit (GFB): The gross field benefit was calculated by multiplying the field/farm gate price that farmers receive when they sell their food barley by modified grain production.

Total Variable Cost (TVC): The labor cost for field management, the cost of NPS fertilizers, the cost of fertilizer application, and the labor cost of weeding for the experiment comprised the total variable cost.

Net Benefit (NB): This was calculated as the amount of money left when the total variable costs for inputs (TVC) are deducted from the gross field benefit (GFB).

NB = GFB – TVC

Marginal Rate of Return (MRR %): was calculated by dividing the change in Net Benefit (ΔNB) by the change in Total Variable Cost (ΔTVC) and multiplying by 100.

$$MRR(\%) = \frac{\Delta NB}{\Delta TVC} x100$$

Dominance Analysis (identification and elimination of inferior treatments): is also used to eliminate those treatments that involve higher costs but do not generate higher benefits. Any treatment that has a higher TVC but net benefits that are less than or equal to the preceding treatment is a dominant treatment (marked as "D").

Data analysis

The collected data was subjected to Analysis of Variance (ANOVA) using appropriate procedures using GenStat 18th edition (64-bit) software [25], and the treatments' significance test was done by employing the Least Significant Difference (LSD) at a 0.05 probability level. Additionally, the interaction graphs were presented to demonstrate the interaction effects of NPS levels and weeding frequency by using R Software [26].

Results

Pre-planting physicochemical properties of the experimental site

The soil test of the study area result showed the soil texture was sand (59%), silt (17%), and clay (24%). The soil's organic carbon content was 2.02%, and its cation exchange capacity (CEC) was 16 Meq/100g. Additionally, the pH of the soil is 5.75, total N is 0.17%, and S is 11.53 mg kg^{-1}. (Table 1). The phosphorus and potassium content was 14.25 mg kg^{-1} and 0.92 mg kg^{-1}, respectively.

Analysis of variance

The interaction between weeding frequency and NPS fertilizer rates had a significant ($p < 0.01$) impact on the number of effective tillers/plant, number of kernels/spike, height of the plant, total tillers, effective tillers, spike length, grain yield, biomass yield, straw yield, and harvest index of food barley, according to the results of the analysis of variance; while days to 50% heading and days to physiological maturity showed no significant interaction impact (Table 2).

Mean performance in phonology

Days to 50% heading and days to 90% maturity: The finding showed that the three weeding sessions yielded the shortest days to 50% heading (70.53), while the one weeding session produced the longest days to heading (73.73). In the same way, the three weeding sessions produced earlier days to 90% physiological maturity (113.7), but one weeding session produced later days to 90% physiological maturity (117.8) (Table 3). On the other hand, the earliest days to heading (70.56) and physiological maturity (113.8) were obtained by applying 200 kg NPS ha^{-1}, while the latest days to heading (78) and physiological maturity (120 days) were obtained respectively from the control or 0 NPS (Table 3),

Growth performance of barley

Plant height: Plots receiving 200 kg NPS ha^{-1} and three hand weeding sessions were found to have larger plant heights than plots receiving 0 kg ha^{-1} and one hand weeding session by 28.18%. When 200 kg NPS ha^{-1} was applied with three weeding frequencies, food barley plants had the highest plant height of

Table 1: Physicochemical characteristics of the soil of the experimental site before planting.

Properties	Result	Rating
Physical properties		
Sand (%)	59	
Silt (%)	17	
Clay (%)	24	
Textural Class	Sandy clay loam	
Chemical Properties		
pH (1:2.5 H_2O)	5.75	moderately Acidic
Organic Matter (%)	3.482	Medium
Organic Carbon (%)	2.02	Medium
Total Nitrogen (%)	0.17	Medium
Available Phosphorus (mg kg-1)	14.25	Medium
Available Potassium (mg kg-1)	0.92	Low
Available Sulfur (mg kg-1)	11.53	Medium
CEC (meq /100g soil)	16	Medium

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Table 2: Mean square values for phenology, growth, and yield parameters as influenced by NPS fertilizer rates and weeding frequencies.

Source of variance	DF	Mean squares											
		DH	DPM	PH	SL	PT	TT	NKPS	TKW	AGBY	GY	SY	HI
Replication	2	0.69	0.20	82.83	1.195	0.82	0.09	11.02	0.35	4464	4500.	8.426	0.19
NPS	4	82.08**	50.86**	876.79**	12.61**	11.41**	12.41**	202.67**	111.78**	18224262**	3448066**	5.9**	3.45**
WF	2	6.0**	2.60*	42.60**	5.55**	1.09**	2.29**	44.02**	43.82**	1803251W6**	5315555**	3.803**	6.85**
NPS*WF	8	1.01ns	1.24ns	16.29**	1.38**	0.98**	0.68**	2.13**	8.14**	1921162**	757479**	3.19**	0.73**
Error	28	0.83	0.87	0.67	0.07	0.11	0.14	0.28	0.36	3609	3628	6.21	0.07
CV (%)		1.2	0.8	0.8	4.5	12.4	10	1.2	1.5	0.9	2.1	0.2	0.6

Where, *= significant at ($p < 0.05$), **= significant at ($p < 0.01$), NS: Non-Significant; DH: Days to 50% Heading; DPM: Days to 90% Physiological Maturity; SL: Spike Length and PH: Plant Height; TT: Total Tillers; PT: Productive Tiller; NKPS: Number of Kernels Per Spike; TKW: Thousand Kernels Weight; AGBY: Above Ground Biomass Yield, GY: Grain Yield; SY: Straw Yield and HI: Harvest Index

Table 3: The primary impact of NPS fertilizer rates and frequency on food barley's days to maturity and heading.

NPS levels (kg ha^{-1})	Days to 50% heading	Days to 90% maturity
0	78.00^{a}	120.1^{a}
50	73.67^{b}	117.1^{b}
100	71.78^{c}	116.1^{c}
150	71.11^{cd}	115.2^{c}
200	70.56^{d}	113.8^{d}
LSD (5%)	0.88	0.89
Weeding frequencies		
1	73.73^{a}	117.8^{a}
2	72.80^{b}	116.6^{b}
3	70.53^{c}	113.7^{c}
LSD value (0.05)	0.68	0.69
CV (%)	1.2	0.8

At the 5% level of significance, the means in a column that are followed by the same letters do not differ substantially. CV (%): Variation Coefficient; LSD: Least Significant Difference.

Table 4: The interaction effect between NPS fertilizer rates and weeding frequency on food barley plant height, spike length, number of kernels per spike, and tillers per plant.

Factors		Plant height	Tillers/plant	Effective tillers/plant	Spike length (cm)	Kernels/spike	Thousand kernels weight
NPS(kg/ha)	WF						
0	1	81.3^{j}	2.00^{f}	1.00^{f}	4.20^{h}	37.00^{k}	34.3^{i}
0	2	83.3^{i}	2.00^{f}	1.00^{f}	4.42^{gh}	38.00^{j}	36.28^{h}
0	3	89.5^{h}	2.00^{f}	1.00^{f}	4.70^{g}	38.00^{j}	36.5^{h}
50	1	98.2^{g}	3.33^{e}	2.00^{e}	5.28^{ef}	39.00^{i}	38.47^{g}
50	2	99.0^{g}	3.00^{e}	2.33^{de}	5.27^{f}	39.00^{i}	39.2^{fg}
50	3	101.7^{ef}	3.33^{e}	2.33^{de}	5.73^{de}	40.00^{h}	39.63^{f}
100	1	101.0^{f}	3.33^{e}	2.67^{cd}	5.75^{d}	40.00^{h}	39.63^{f}
100	2	101.2^{ef}	4.00^{d}	3.00^{c}	5.73^{de}	41.00^{g}	40.0^{f}
100	3	102.5^{e}	4.00^{d}	2.67^{cd}	6.25^{c}	43.00^{f}	41.5^{de}
150	1	105.2^{d}	4.00^{d}	3.00^{c}	6.42^{c}	45.00^{e}	41.16^{e}
150	2	105.7^{d}	4.00^{d}	3.00^{c}	6.17^{cd}	47.00^{c}	41.2^{e}
150	3	110.2^{b}	5.00^{b}	3.67^{b}	7.08^{b}	49.33^{b}	45.0^{b}
200	1	108.5^{c}	4.33^{cd}	3.00^{c}	6.60^{c}	46.00^{d}	42.5^{cd}
200	2	109.3^{bc}	4.67^{bc}	3.67^{b}	6.50^{c}	47.67^{c}	42.75^{c}
200	3	113.2^{a}	6.33^{a}	5.33^{a}	9.67^{a}	51.67^{a}	49.93^{a}
LSD (5%)		1.35	0.62	0.55	0.55	0.89	1.001
CV (%)		0.8	10	12.4	4.5	1.2	1.5

The means in a column that are followed by the same letters do not significantly differ at the 5% level of significance. CV: Coefficient of Variation; LSD: Least Significant Difference; WF: Weeding Frequency

113.2 cm, while plants supplied with zero kg NPS ha^{-1} were the shortest in plant height (81.3 cm) (Table 4).

Tillers/plant: In comparison, the lowest number of total tillers (2.00) was obtained with the first weeding of 0 kg NPS ha^{-1}. The highest number of total tillers (6.33) was obtained with three weeding times and applications of 200 kg NPS ha^{-1} (Table 4). The application of 0 kg NPS ha^{-1} with one weeding session produced the fewest productive tillers (1.0), whereas the usage of 200 kg NPS ha^{-1} with three weeding sessions produced the greatest effective tillers per plant (5.33) (Table 4).

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Yield component and yield performance of barley

According to the results, the application of 200 kg NPS ha^{-1} with three weeding sessions produced the longest spike length (9.67 cm), which was 56.56% longer than the least spike length (4.20 cm) produced by applying 0 kilograms NPS ha^{-1} with one weeding session (Table 4). The highest number of kernels per spike (51.67) was recorded from the application of 200 kg NPS ha^{-1} with three times weeding, conversely, with a single weeding, the lowest number of kernels per spike (37.0) was observed at 0 kg NPS ha^{-1} (Table 4). The highest application rate of NPS fertilizer (200 kg NPS ha^{-1}) with three weedings raised thousand kernel weight by 31.3% as compared to control NPS with one weeding (Table 5). Thus, the application of 200 kg NPS ha^{-1} and three rounds of weeding resulted in the maximum thousand kernel weight of 49.93 g, whereas at control NPS fertilizer and one round of weeding produced the lowest thousand kernel weight of 34.3 g (Table 4).

The highest above-ground biomass yield (10202 kg ha^{-1}) was recorded from the application of 200 kg NPS ha^{-1} fertilizer rates with the three times weeding frequencies, whereas the lowest above-ground biomass yield (4473 kg ha^{-1}) was recorded from the 0 kg NPS ha^{-1} fertilizer rates with one-time weeding frequency (Figure 2). Furthermore, food barley with the highest grain yield (4726 kg ha^{-1}) was recorded at 200 kg NPS ha^{-1} fertilizer rates with three weedings, while the lowest grain yield (1987 kg ha^{-1}) was created by using 0 kg NPS ha^{-1} fertilizer rate with one weeding (Figure 3). Additionally, the maximum harvest index (47.08%) (Figure 4) and highest straw yield (5476 kg ha^{-1}) of barley were obtained from the application of 200 kg NPS ha^{-1} fertilizer rates with three weeding frequency; whereas the lowest straw yield (2486 kg ha^{-1}) was obtained from the application of 0 kg NPS ha^{-1} fertilizer rates with one weeding (Figure 5).

Estimation of economic feasibility

The application of 200 kg ha^{-1} NPS fertilizer combined with three weeding operations produced the most net benefit (106,889.8 ETB ha^{-1}) with an acceptable marginal rate of return (47430.8%), according to the partial budget analysis. The lowest net benefit, however, was obtained by applying 0 kg ha^{-1} NPS combined with a single weeding operation (48,184.1 ETB ha^{-1}) (Table 5). Thus, the application of 200 kg ha^{-1} NPS

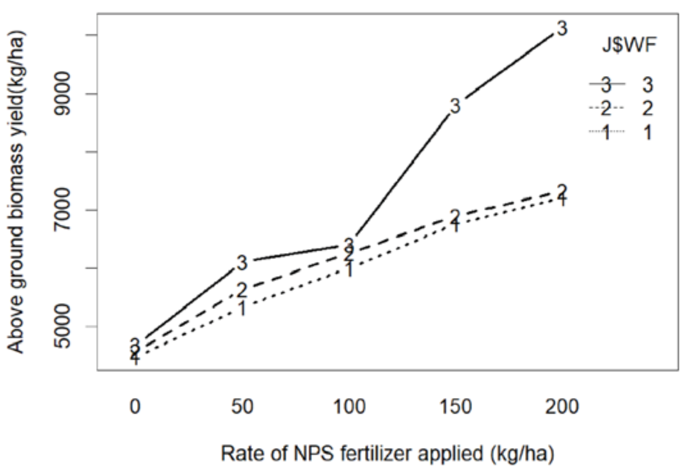

Figure 2: The effect of weeding fervency and rates of NPS fertilizer on aboveground biomass yield of food barley.

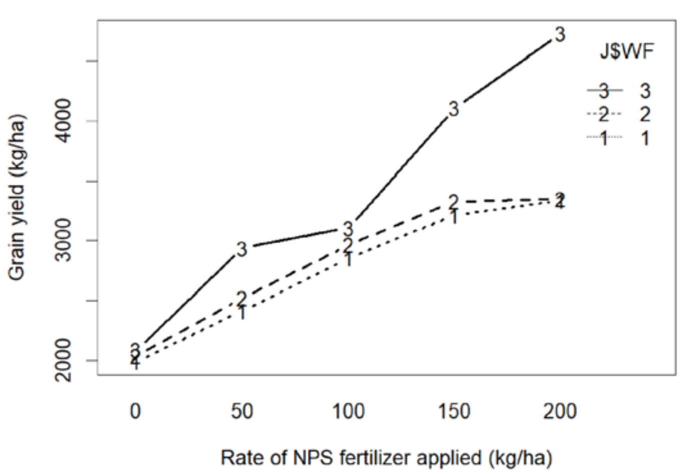

Figure 3: The effect of weeding fervency and rates of NPS fertilizer on grain yield of food barley.

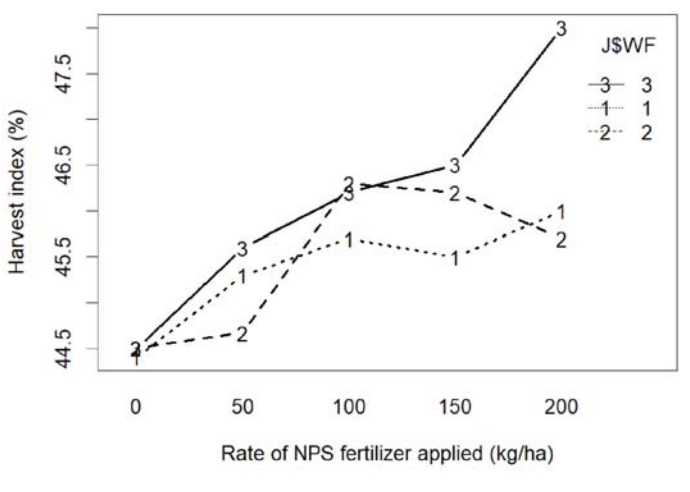

Figure 4: The effect of weeding fervency and rates of NPS fertilizer on harvest index (%) of food barley.

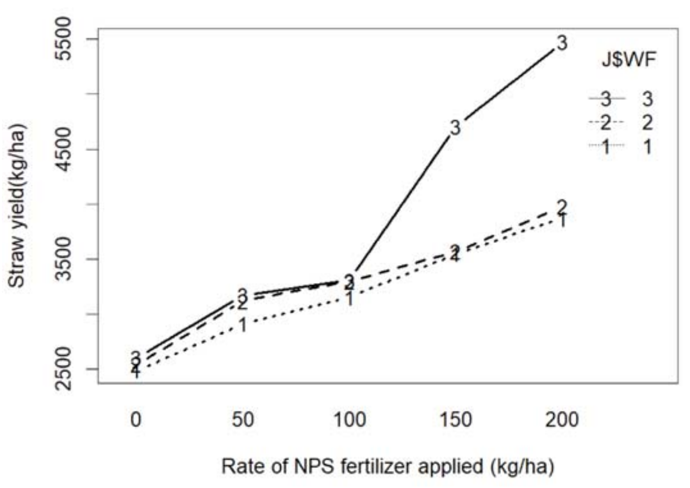

Figure 5: The effect of weeding fervency and rates of NPS fertilizer on straw yield of food barley.

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Table 5: Economic feasibility NPS fertilizer application and weeding frequency on food barley production at Shambu, 2023.

Treatments		AY Kg ha-1	AGY Kg ha-1	GFB (ETBha-1)	TVC (ETBha-1)	NB (ETBha-1)	MRR (%)
NPS Kg ha-1	WF						
0	1	1987	1788.3	48284.1	100	48184.1	-
0	2	2041	1836.9	49596.3	150	49446.3	2524.4
0	3	2087	1878.3	50714.1	200	50514.1	2135.6
50	1	2415	2173.5	58684.5	2038	56646.5	333.65
50	2	2520	2268	61236	2088	59148	5003
50	3	3038	2734.2	73823.4	2138	71685.4	25074.8
100	1	2453	2207.7	59607.9	3976	55631.9	D
100	2	2566	2309.4	62353.8	4023	58330.8	5742.3
100	3	3306	2975.4	80335.8	4073	76262.8	35864
150	1	2512	2260.8	61041.6	5914	55127.6	D
150	2	2598	2338.2	63131.4	5964	57167.4	4079.6
150	3	4305	3874.5	104611.5	6014	98597.5	52860.2
200	1	2538	2284.2	61673.4	7852	53821.4	D
200	2	3748	3373.2	91076.4	7902	83174.4	58706
200	3	4726	4253.4	114841.8	7952	106889.8	47430.8

Where, NPS: Blended rates of NPS fertilizer (kg ha-1); WF: Weeding Frequency; AY: Average Yield; AGY: Adjusted Grain yield; GFB: Gross Field Benefit; TVC: Total Variable Costs; NB: Net Benefit, MRR: Marginal Rate of Return; ETB ha-1: Ethiopian Birr Per Hectare; D: Dominated Treatment; Labor cost in NPS application and weeding = 50 ETB/day/person, barley seed price = 27.00 ETB kg-1

fertilizer rate with three times weeding resulted in the highest grain yield (4726 kg ha-1) and was economically profitable in the study area.

Discussion

The soil analysis before planting showed that the soil was sandy clay loam soil according to the USDA's textural soil classification [18]. The experimental soil has a moderate CEC (16 Meq/100g soil) [27] and the organic carbon content (2.02%) is categorized as medium [28]. According to ESIS [29], the study area has a medium pH (5.75) reaction, medium in total N (0.17%), and inaccessible S (11.53 mg kg-1). Additionally, the available phosphorus (14.25 mg kg-1) content was also medium [30]. The kaolinite clay's weak potassium ion retention capacity and consequently high sensitivity to cation leaching may be due to the low accessible potassium concentration (0.92 mg kg-1) [31]. Although food barley can grow across a range of pH levels, Hazelton and Murphy [27] indicated that the optimal range of soil pH for barley is 5.0 to 6.5, which ranges from a moderately acidic to a slightly acidic reaction.

The analysis of variance showed that the interaction effect of weeding frequencies and NPS fertilizer rates had a significant positive influence on different yield and yield components of barley (Table 2). Hence further mean separation test was done to assess the magnitude of the significant influence of weeding frequency and NPS fertilizer on barley. Thus, at three weeding frequency and the highest NPS tended barley to mature earlier (Table 2). Similarly, Negewo, et al. [32] and Gupta [33] reported that, in contrast to the maximum weeding frequency in barley, delayed days to heading occurred when crop plants were suppressed by weeds for growth resources at the initial weeding frequency. This study in accordance with Gebeyehu, et al. (2021) [16] report which indicated an increase in NPS fertilizer rates accelerated maturity. Wakene, et al. [34] and Chimdessa [35] stated phosphorus has a vital role in the development of the reproductive part of plants and is used in dry matter distribution, which facilitates plant development and encourages the early maturity of crops. Furthermore, according to Sisie & Mirshekari [36], P promotes the accumulation of dry matter in plant cells, which helps the plant grow and develop and speeds up crop maturation by shortening the time for crop blossoming, seedling development, early root growth, and early heading formation.

An increased plant height and tiller formation as a result of higher NPS fertilizer rates and more frequent weeding in the present study could be explained by the NPS nutrients, which promoted more cell elongation and vegetative development. In a similar vein, Kamel, et al. [37] reported that plants with adequate light, moisture, and nutrients grew higher and more vigorously. According to Megersa, et al. [38], control plots with a single wedding yielded lower plant heights than those with three weddings, which resulted from applying a higher amount of NPS fertilizer. In a similar vein, Dalga, et al. [39] reported that fewer total tillers were produced under the minimum weeding frequency due to increased competition between crop weeds for growth resources and the crop's decreased availability of nutrients and moisture. Ijaz, et al. [40] found that weed-free periods enhanced nutrient levels and availability for the crop, increasing the number of tillers. Moreover, Chandramohan, et al. [41] described that weeds compete with crops and reduce tillering by competing with crops for resources such as light, nutrients, moisture, and space as a result reduce productive tillers. Takele, et al. [42] reported that in barley crops, there are fewer tillers per plant when weed populations rise.

The current study found that applying 200 kg NPS ha-1 rates of fertilizer and three times the weeding strategy increased the yield components of grain barley. Naveed, et al. [43], weeds are natural competitors with crops for growth resources which can reduce the crop's total output and yield-related components. The results of Dinka, et al. [44] further demonstrated that the application of 200 kg NPS ha-1 rates of fertilizer extended the length of the food barley spike. Furthermore, Rashid, et

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al. [45]. found that applying 200 kg of NPS ha^{-1} fertilizer to barley considerably increased the weight of the grain when compared to the control. Melaku [46] stated that the readily available phosphorous during the early season enhanced the number of grains per spike due to its involvement in grain formation and development. According to Shrestha, et al. [47], removing weeds at an earlier stage can improve yield and yield components of crops. Manual weeding allows the eradication of weeds, which promotes healthy crop growth and development, inhibits the spread of weeds, and aids in the crop's efficient use of resources [38].

Furthermore, barley grain yield increased with the duration of the weed-free period, whereas grain output decreased with prolonged weed clearance delays, per Merhawit [10]. According to another study, weeding barley three times is the ideal weeding frequency for the HB-1307 variety to increase grain yield (1422 kg ha^{-1}) in the Amuru area [48]. Weed density significantly decreased barley grain yield, mostly as a result of decreased tiller counts, productive spikes, and barley biomass production. With an increase in weed density, barley grain yield fell linearly ($r^2 = -0.59$) [49]. Furthermore, an application of NPS fertilizer rate of 200 kg ha^{-1} provided the highest grain yield (4592 kg ha^{-1}) [2]. High NPS application combined with three weedings produced a much higher maximum harvest index, while one-time weeding achieved the lowest harvest index [38]. Increased barley straw is useful for animal feed in Ethiopia in parallel to grain yield. This was also reported by Keno et al. [4] who stated that there is high demand for barley straw biomass in the mixed barley livestock system creating competition between the two uses in Ethiopia and the report indicated total cost of straw for feeding per hectare was estimated at USD 119.37 (ETB 4930) in 2021. In addition to this, another research showed that among the various crop residues produced for animal feed, barley straw has a considerable share of the total annual crop residue production in Ethiopia [50]. Thus, study revealed that the highest grain yield (4726 kg ha-1) was achieved by the application of 200 kg ha-1 NPS fertilizer rate with three times weeding and was economically profitable in the study area. However, in the present study, there are some limitations to describe such as a partial budget analysis which only considers variable costs (those that change with the treatment) and ignores fixed costs (e.g.,rent, machinery). This might underestimate the true cost of implementing the treatments on a farm. The analysis also assumes constant market prices for barley and inputs, which might not reflect real-world fluctuations. The economic analysis is based on data from a single season and location. Repeating the study across multiple years and locations would strengthen the generalizability of the findings.

Conclusion

Food barley's days to 50% heading and 90% physiological maturity were shown to be significantly ($p < 0.05$) impacted by the primary effects of weeding frequencies and NPS fertilizer rates. The earliest three weedings provided the days to 50% heading (70.53) and 90% physiological maturity (113.7), while the single weeding produced the days to 50% heading (73.73) and 90% physiological maturity (117.8). Conversely, the interaction between NPS fertilizer rates and weeding frequency had a substantial ($P<0.01$) effect on all yield and yield-related indicators that were examined. Following the application of 200 kg NPS ha^{-1} fertilizer rates with the three times weeding frequency, the maximum weight of thousand kernels (49.93g), above-ground biomass yield (10202 kg ha^{-1}), grain yield (4726 kg ha^{-1}), straw yield (5476 kg ha^{-1}), and harvest index (47.08%) were recorded. The application of 200 kg NPS ha^{-1} fertilizer rate with the three times weeding produced the highest net benefit (106,889.8ETB ha^{-1} with a marginal rate of return of 47430.8%), according to the economic profitability analysis. In conclusion, the finding showed the application of 200 kg NPS ha^{-1} fertilizer rate with three times weeding resulted in improvement of phonology, growth, and yield components with the highest grain yield (4726 kg ha^{-1}) performance of food barley (HB-1307) and was found economically profitable in the study area.

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Data availability

The data is freely available and accessible in the Mendeley data repository (https://data.mendeley.com/drafts/ycw2wh32d and Mendeley Data, V1, doi: 10.17632/ycw2wh32d7.1).

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