International Journal on Food, Agriculture, and Natural Resources
Volume 6, Issue 1, Page 50-54
ISSN: 2722-4066
http://www.fanres.org

Original Paper

Effects of Combining Compost, Nitrogen, and Phosphorus on Barley Production in Wag-Lasta, Ethiopia.

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Received: 30 October 2024; Revised: 30 October 2024; Accepted: 27 December 2024
DOI: https://doi.org/10.46676/ij-fanres.v6i1.424

***Abstract*— This trial aimed to assess the composting potential of local materials and their integration with inorganic fertilizers to enhance barley productivity. The experiment involved preparing compost and evaluating its effects on barley production at two locations over two years. Mean treatment differences were analyzed using the analysis of variance (Proc-GLM) procedure. The combined analysis over the two years in the Dahana and Lalibela areas revealed that applying the recommended blanket inorganic fertilizer resulted in the highest biomass and grain yield. However, using one tone of compost along with half of the recommended nitrogen and phosphorus also achieved comparable biomass and grain yield. Additionally, this approach improved the soil's physical and chemical properties over time. Therefore, using one ton of compost with half the recommended nitrogen and phosphorus is recommended for the Wag and Lasta highlands and similar agro-ecologies where barley is grown.**

Keywords*— *barley, biomass, compost, grain, organic fertilizer

I. Introduction

The world's increasing demand for food will primarily be met by boosting yields in currently cultivated areas and, to a lesser extent, by expanding the area under cultivation. Without the enhanced use of fertilizers and optimal soil moisture, crop yields would be significantly lower. Barley is a vital cereal crop, especially in challenging environments. Its production is considered relatively stable compared to other cereals and can yield acceptable grain outputs in regions where other crops fail entirely. Farmers often resort to planting barley or tef if the rains do not arrive early in May, preventing the sowing of sorghum. While sorghum is more drought-resistant than wheat and can thrive in areas with minimal rainfall, barley's productivity remains low in these conditions [1]. Immediate strategies that utilize resources readily available to farmers are essential for achieving faster results. Although fertilizers are used in much of Sub-Saharan Africa, the quantities applied are often insufficient to meet crop demands, compounded by socio-economic and environmental challenges. Organic inputs are proposed as alternatives to mineral fertilizers [2]. Most soil fertility management for barley has historically relied on inorganic fertilizers. For example, research conducted in Holetta demonstrated a significant response to nitrogen and phosphorus applications in Notosol soils [1]. The long-term benefits of compost should also be considered, as even a one-time application can yield economical returns. Studies have shown that one application of compost can lead to increases in soil organic matter, total nitrogen, phosphorus, potassium, and improved water infiltration for many years after the initial application [3]. Compost is an affordable organic fertilizer that can be produced on the farm. Unlike other organic fertilization methods, composting accelerates the natural decomposition process in the soil through human intervention. The most critical resource in this process is farmers' labor, as the necessary materials, such as crop residues and animal manure, are typically accessible on-site. Furthermore, composting enhances the quality of manure by eliminating the viability of weed seeds that may be present. According to [4], weed seeds in the manure will germinate in moist compost but will ultimately die due to a lack of light. The Wag and Lasta area is one of the country's drought-affected regions. They have experienced crop damage due to fertilizer application, resulting in reduced yields-especially during periods of drought-compared to unfertilized fields under similar moisture conditions, which often leads to crop failure. Consequently, this proposal aims to identify the best combinations of compost and inorganic fertilizers to enhance barley yield and improve soil chemical and physical properties.

II. Material And Methods

A. *Geographic Location of The Study Area*

The study area is located in the eastern part of the Amhara National Regional State, specifically in Wag-Lasta. This region is characterized by a unimodal rainfall pattern, which occurs from late June to late August or early September, allowing for summer crop cultivation. The mean annual rainfall in this area ranges from 333 to 1,016 mm, while the mean minimum and maximum annual temperatures are 8°C and 21°C, respectively. The primary agro-ecological features of this catchment include hot and warm sub-moist to semiarid lowlands, with a tepid to cool sub-moist environment. Farmlands in this region are typically found on slopes ranging from 0% to 8%, although they are more commonly situated between 0% and 25%. The soil is primarily composed of alluvial deposits that are well-drained and vary in color from light to dark brown. The soil depth is generally very shallow to shallow, with a texture that ranges from sandy to sandy clay loam. This soil has experienced significant erosion and is continuously cultivated; with rock outcrops of basalt and sandstone present [5].The research was carried out on a farmer's field during the 2008/2009 and 2009/2010 cropping seasons.

B. *Compost Preparation*

To create quality compost from locally available materials, we followed these procedures:

1. Materials Collection: We gathered wood ash, farmyard manure (FYM), straw (collected from cattle feed waste), and maize Stover from various sources.
2. Compost Pits: We dug two pits, each measuring 1 meter wide, 1 meter long, and 1 meter deep. These pits were used rotationally every 21 days to invert the compost material, ensuring uniform decomposition.
3. Layering Process:
   - First layer: To improve aeration, we placed a layer of sorghum Stover cuttings, mounding it up to 30 cm thick and sprinkling it with water.
   - Second layer: We added a mixture of straw (approximately 15 cm thick) and FYM (about 9 cm thick), also sprinkling this layer with water.
   - Third layer: In this layer 3 cm thick of wood ash was added.
   - Fourth layer: We included 3 cm of forest topsoil, which contains essential microorganisms that aid in decomposing the organic material.
4. Continued layering: We continued this layering process until the pit was filled to its 1-meter capacity.
5. Covering the compost: We covered the composting material with grass to prevent moisture loss. Throughout the process, we sprinkled water on each layer to maintain moisture and expedite decomposition.

Additionally, we inserted a long stick at a 45-degree angle and checked it weekly to enhance air circulation and monitor moisture and temperature variations. After one month, we turned the compost into the other pit, allowing it to mature fully within three months.

C. *Field Trial*

The experiment was designed using a randomized complete block design with three replications, covering a total plot size of 22 m x 11 m. The experimental units measured 4 m x 3 m. The treatments were as follows:

1. Control (no fertilizer)
2. Blanket recommendation (41 kg ha^{-1} N + 46 kg ha^{-1} P_2O_5)
3. 20.5 kg ha^{-1} N + 23 kg ha^{-1} P_2O_5 + 1 tone of compost
4. 13.7 kg ha^{-1} N + 15.3 kg ha^{-1} P_2O_5 + 3 tone of compost (with four levels of compost)
5. 5 tone of compost.

The compost was applied to treatments 3, 4, and 5 one month before planting. All phosphorus was applied at the time of planting barley, and nitrogen was applied in two parts: half at planting and half when the plants reached knee height.

D. *Soil Analysis*

Soil samples were collected from each treatment using an auger at a depth of 0-20 cm. These samples were taken across the replications and then combined to create one composite sample per treatment. The collected samples were air-dried and ground to pass through a 2 mm-diameter sieve for laboratory analysis, following standard procedures. The methods used for analysis include:

Particle size distributions were analyzed by the Bouyoucos hydrometer method using sodium hexa-meta-phosphate as dispersing agents as described by [6].Soil pHe was measured potentiometrically using a digital pH-meter and ECe by digital conductivity meter according to the methods stated by [7].

According to [8], the digestion method was used to determine soil organic carbon content and percent soil organic matter was obtained by multiplying percent soil organic carbon by a factor of 1.724.

-Cation Exchange Capacity (CEC):NH_4^+-acetate method

E. *Statistical Analysis*

The data collected from field studies and soil laboratory analyses were analyzed using ANOVA in SAS software. When treatment effects proved significant, mean separations were conducted using the least significant difference (LSD) method.

III. Results And Discussions

A. *Soil Physical And Chemical Properties*

The average soil pH was 5.66, indicating moderately acidic conditions [9; 10], with a mean cation exchange capacity of 25.0. The mean organic matter content of the soil was 1.88%, which is considered very low. This low level is attributed to continuous cultivation, significant soil erosion, and high temperatures in a moist, drained soil environment that promotes the decomposition of organic matter rather than its accumulation (Table I). This finding is consistent with [11], who reported considerable variation in organic matter levels among the analyzed samples.

TABLE I. GENERAL SELECTED SOIL CHEMICAL PROPERTIES OF THE STUDY AREAS.

Parameter	Mean	Mean square	CV%	F-value	Pr>F
pH	5.66	0.043	5.28	0.48	0.75
CEC	25.01	1.866	5.50	0.99	0.49
0M%	1.88	1.166	17.21	11.12	0.01

The average soil pH was 5.66, indicating moderately acidic A notable increase in organic matter was observed in Dahana Wereda with the application of the recommended nitrogen and phosphorus fertilizers, compared to other treatments. This improvement is attributed to the high root biomass production and the organic matter contributed by decomposing roots (Table II). The overall analysis of variance showed that soil organic matter significantly improved after applying various rates of compost in combination with inorganic fertilizers, with results varying by location (Table II). Specifically, the application of 5 tone of compost per hectare enhanced the soil's organic matter status by 80% in Lalibela and 58% in Dahana compared to the unfertilized plots. This increase in organic matter benefits cation exchange capacity (CEC), water retention, and nutrient availability in the soil.

TABLE II. OVERALL TREATMENT EFFECT ON SELECTED CHEMICAL PROPERTY STATUS AFTER THE CROP HARVEST

Location	Treatment	Depth (cm)	Texture	Mean value of chemical properties				
				pH	*EC*	*CEC*	*OC (%)*	*OM (%)*
Dahana	No fertilizer	0-20	Clay loam	5.78	45.8	24.2	0.72	1.25
	$41N+46P_2O_5$	0-20	Clay loam	5.60	53.3	26.6	1.26	2.18
	1ton compost+$20.5N+23P_2O_5$	0-20	Clay loam	5.58	56.6	23	2.48	4.27
	13.7N+15.3P2O5+3ton compost	0-20	Clay loam	5.46	74.5	26.4	1.25	2.17
	5 ton compost		Clay loam	5.11	139.4	25.6	0.88	1.52
Lalibela	No fertilizer	0-20	Sandy clay loam	5.86	29.3	27	0.32	0.56
	$41N+46P_2O_5$	0-20	Sandy clay loam	5.79	46.7	25.4	0.74	1.28
	1ton compost+$20.5N+23P_2O_5$	0-20	Sandy clay loam	7.98	16.6	24	0.94	1.61
	13.7N+15.3P2O5+3ton compost	0-20	Sandy clay loam	5.53	55.9	24.2	1.52	2.63
	5 ton compost	0-20	Sandy clay loam	5.94	43.0	23.8	1.62	2.79

NOTE:-TON-TONE; CM-CENTIMETER; EC-ELECTRICAL CONDUCTIVITY; CEC-CATION EXCHANGE CAPACITY; OC-ORGANIC CARBON; OM-ORGANIC MATTER

B. *Responses To Yield And Yield Components*

Treatment effects on barley yield varied across different years and locations (Tables III and IV). In the 2008 cropping season, a combination of 1 tone of compost, 20.5 kg of nitrogen per hectare, and 23 kg of (P_2O_5) per hectare resulted in significantly higher grain yields compared to other treatments. This was comparable to the recommended nitrogen and phosphorus application rates of 46 kg of P_2O_5 and 41 kg of nitrogen per hectare, as supported by the findings of [12]. At Lalibela, the recommended nitrogen and phosphorus fertilizers produced the highest grain yield (1244.44 kg per hectare), biomass (3458.33 kg per hectare), and plant height (91.99 cm) compared to other treatments.

TABLE III. MEAN BIOMASS AND GRAIN YIELD OF FIVE COMBINATIONS EVALUATED AT LALIBELA AND DAHANA IN THE FIRST YEAR CROPPING SEASON.

Treatment	Lalibela			Dahana		
	Ph(cm)	*By(kgha^{-1})*	*Gy(kgha^{-1})*	*Ph(cm)*	*By(kgha^{-1})*	*Gy(kgha^{-1})*
$41N+46P_2O_5$	91.99^{a}	3458.3^{a}	1244.4^{a}	108.3^{a}	6512.5^{ba}	1527.7^{b}
1ton compost+$20.5N+23P_2O_5$	70.50^{cb}	1920^{b}	597.2^{b}	98.3^{c}	6841.7^{a}	1694.4^{a}
13.7N+15.3P2O5+3ton compost	70.50^{cb}	1690c	638.9^{b}	105.9^{b}	5908.3^{c}	1524.4^{b}
5 ton compost	68.9^{c}	1072.8^{d}	447.2^{c}	105.6^{b}	6491.7^{b}	1267.2^{c}
No fertilizer	73.39^{cb}	795.3^{e}	399.4^{c}	93.1^{d}	4908.3^{d}	1205.0^{d}
Mean	75.07	1788.9	665.4	102.3	6132.2	1443.8
CV (%)	2.98	1.84	4.7	0.64	2.87	0.82

Note;-Ph-plant height; By-biomass yield; Gy-grain yield and Cm-centimeter; Kg-Kilo gram; ha-hectare; Ton-tone

However, integrating compost with nitrogen and phosphorus resulted in a 48.6% reduction in yield at Lalibela, indicating that the effectiveness of these combinations can differ by location. Conversely, at Dahana in the same year, the combined use of compost and inorganic fertilizers yielded more favorable results. The combination of 1 tone of compost, 20.5 kg of nitrogen per hectare, and 23 kg of P_2O_5 per hectare resulted in a grain yield of 1694.44 kg per hectare. In this instance, the recommended nitrogen and phosphorus fertilizers favored biomass yield (6512.5 kg per hectare) and plant height at maturity (108.32 cm) (Table III).

The results from the second year revealed a trend similar to that of the first year. At Lalibela, the application of the recommended amounts of nitrogen and phosphorus led to a plant height at maturity of 73.62 cm, a biomass yield of 6,316.39 kg per hectare, and a grain yield of 2,295 kg per hectare (Table IV). Notably, applying 1 tone of compost along with half the recommended amounts of N and P resulted in even higher yield increases compared to the first year (Table IV). In Dahana, the recommended nitrogen and phosphorus application achieved the highest grain yield of 1,508.33 kg per hectare, a biomass yield of 5,152.78 kg per hectare, and a plant height at maturity of 91.49 cm. This was closely followed by the combination of 1 tone of compost with half the recommended nitrogen and phosphorus (Table IV).

TABLE IV. MEAN BIOMASS AND GRAIN YIELD OF FIVE COMBINATIONS EVALUATED AT LALIBELA AND DAHANA IN THE FIRST YEAR CROPPING SEASON.

Treatment	Lalibela			Dahana		
	Ph(cm)	*By(kgha^{-1})*	*Gy(kgha^{-1})*	*Ph(cm)*	*By(kgha^{-1})*	*Gy(kgha^{-1})*
41N+46P_2O_5	73.6^{a}	6316.4^{a}	2295^{a}	91.5^{a}	5152.8^{a}	1508.3^{a}
1toncompost+20.5N+23P_2O_5	54.6^{b}	4579.4^{b}	1545^{b}	76.4^{c}	3383.3^{c}	989.7^{b}
13.7N+15.3P2O5+3ton compost	52.5^{b}	2023.9^{c}	727.8^{c}	73.1^{d}	4111.1^{b}	903.6^{b}
5 ton compost	51.7^{b}	1945.8^{c}	544.4^{d}	80.7^{b}	3444.4^{c}	955.6^{b}
No fertilizer	55.8^{b}	1213.6^{d}	336.7^{e}	65.8^{e}	1911.1^{d}	675.0^{c}
Mean	57.7	3215.8	1089.8	77.5	3600.6	1006.4
CV (%)	8.6	1.3	3.3	0.7	1.7	6.0

Note;-Ph-plant height; By-biomass yield; Gy-grain yield and Cm-centimeter; Kg-Kilo gram; ha-hectare; Ton-tone

A two-year combined analysis of different locations revealed that applying the recommended amounts of nitrogen and phosphorus maximized both the grain and biomass yields of barley (Table V). Significant differences were noted among the treatments ($P < 0.05$) in terms of plant height at maturity, biomass, and grain yields (Table V and VI). The results showed that using one tone of compost along with half of the recommended amounts of nitrogen and phosphorus fertilizer resulted in significantly higher grain yield, biomass yield, and plant height at maturity (Tables V and VI).

TABLE V. MEAN BIOMASS AND GRAIN YIELD AT LALIBELA AND DAHANA COMBINED OVER YEARS CROPPING SEASON.

Treatment	Lalibela			Dahana		
	Ph(cm)	*By(kgha^{-1})*	*Gy(kgha^{-1})*	*Ph(cm)*	*By(kgha^{-1})*	*Gy(kgha^{-1})*
41N+46P_2O_5	82.8^{a}	4887.4^{a}	1769.7^{a}	99.9^{a}	5832.6^{a}	1518.0^{a}
1toncompost+20.5N+23P_2O_5	62.6^{b}	3249.7^{b}	1071.1^{b}	87.4^{d}	5112.5^{b}	1342.0^{b}
13.7N+15.3P2O5+3ton compost	61.5^{b}	1860.9^{c}	683.3^{c}	89.5^{c}	5008.9^{b}	1214.0^{cb}
5 ton compost	60.3^{b}	1509.3^{d}	495.8^{d}	93.2^{b}	4968.1^{b}	1111.4^{c}
No fertilizer	64.5^{b}	1004.4^{e}	368.1^{e}	79.5^{e}	3409.7^{c}	940.0^{d}
Mean	64.4	2502.4	877.6	89.8	4866.4	1225.1
CV (%)	6.6	2.6		1.5	4.6	9.8

NOTE;-PH-PLANT HEIGHT; BY-BIOMASS YIELD; GY-GRAIN YIELD AND CM-CENTIMETER; KG-KILO GRAM; HA-HECTARE; TON-TONE

TABLE VI. MEAN BIOMASS AND GRAIN YIELD AT LALIBELA AND DAHANA COMBINED OVER YEARS CROPPING SEASON

Treatment	Ph(cm)	By(kgha^{-1})	Gy(kgha^{-1})
41N+46P_2O_5	91.4a	5360.0a	1643.8a
1toncompost+20.5N+23P_2O_5	74.9b	4181.1b	1206.6b
13.7N+15.3P2O5+3ton compost	76.8b	3238.7c	803.6d
5 ton compost	75.5b	3134.7c	948.9c
No fertilizer	72.0c	2207.1d	654.0e
Mean	78.1	3684.4	1051.3
CV (%)	3.3	7.9	10.7

Note;-Ph-plant height; By-biomass yield; Gy-grain yield and Cm-centimeter; Kg-Kilo gram; ha-hectare; Ton-tone

IV. RECOMMENDATION

In general, recommended rates of nitrogen and phosphorus fertilizers resulted in higher yields compared to combinations of compost with these fertilizers. However, compost has the added benefit of improving the physical and chemical properties of the soil. In dry-land areas, rainfall can be erratic and unpredictable, often leading to crop failures. Given the low moisture levels, relying solely on nitrogen and phosphorus fertilizers can be risky. Therefore, the best approach is to combine compost with nitrogen and phosphorus fertilizers. Applying one ton of compost along with half the recommended rates of nitrogen and phosphorus provides yields of grain and biomass comparable to those achieved with the full recommended rates. Additionally, this combination gradually enhances the soil's physical and chemical properties over time. Considering the economic circumstances of farmers, particularly their limited capacity to purchase fertilizers, it is advisable to recommend half the standard rates of nitrogen 20.5kgha^{-1} and 23kgha^{-1} P_2O_5 alongside one ton of compost. This recommendation is specifically for the Wag-himira and Lasta highland areas, as well as similar agro-ecological regions where barley is cultivated.

ACKNOWLEDGMENT

I want to express my gratitude to the Amhara Regional Agricultural Research Institute (ARARI) and Sekota Dry-Land Agricultural Research Centre for their financial support in conducting this study.

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