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Original Research Article

Impact of Combined Vermicompost and Inorganic Fertilizers on Bread Wheat Yield, Yield Component and Soil Properties in Sinana District, Bale Highlands, Ethiopia

Regassa Gosa[1*], Tesfaye Ketema[1], Mulugeta Eshetu[1], Girma Getachew[1]

[1]Sinana Agricultural Research Center, Oromia Agricultural Research Institute P. O. Box 208, Bale-Robe, Ethiopia

***Corresponding author:** Regassa Gosa

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Abstract: A field experiment was made to evaluate the effects of organic and inorganic fertilizers on the growth and yield of wheat and soil chemical properties. The study was conducted for two consecutive cropping seasons (2023-2024) on farmers' fields in the Sinana district of Oromia National Regional State. Therefore, this study has attempted to evaluate the effect of the integrated use of vermicompost and inorganic fertilizer on bread wheat production and soil fertility improvement in the study area. Fertilizer source organic Sources of nutrients both included (vermicompost) and inorganic fertilizer (urea and NPS) were used in the integrated form. These treatments consist of: T_1 = Control (no input) T_2 = Recommend NP, T_3 =25% RVC + 75% N + Rec P, T^4 =100% RVC + rec P, T_5 =50% RVC + 50% N + rec P and T_6 =75% RVC + 25% N + Rec P. The experiment was a randomized complete block design with three replications. Soil sampling and agronomic data on wheat grain yield and yield components were collected. Accordingly, the highest mean grain yield (5403.67kgha^{-1}) was recorded from the plot of T2 (Recommended rate from inorganic) flowed by (5186.00 kgha^{-1}) was recorded from T3 (25% RVC + 75% N + Rec P) while the lowest grain yield (2637.67 kgha^{-1}) was recorded from control plot. The partial budget analysis was performed for alternative uses of integrated organic and inorganic fertilizer applications for bread wheat production. The results showed that the application of integrated vermicompost with recommended rates of inorganic NP significantly increased the yield and yield components. It can be concluded that the application of integrated vermicompost and recommended rate of inorganic NP fertilizers (25 % Equivalent N from + 75 % N + Rec P is desirable) based on environmental sustainability for future productivity. This experiment has to be repeated over seasons and locations to make conclusive recommendations for the study area.

Keywords: Compost, Vertosol, Nitrogen, Phosphorus, Vermicompost and Bread Wheat.

1. INTRODUCTION

In Ethiopia, smallholder farmers cultivate wheat (*Triticum aestivum* L.), one of the most significant cereal crops, in rainfed circumstances. In terms of area coverage, it comes in second to barley in high-altitude regions and tef (*Eragrostis tef*) in mid-altitude regions. At 2.5 t ha-1, wheat productivity is often low [1]. Reduced soil fertility, insufficient fertilizer use, and a dearth of rust disease-resistant cultivars are the causes of this [2, 3]. This is particularly true for N and P nutrients because grains are continuously grown and fertilizer use is minimal [4].

However, because it reduces some of the negative impacts of organic wastes in the soil, new thermophilic composting techniques have gained a lot of popularity. According to Hoitink and Keener [5], it is also an economical and environmentally responsible method of treating a variety of organic wastes. Vermicomposting is the term for the composting process that is aided by earthworms in the compost pile. However, since thermophilic composting removes some of the negative impacts of organic waste in the soil, new techniques have gained a lot of popularity. For the treatment of numerous organic wastes, it is also an economical and ecologically responsible method [5]. Vermicomposting is the term for the composting process that is aided by the earthworms present in the compost heap.

Earthworms and microorganisms transform organic resources into rich soil amendments with

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significantly higher microbial activity and nutrient availability through a non-thermophilic process. In comparison to conventional composts, vermicomposting can greatly enhance the chemical and physical characteristics of soils [6].

Increased application of N fertilizer is regarded as one of the main strategies for raising Ethiopia's wheat crop output, according to Asnakew *et al.*, [2]. Asif *et al*., [7], concluded that raising N fertilization levels considerably enhanced the number of grains per spike, biomass, and fertile tillers per unit area. This experiment was, therefore, carried out with objective of to evaluate effects integrated organic and inorganic fertilizers on yield and yield components of bread wheat production and to determine effects of integrated organic and inorganic fertilizers on soil Physicochemical properties of the study area.

2. MATERIALS AND METHODS

2.1 Description of the Study Area

The experiment was carried out in the Sinana district, which is over 460 kilometers away from Addis Ababa, the capital. Geographically, the Sinana region extends between 39°55'0"E and 40°20'50"E and 6°48'20"N and 7°21'40"N. At an elevation of 1700 to 3100 meters above mean sea level, the area is topographically composed of a gently undulating plain (Fig. 1).

Crop agriculture is the district's primary economic activity and the main source of their livelihood income. The district's primary crops are field peas, faba beans, wheat, barley, and others [8]. The average temperature ranges from 10.72°C at the lowest to 21.98°C at the highest [8]. The region is distinguished by bimodal mean monthly rainfall, with monthly totals ranging from 8 to 160 mm and annual totals from 452.7 and 1129.5 mm.

2.2 Experimental Design and Treatments

Two phases were used to conduct the experiment. In phase one (1) of this study, vermicompost production and worm multiplication were conducted, and in phase two, the nutritional equivalency of vermicompost was characterized. The experiment was carried out in the Sinana area at various locations during phase two (2). The randomized complete-block design (RCBD) was used for field tests with three replications on farmers' fields in 2023 and 2024. On a 9 m2 (3 m x 3 m) plot, the test crop was bread wheat (dambal variety), with a suggested seed rate of 150 kg ha-1. Typically, six treatment levels are combined and integrated in the following ways:

- T1 = Control (no input)
- T2 = Recommend NP
- T3 =25% RVC + 75% N + Rec P
- T4 =100% RVC + rec P
- T5 =50% RVC + 50% N + rec P
- T6 =75% RVC + 25% N + Rec P

Where, NP: was nitrogen and phosphorus, RVC: recommended vermicompost

2.3 Soil Sample and Laboratory Analysis

Before applying a treatment, composite surface soil samples were taken from experimental fields that ranged in depth from 0 to 20 cm. Likewise, following crop harvest, soil samples were taken from each plot and composited by replication to provide one representative sample for each treatment. pH, organic carbon (OC), total N, and accessible P were measured in the collected samples. Using a pH electrode, the soil's pH was measured at a 1:1 (w/v) ratio to water (Tekalign, 1991). Total N was computed using the Kjeldahl method (Tekalign, 1991), and organic carbon was calculated using the Walkley and Black [9], method. Available P has been determined using Bray and Kurtz's [10], methods.

2.4 Data Collection and Analysis

The amount of bread wheat and its components, including biomass yield (kg), grain yield (kg), number of tillers, plant height (cm), seed spike length (cm), and number of seeds per spike, were measured. Using the EXCEL computer program, the gathered soil and agronomic data from several sites was appropriately maintained. The R software version 4.3.1's linear model was then used to do an analysis of variance (ANOVA).

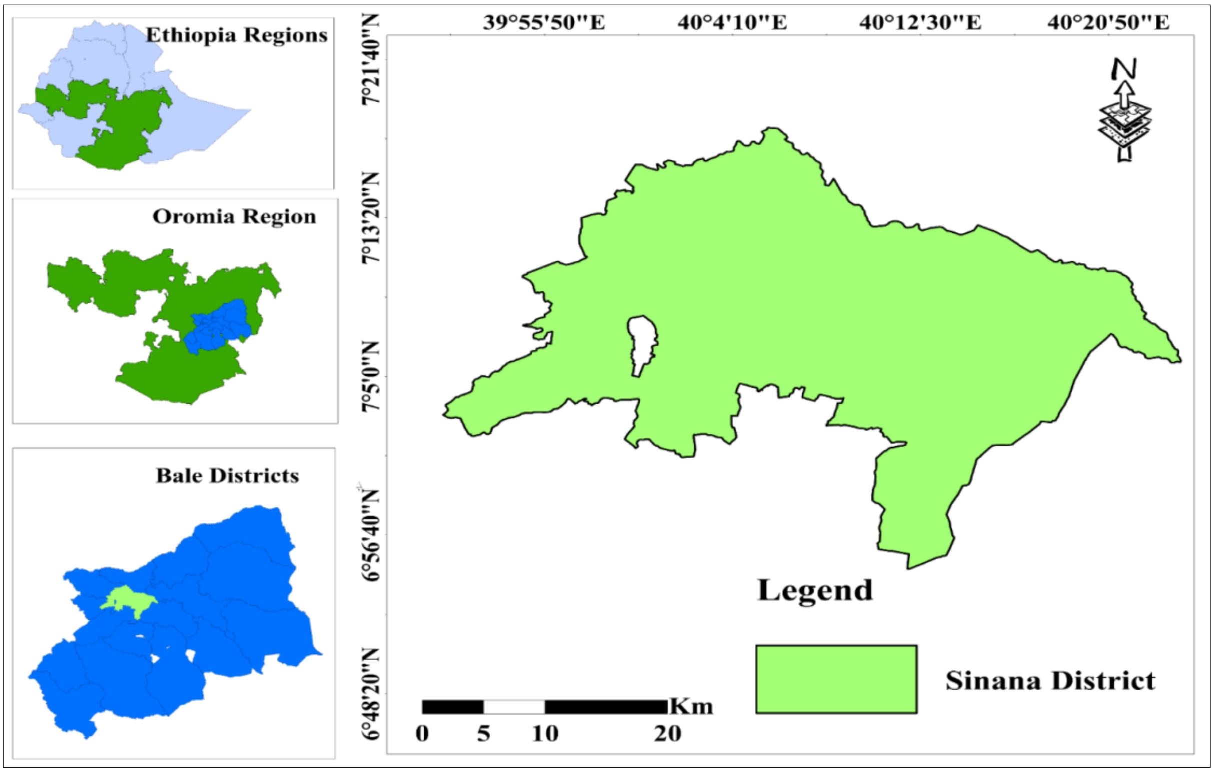

Fig. 1: Map the study site

Grain yield, aboveground total biomass, plant height, and spike length (average of five plants) were the plant parameters that were collected. Plant samples from ten central rows (2 m x 4 m = 8 m2) were used to calculate grain and biomass yield. Five randomly chosen plants per plot were measured for height (in cm) from the soil surface to the crop's tip at full maturity. A moisture content of 12.5% was applied to the grain yield before weighing and statistical analysis.

2.5 Partial Budget Analysis

Economic information has been collected to evaluate the advantages and disadvantages of various treatments, partial budget, dominance, and marginal analyses using the methodology outlined by CIMMYT [11]. The discrepancy between the experimental output and the estimated production of farmers from the same treatment was reflected in a 15% downward adjustment to the average yield. This is because, even when conducted on-farm under typical conditions, experimental yields are frequently higher than what farmers may anticipate from the same treatments. Gross yield benefits were calculated using the adjusted yields and the average wheat price for the two years (2023–2024). Daily labor and fertilizer expenses were also deducted from the research areas.

3. RESULTS AND DISCUSSION

3.1 Effects of Fertilization on Soil Chemical Properties

Before planting, samples of composite surface soil (0–20 cm) were taken from each replication, and a few physico-chemical characteristics were examined. Clayey is the textural class of soil that was found, and its percentages were clay (33%), silt (53%), and sand (17%). With special reference to the pH (6.43), which indicates moderately acid according to Bruce and Rayment (1982), the investigation of a few selected soil chemical characteristics and parameters demonstrated that all of them are classified as low according to the standard rating as shown in Table 1. According to Tekalign's [12], classification of soil total nitrogen (0.083), available phosphorus (2.64), and soil organic matter (1.66), the studied area's soils were categorized as having very low levels of organic carbon and available phosphorus. This finding revealed the poor availability of each parameter, demanding the need of integrated fertilizer application from various sources.

The application of various rates of organic and inorganic fertilizers had an impact on the chemical characteristics of the soil, including pH, OC, OM, total N, and accessible P, as evaluated for samples collected after harvest (Table 2). A wide range of chemical and biological processes that take place in soils are influenced by the pH of the soil, which also represents the soil's general chemical condition. The pH value of 6.46 was the lowest recorded from the control plot, whereas 6.54 was the lowest recorded from the combination of 50% RVC + 50% N + rec P. The study's research revealed that, according to Bruce and Rayment's (1982) suggested soil pH rating, the soil was slightly acidic, falling between 6.46 and 6.54.

This finding coincides with studies by Ano and Ubochi [13], and Eghball *et al*., [14], that found that adding compost and animal dung raised the pH of the soil.

50% RVC + 50% N + rec P recorded organic carbon (2.64), whereas 25% RVC + 75% N + rec P recorded organic carbon (2.98). The study's findings suggested that the soil had a high organic carbon range rating, as suggested by Charman and Roper (2000).

According to Charman and Roper's (2000) recommendations, the soil had a low organic matter range rating, with the control plot having the lowest organic matter (1.61) and the 25% RVC + 75% N + Rec P plot having the highest (1.73).

Table 1: Soil physicochemical properties of the experimental site before planting

Soil physical properties	**Sand (%)**	**Silt (%)**	**Clay (%)**	**Textural Class**
	17	**53**	**33**	**Clayey**
Soil chemical properties	pH	OM (%)	TN (%)	Av. P (ppm)
	6.43	1.66	0.083	2.64

Where, OM = soil organic matter, TN= total Nitrogen, Av. P = Available Phosphorus

Table 2: Effect of treatments on same soil chemical properties after harvesting

Treatments	**pH (H2O)**	**OM (%)**	**OC (%)**	**TN (%)**	**Av. P(mgkg-1)**
Control (no input)	6.46	1.61	2.77	0.14	2.21
Recommend NP	6.51	1.49	2.56	0.19	7.275
25% RVC + 75% N + Rec P	6.44	1.73	2.98	0.21	14.05
100% RVC + rec P	6.54	1.53	2.64	0.33	18.2
50% RVC + 50% N + rec P	6.44	1.58	2.72	0.24	13.33
75% RVC + 25% N + Rec P	6.53	1.59	2.74	0.27	14.05

Total Nitrogen was highest in the 100% RVC + rec P plot and lowest in the control plots (0.14) and (0.33). The study's research indicated that, according to Bruce and Rayment's (1982) Total Nitrogen rating, the soil was in the low to medium range (0.14-0.33). Based on the (Hazelton, 2007). rating system, the study's analysis revealed that Available Phosphors ranged from very low to high, with the lowest being recorded from the control plot (2.21) and (18.2) and the highest being reported from 100% RVC + rec P.

According to Gichangi and Mnkeni [15], and Agbenin and Igbokwe [16], humic nutrients improve the absorption and utilization of P fertilizers in acidic soils, while organic additions have been shown to boost P availability in P-fixing soils [17]. This outcome is in line with a study by Kasahun *et al*., 2019. That found that plots treated with compost had significantly higher levels of total nitrogen, available phosphorous, potassium, CEC, and soil organic carbon following the first crop harvest than plots treated with only inorganic fertilizer.

Since no fertilizer was given to the control plots, this could be linked to the high nitrogen content of organic fertilizers. It could also be related to the farmers' historical cropping practices. The kind and quantity of organic colloids found in the soil generally had a direct impact on TN and OC.

3.2 Effects of Integrated Nutrient Application on Wheat Yield and Yield Components

Plant height, spike length, 1000 seed weight, total biomass, and grain production all varied significantly between treatments, according to the combined Analysis of Variance (ANOVA). The treatment (T2), which was Recommend NP, produced the longest spike (5.77 cm), while the control plot produced the shortest spike (4.79 cm) (Table 3). This supports the findings of Gooding and Davies [18], and Mekonen and Kasahun (2024), who asserted that spike length markedly increased with nitrogen.

3.2.1 Plant Height

The treatment plots differed statically in terms of plant height. The treatment (6), which is 75% RVC + 25% N + Rec P, had the lowest plant height (69.47 cm), whereas the maximum plant height (78.53 cm) was observed from the Recommend NP (Table 3). The current study supported the findings of Rehman *et al*., [19], who found that adding farm manure exceeded the control in terms of plant height. This finding is supported by the substantial impacts of integrated nutrition management on bread wheat plant height reported by Mekonen and Kasahun (2024).

3.2.2 Grain Yields

There are statistical differences between the treatments in the grain yield as well. Grain yields from 25% RVC + 75% N + Rec P were the highest at 5186 kg/ha, whereas the control plot produced the lowest at 2637.67 kg/ha (Table 3). The results of this study aligned with those of Rehman *et al*., 2016 and Mekonen and Kasahun (2024), who found that the use of vermicompost combined with chemical fertilizer greatly enhanced the yield of wheat grain and straw. Similar studies also found that the plots treated with compost and inorganic fertilizer had higher maize grain yields during the first cropping season [20, 21]. Vermicompost can help improve root growth, nutrient absorption, and the macro and micronutrient condition of the soil, which may lead to increased grain output [22].

Therefore, rather than delivering nutrients from a single source, the results of this study have made it abundantly evident that a combination or multiple nutrient treatment technique can fairly boost wheat output. Research findings from Tekalign Mamo *et al*., [12]. Getachew Agegnehu *et al*., [23]. Kasahun and Abay (2019); Wakene *et al*., [21]. Mekonen and Kasahun (2024), and Tesfaye *et al*., (2024) are consistent with the current outcome. shown that under farmers' field conditions, wheat has responded significantly to combined soil fertility management treatments that contain both organic and inorganic forms, suggesting that they could be taken into consideration as alternate options for sustainable soil and crop productivity in Ethiopia's degraded highlands. Furthermore, depending on the kind of soil, the crop has reacted differently to N and P applications [24, 25].

3.3 Economic Analysis

Partial budget analysis was executed undertaken to determine the profitable treatments as farmers tried to assess the financial advantages of changing their practices. To reflect the difference between the experimental yield and the yield that farmers may anticipate from the same treatment, the yield from on-farm experimental plots was reduced downward by 15%, or 10% for management difference and 5% for plot size difference. Table 4 presents the findings of the partial budget study. TR2, which applied simply Recommend NP, had the highest MRR (1560%), followed by TR3, which applied 25% RVC + 75% N + Rec P, which had the highest MRR (1477%). However, treatments with maximal NB will be suggested for those whose MRR exceeds the minimum acceptable rate of return (100%).

As a result, both treatments (treatments 2 and 3) have above-acceptable rates of return (100%), and both treatments are economically feasible. Treatment 2 also provides the biggest net benefit (282798.18 ETB). Treatment 3 (25 percent RVC + 75 percent N + Rec P) was deemed environmentally impact-friendly and economically viable for an extension in Sinana district.

Because it is environmentally viable for Sinana soil productivity to be sustained at 25% RVC + 75% N + Rec P, farmers in Sinana and similar agroecology adopted this combination to produce bread wheat.

Table 3: Effects of organic and inorganic fertilizers application on wheat yield and yield component

Treatments	PH (cm)	SPL (cm)	SPS	NT	BM (ton/ha)	GY (kg/ha)
Control (no input)	70.27c	4.79b	40.47ab	1.93	10.20b	2637.67e
Recommend NP	78.53a	5.77a	43.00a	2.20	12.80a	5403.67a
25% RVC + 75% N + Rec P	72.60bc	5.47ab	40.40ab	2.13	11.73ab	5186.00a
100% RVC + rec P	76.33ab	5.20ab	40.13ab	1.93	11.73ab	4084.67c
50% RVC + 50% N + rec P	76.60ab	5.13ab	42.67a	2.13	11.53a	4656.33b
75% RVC + 25% N + Rec P	69.47c	4.79b	38.13b	1.73	10.67b	4224.67c
Mean	73.25	5.17	40.76	2.25	11.45	4241
LSD (0.05)	4.80	0.71	4.50	NS	1.84	378.05
CV (%)	3.74	7.90	6.30	23.38	9.17	15.09

Whereas PH: plant height, SPL: spike length SPS: seed per spike NT: number of tillers, BM: biomass GY: grain yield

Table 4: Partial budget and dominance analyses of organic and inorganic fertilizers trial on wheat

Trt	UnGY (kgha-1)	AGY (kgha-1)	GB (ETB)	TVC (ETB)	NB (ETB)	MRR (%)
Control (no input)	2637.67	2373.90	142434.18	0	142434.18	-
Recommend NP	5403.67	4863.30	291798.18	9000	282798.18	1560
25% RVC + 75% N + Rec P	5186.00	4667.40	280044	8725.50	271318.5	1477
100% RVC + rec P	4084.67	3676.20	220572.18	7900.00	212672.18	889
50% RVC + 50% N + rec P	4656.33	4190.70	251441.82	8450.00	242991.82	1190
75% RVC + 25% N + Rec P	4224.67	3802.20	228132.18	8174.50	219957.68	948

TVC= total variable cost; NB= net benefit; MC= marginal cost; MB= marginal benefit and MRR= marginal rate of return

Both MRR are above the required amount so in terms of their environmental impact TR3 increases the soil fertility in was increase and increases its OM and OC as well as the water holding capacity of the soil while TRT 2 (Recommend NP) was vise verse. Therefore, the results of this study TRT3 (25% RVC + 75% N + Rec P) are recommended for the farmer to use in terms of its impact on the environment.

4. CONCLUSION AND RECOMMENDATION

The results of this experiment suggested that, because the plots were fixed during the experimental period, the two years' results differed significantly from one another. This difference was most likely caused by seasonal variations and the carryover impact of the previous year's fertilizer application. Application of organic fertilizer enhanced soil pH, OC, total N, and accessible P, according to results of soil analysis conducted after harvest. The application of integrated vermicompost and the suggested rate of inorganic NP fertilizers (25 percent equivalent N from + 75 percent N + Rec P is desired) based on environmental sustainability for future production may therefore be inferred from the study's findings for the wheat crop. To provide firm suggestions for the study, this experiment must be conducted again in other seasons and areas.

Therefore, the most effective method to achieve higher fertilizer-use efficiency, maximum yield, and economic return of input is to apply chemical fertilizer and locally accessible organic fertilizer in combination or several applications rather than using either input type alone.

Disclaimer (Artificial Intelligence)

Author(s) hereby declare that NO generative AI technologies such as Large Language Models (ChatGPT, COPILOT, etc.) and text-to-image generators have been used during the writing or editing of this manuscript.

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