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Research Article

Demonstration of Integrated Applications of Site Specific NPS Fertilizer Recommendation with Vermicompost for Bread Wheat Production in the Burka Jiren Watershed Under Lime Condition

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Abstract

Degradation of physical properties caused as a result of the loss of soil organic matter and reduced presence and activity of soil organisms also occur in heavily polluted soils. The addition of vermicompost is used to increases organic matters in the soil. Therefore, this study was conducted to demonstration of integrated applications of site specific NPS fertilizer recommendation with vermicompost for Bread wheat production in the Burka Jiren watershed under lime condition. The experiment was implemented during 2024 crop season in Gechi district at Burka Jiren community watershed. The treatments was consisted two level; namely (T1) Blanket Recommendation (1:1 ratio of urea and NP respectively) and (T2) 1/2 Recommended vermicompost + 1/2 recommended N + recommended NPS). The collected data was analyzed using T-test and interpreted as mean and standard deviation by SAS software version 9.0. Results indicated that the grain yield of bread wheat was significance ($P<0.05$) influenced between two treatments. The highest grain yield (47.224 qt/ha) was recorded from treatment two which treated by 1/2 Recommended vermicompost + 1/2 recommended N + recommended NPS). However the lowest grain yield (23.625 qt/ha) was obtained from blanket recommendation of NPS fertilizer alone. The integrated use of Vermicompost with NPS fertilizer significantly increased the mean of soil pH from 5.0 to 5.26. Both treatments presented similar levels of organic carbon and total nitrogen. Farmers in the Burka Jiren community watershed should consider integrating agricultural lime with site specific NPS fertilizer to mitigate soil acidity and enhance crop productivity.

Keywords

Vermicompost, Bread Wheat, NPS Fertilizer, Urea

1. Introduction

Degradation of physical properties caused as a result of the loss of soil organic matter and reduced presence and activity of soil organisms also occur in heavily polluted [1]. It has been estimated that soil pH has reduced globally an average of 0.26 due to acid deposition and N additions. Soil acidification also enhances the mobilization and bioavailability

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of certain trace elements, increasing the risk to human health and the environment and decreasing crop growth [2].

Smallholder farmers in Africa typically only have access to blanket fertilizer recommendations which are defined over very broad areas and may not be optimal for local production conditions. Blanket fertilizers recommendations are used to encourage farmers adopt particular blends of fertilizer in Ethiopia. These recommendations, however, may not be optimal (or even suitable) for particular soil types or agro-climatic conditions within broad areas receiving such recommendations [3].

Soil degradation and nutrient depletion have been serious threats to agricultural productivity and food security in Ethiopia. Over the years, soil fertility has also declined due to the increase in population size and decline in plot size. Nitrogen (N) and phosphorus (P) are the nutrients that are most lacking [3, 4]. In 2007, the Ministry of Agriculture and Natural Resources (MoANR) and Agricultural Research Centers together developed regional or blanket fertilizer recommendations (fertilizer types and application rates for different crops). These recommendations inform farmers how much fertilizer in kilograms they should apply per hectare without performing any soil test and regardless of agro-ecological zones. Since nutrient management requirements of farms vary across crop type, soil type and other agro-ecological characteristics, these blanket fertilizer recommendations may not be suitable for all farmers. The adoption of fertilizer remains low and the average application rates by those who do use fertilizer are generally lower than recommended rates [3]. Bread wheat (Triticum aestivum L.) is one of the most important cereal crops playing a vital role in the country's economy, food security, and consumption. In Ethiopia, wheat covers an estimated area of 1.7 million ha with total annual grain production of 4.6 million tons by 4 million smallholder farmers. In terms of area of production, wheat ranks fourth after tef (Eragrostis tef [Zucc.] Trotter), maize (Zea mays L.) and Sorghum (Sorghum bicolor L.) and third in total grain production after tef and maize in Ethiopia [5]. However, the productivity of wheat is still low with a national average yield of 3 t ha^{-1} stations, i.e., 5 t ha^{-1} compared to yields obtained from the research [6].

Integrated soil fertility management is a set of soil fertility management practices that necessarily include the use of fertilizer, organic inputs, and improved germplasm combined with the knowledge on how to adapt these practices to local conditions, aiming at maximizing agronomic use efficiency of the applied nutrients and improving crop productivity [7].

Lime is a soil conditioner and controls the soil acidity by neutralizing the effects of acids from nitrogen (N) fertilizer, slurry and high rainfall. Other benefits include an increase in earthworm activity, improvement in soil structure and grass is more palatable to livestock [3].

The primary reason to apply agricultural lime is to correct the high levels of acidity in the soil as acid soils reduces plant growth by inhibiting the intake of major plant nutrients -nitrogen, phosphorus and potassium. Some plants, for example legumes, will not grow in highly acidic soils.

Soils become acidic in a number of ways: Leaching of land caused by high rainfall levels, Minerals loss over time caused by crop removal Application of modern chemical fertilizers, which are the major contributors of acidified soil. Soil with pH below 5.5 and below 70% of saturation requires liming. Agricultural lime has good effects on soil as it increases the pH of acidic soil, provides a source of calcium and magnesium for plants, Permits improved water penetration for acidic soils and Improves the uptake of major plant nutrients (nitrogen, phosphorus, and potassium) of plants growing on acid soils [8].

Application of the mineral P fertilizer with other amendments can be used to improve P deficiency in acid soils. Even though the chemical fertilizers including mineral P are used to increase productivity for a certain time, their negative impacts coupled with their high cost have prompted the interest in the use of organic fertilizers as source of nutrients. Organic fertilizer application has been reported to improve crop growth by supplying plant nutrients as well as improving soil physical, chemical, and biological properties [9, 10].

Vermicompost is one of the stabilized, finely divided organic fertilizers with a low C: N ratio, high porosity, and high water-holding capacity, in which most nutrients are present in forms that are readily available for plants [11, 12]. Application of Vermicompost improves overall physical and biochemical properties, and at the same time, decreases exchangeable acidity which can support a release of plant nutrients in the acidic soils, promotes growth of plants and positive effect on growth and productivity of cereals and legumes. When it is compared with conventional compost, different research on Vermicompost indicated that Vermicompost very important in promoting plant growth from 50 to 100% over conventional compost and from 30 to 40% over chemical fertilizers. Therefore this demonstration initiated with these objectives: To demonstrate integrated use of site specific NPS fertilizer recommendation with vermicomposting and under lime condition as acid soil management practices and to improve farmers' awareness about integrated use of site specific NPS fertilizer recommendation with vermicomposting for Bread wheat production and under lime condition as acid soil management.

2. Materials and Methods

2.1. Descriptions of the Study Area

The watershed is situated in the Gechi district of Buno Bedele zone, southwestern Ethiopia (Figure 1). The specific place of the watershed is Bido Jiren Kebeles, and so the local communities named the watershed Burka Jiren Community Watershed. The watershed lies between 8°12'50.4" or 8°14'52.8 N latitudes and between 36°25'27.48" or 36°26'52.8" E longitudes. Burka Jiren Community Watershed is about 15 km from Gechi town in Gechi district and about 35 km from Bedele town in Buno Bedele zone. The watershed covers about 535.13 hectares, and 148 smallholder households benefit from the watershed. According to the Google Earth Pro software, the length of the Burka Jiren Community Watershed is about 6 kilometers from the watershed in-late to the outlet. Based on slope gradient, Burka Jiren Community Watershed is characterized mostly by slop, gently slop, and strongly slop. The dominant soil type of the watershed is nitisils, and the common crops produced by the communities are tef and wheat.

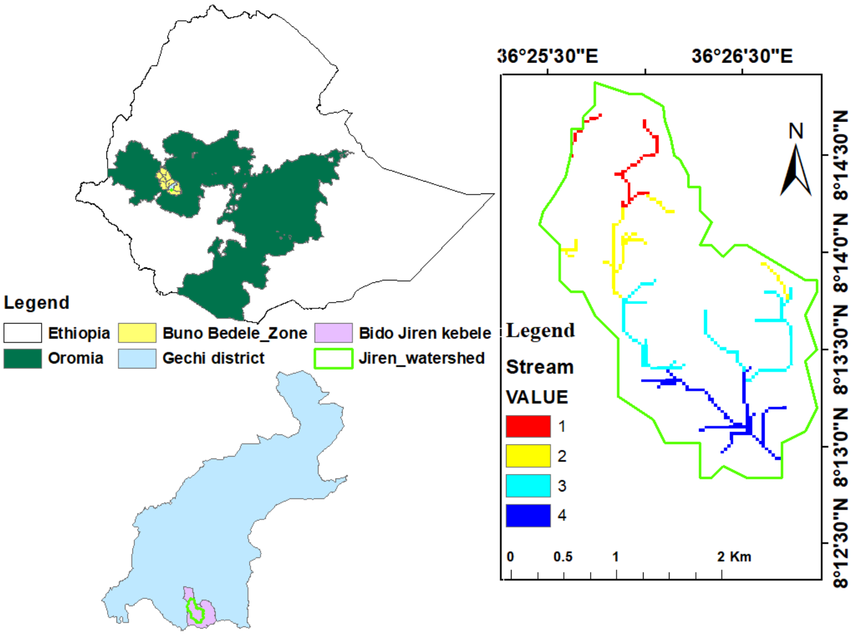

Figure 1. *Map of Burka Jiren Community Watershed.*

2.2. Sites, Farmer's Selection and Technology Promotion Events

The activity was conducted in purposively on four selected farmers from the watershed based on wheat production potential, for two years initial available phosphorus level of soil and their accessibility for determine the amount of P_2O_5 from NPS was determined. One FREG having 15 members (male and female) was established in each upper, middle and lower parts of the watershed. After, stablished of FREG four host farmers were selected among the FREG members and the activity were implemented on their farm land. The farmers Selection was done with collaboration of district experts and development agents. After the establishment of FREGs Mini-field day and training was provided for development agents, subject matter specialists (SMS) and FREG members on the use of site specific NPS Fertilizer with vermicompost on wheat production, management and its dissemination methods.

2.3. Experimental Design

The experiment consisted of two treatments namely (T1) Blanket Recommendation (1:1 ratio of urea and NP respectively) and (T2) 1/2 Recommended vermicompost + 1/2 recommended N + recommended NPS). The plot size was 10 m x 10 m (100 m^2) for each plot and the liben wheat variety was planted in rows. Recommended lime was broadcast manually and mixed thoroughly in upper soils at 20 cm depth (plow depth) to each plots. Amount of recommended N fertilizer kg/ha in vermicompost equivalent ratio of N in urea was calculated and was applied the recommended amount at sowing time. The experiment was conducted on four sites in sub-watershed.

2.4. Data to Be Collected

Soil data (pH, organic carbon (OC), total N, available P, CEC and exchangeable acidity) before and after applications. Agronomic data of grain yield and farmer's perceptions on integrated use of site specific NPS fertilizers and vermicopost was collected.

2.5. Data Analysis

The collected data was analyzed using T-test and interpreted as mean and standard deviation. Partial budget analysis was done to identify economically feasible recommended site specific NPS fertilizer with vermicompost and NPS fertilizer alone.

3. Results and Discussions

3.1. Soil Chemical Properties Before Planting of Experimental Field

The soil PH (H_2O) of the study sites were strongly to slightly acidic the value ranged from 4.7 to 5.52 with mean 5.0 (Table 1) according to the rating indicated by [13]. The available phosphorus contents of the soil were very low which ranged from 0.74 to 2 ppm with mean 1.3 ppm (Table 1) this results agreed with [13] indicated that the available Phosphorus which put under less than 5 ppm was very low. The results of organic carbon indicated medium with value ranged from 3.25 to 4.75% with mean 4.1% of organic carbon (Table 1) this obtained results linked with [13]. Looking this result the study area of soil needed additional organic material to full fill the educated level of the organic carbon. The gain results of Total Nitrogen of the study sites before planting was medium with value ranged 0.28 to 0.41% with mean 0.4% of TN (Table 1) it is also, agreed with [13] and Cation Exchange capacity of the soil ranged from 14.5 to 23 cmol (+)/kg soil, with the mean 16.6 cmol (+)/kg soil (Table 1) results shows medium level.

Table 1. *Soil Chemical Properties before Planting of Experimental Field.*

Sites	Site 1	Site 2	site 4	site 4	Mean
pH (H_2O)	4.9	4.7	4.8	5.52	5.0
Exchangeable Acidity (cmol (+)/kg soil)	2.96	2.69	2.32	0.12	2.0
Available Phosphorus (ppm)	1.64	2	0.74	0.98	1.3
Organic Carbon (%)	4.03	4.75	4.23	3.25	4.1
Total Nitrogen (%)	0.35	0.41	0.36	0.28	0.4
Cation Exchange Capacity (cmol (+)/kg soil)	14	23	14.7	14.5	16.6

The soil chemical properties of experimental sites after harvesting wheat, comparing two treatments:

The application of vermicompost significantly increased the mean of soil pH from 5.0 to 5.26, (Tables 1 & 2) demonstrating its effectiveness in reducing soil acidity. Organic Carbon and Nitrogen: Both treatments presented similar levels of organic carbon and total nitrogen, telling that Vermicompost application did not negatively influence these soil health indicators. The combined use of site specific NPS fertilizer and vermicompost improved soil pH (reducing acidity) without compromising organic carbon or nitrogen content, supporting better wheat production in acidic soils.

Table 2. *Soil Chemical properties of experimental sites after harvesting.*

Treatments	Mean of soil PH	Mean of organic carbon	Mean of total nitrogen
Blanket recommended of NPS and urea	4.98	3.36	0.26
Site specific NPS +½RN from urea + ½ RN from vermicompost	5.26	3.88	0.33

3.2. Participatory Mini-Field Visit Based Training for Participants

Participatory mini-field visit based training was given to participants on the concept and principles of FREG, the role and accountability of the FREG members in management of the trial, application of Site specific NPS Fertilizer with vermicompost and alone NPS fertilizer on wheat production and influence of vermicompost on selected soil chemical properties. Participants visit the trial field as all FREG members practice on their own field and whereas others share the experience. A total of 37 participants among which 33 farmers (29 male and 4 female), 2 DAs (1 male and 1 female) and 2 other concerned stakeholders (2 male and 0 female) were participated on field visit based training (Table 3).

Table 3. Stakeholders participated on field visit based training events.

Watershed	Participant	Male	Female	Total
	Farmers	29	4	33
Burka Jiren Community	DAs	1	1	2
	Other stakeholders	2	0	2
Total		32	5	37

3.3. Effects of Site Specific NPS-fertilizer with Vermicompost and NPS-fertilizer Alone on Wheat Grain Yield

The results of these study indicated that significance ($P<0.05$) difference between mean grain yield of bread wheat. The lowest mean grain yield (23.625 qt/ha) in Table 3 was observed from treatment one (T1) which was treated by farmer practice (blanket recommended of NPS and urea). Whereas, the highest mean grain yield (47.224 qt/ha) in Table 4 was obtained from treatment T2 (that treated by NPS + half of recommended N from urea + half of N from vermicompost recommended). The integrated approach (T2) nearly doubled the grain yield compared to T1, demonstrating its effectiveness for bread wheat production. The higher standard deviation in T2 suggests greater variability in yield outcomes, possibly due to factors like soil heterogeneity or management practices. Combining site-specific NPS fertilizer with vermicompost under lime conditions can substantially enhance wheat productivity. Similarly, the pre-sowing application of the vermicompost extract had the evidential impact on the grain yield [14]. This results also, agreed with [15] who stated that combined application of vermicompost and NPS fertilizers significantly increases grain yield. This suggests that the application of NPS fertilizer along with vermicompost (T2) had a real and measurable positive effect on wheat grain yield compared to the blanket recommendation (T1).

Table 4. The Effect of site specific NPS and vermicopost on bread wheat grain yield (qtha^{-1}).

Treatments	Mean grain yield (qt/ha)	Standard deviation
Blanket recommended of NPS and urea	23.625	4.1633
Site specific NPS +½RN from urea + ½ RN from vermicompost	47.224	9.6854
P-value	0.03	

3.4. Farmer's Preference of Wheat Production

Farmers selected T2 which treated by Site specific NPS +½RN from urea + ½ RN from vermicompost rather than blanket recommendation depending on the result obtained.

Table 5. Reason for preference of result obtained on wheat grain yield.

Treatments	Rank	Reason of farmers preference
Blanket recommended of NPS and urea	2nd	Medium performance of head, medium length, and medium headed yield
Site specific NPS +½RN from urea + ½ RN from vermicompost	1st	Very good performance than T1, full head, attractive green color, longer than T1 and long headed yield, changed soil color from red to black and believed to improve soil fertility and structure

3.5. Economic Partial Budget Analysis

The partial budget analysis of the treatments was done considering all variable costs and all benefits of grain yield. The analysis of marginal rate of return (MRR), revealed that the rate of return per unit cost of production was highest for application of site specific NPS + half of recommended N from urea + half of N from vermicompost recommended (% MRR =626). This showed that it would yield gave 6.26 Ethiopian Birr for every Birr invested. Thus, applications of site specific NPS + half of recommended N from urea + half of N from vermicompost recommended ha^{-1} of is economically beneficial as compared to the blanket recommendation of NPS with Urea treatments, because the highest net benefit (NB) and marginal rate of return (MRR) was above the minimum level (100%) (Table 6).

Table 6. *Partial budget analysis for the site specific NPS and Agricultural Lime on bread wheat grain yield.*

Variables	Treatments	
	Bread Wheat with Vermicompost application	**Bread Wheat without Vermicompost application**
Yield obtained (qt ha^{-1})	47.224	23.625
Sale price (ETB/qt)	8,000	8,000
Total Revenue (Price * Qt)	377,792	189,000
Variable Costs/ha in ETB.		
Land preparation	4,000	4,000
Seed purchase	6,500	6,500
Fertilizers purchase	7,838	7,838
Cost of lime	500	0
Cost of labor for weeding	3,200	3,200
Cost of labor for Vermicompost application	1,000	0
Cost of Labor for harvesting	3,300	3,300
Cost of Labor for threshing	4,000	4,000
Total Variable Costs	30,338	28,838
Cost of Land ETB/ha	30,000	30,000
Total cost (TVC + TF C)	60,338	58,838
Gross Margin (GM)=TR-TVC	347,454	160,162
Net Profit=TR-TC or GM-TFC	317454	130,162
Benefit-cost ratio=Total Revenue/Total Cost	6.26	3.21

4. Conclusions and Recommendations

The integrated use of site-specific NPS and vermicompost (T2) significantly increased wheat grain yield compared to the alone Site-specific NPS fertilizer (T1).

Farmers could potentially double their wheat yield by adopting this treatment, though further field trials may be needed to confirm consistency across different conditions.

Abbreviations

FREG	Farmers Research Extension Group
DAs	Development Agents
NB	Net Benefit
MRR	Marginal Rate of Return
ETB	Ethiopian Birr
Qt	Quintal
TVC	Total Variable Costs

TFC	Total Farmers Land Cost
GM	Gross Margin
TR	Total Revenue
P	Phosphorus
CEC	Catio Exchange Capacity
TN	Total Nitrogen

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Author Contributions

Bati Dube: Conceptualization, Formal Analysis, Investigation, Methodology, Writing – original draft

Amanuel Kejela: Data curation, Investigation, Validation, Visualization

Dechasa Mengistu: Data curation, Investigation, Software, Visualization, Writing – review & editing

Dagne Chimdessa: Project administration, Supervision

Gedefa Sori: Funding acquisition, Resources, Software

Conflicts of Interest

The authors declare no conflicts of interest.

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