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Original Research Article

Pre-Extension Demonstration of Phosphorus Fertilizer Recommendations Based on Soil Tests for Bread Wheat Production in the Sinana District, Bale Highland, Oromia, Southeastern Ethiopia

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Abstract: Participatory on-farm pre-extension demonstrations of soil test crop responses fertilizer recommendations were carried out for bread wheat production in the Sinana District. *The study aimed to evaluate and demonstrate* soil test crop responses fertilizer recommendations for bread wheat production and to enhance farmers' understanding and capabilities. The experiment was conducted across seven farmers' fields, with each field allocated 0.25 hectares per treatment. The treatments applied were based on specific recommendations using optimum nitrogen (46 $kgha^{-1}$), phosphors requirement factor (Pf) (5.24), phosphorus critical level (Pc) (22 ppm) using bread wheat Galan verity 150 $kgha^{-1}$ as test crop. During the experimental conducted in the Sinana District, two Farmer Research Groups (FRGs) having a total of 15 members were established. The results indicated that the highest grain yield of 60.325 $kgha^{-1}$ was achieved with soil test-based fertilizer recommendations, while the lowest yield of 44.25 $kgha^{-1}$ was obtained using traditional farmer practices. Soil test-based fertilizer recommendations significantly enhanced grain yield compared to traditional farmer practices, highlighting the effectiveness of targeted fertilizer application in optimizing crop production. Furthermore, the partial budget analysis demonstrated that soil test-based fertilizer recommendations yielded a net profit of 310,563.66 birr, with a remarkable marginal rate of return of 1190.83%. In contrast, the blanket recommendations used in traditional farmer practices were less profitable. Therefore, the dissemination of soil test-based fertilizer recommendations should be prioritized in the Sinana District and similar soil type and agroecology through scaling up and large-scale production is recommended.

Keywords: Bread Wheat, Farmers Preferences, Farmers Research Group (FRG), Fertilizer Recommendation, Soil Test.

INTRODUCTION

Soil fertility depletion is a critical issue hindering sustainable crop production, particularly in areas affected by inadequate fertilizer use, climate change, soil erosion, and poor management practices. The crop productivity can vary significantly across different areas of a field, and this variation is largely influenced by the inputs applied, which should ideally be based on the specific soil fertility status in each area. Tadesse *et al.,* (2016) highlights the importance of site-specific management practices, as uniform application of inputs might not optimize productivity across a field with variable soil fertility. Wheat production is significantly influenced by various factors, and soil fertility decline is one of the most critical. The continuous depletion of essential nutrients, due to factors like erosion, monocropping, and poor soil management, reduces the soil's capacity to support optimal wheat yields. Studies like those by Kihara *et al.,* (2022), Mulugeta *et al.,* (2022), and Devate *et al.,* (2023) emphasize how nutrient imbalances, declining organic matter, and suboptimal fertilization practices negatively impact wheat production.

Addressing soil fertility depletion is vital for achieving sustainable agricultural production. This can be accomplished through integrated approaches that focus on balanced fertilizer use, soil conservation techniques, and improved land management. Integrated soil fertility management (ISFM) practices, such as crop rotation, organic amendments, conservation tillage, and

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the implementation of soil and water conservation structures, can mitigate the adverse effects of climate change and soil erosion.

The principles the "4Rs" (the right rate**,** right source**,** right place**,** and right time) for fertilizer application are fundamental to achieving sustainable soil fertility management and optimizing crop yields. The application of environmentally sound and economically affordable fertilizers, guided by soil testing, is essential for sustainable crop production. Studies like those by Mulugeta *et al.*, (2022) and Mintesinot *et al.*, (2024) highlight the critical role of soil testing in determining the precise nutrient requirements for crops, thus optimizing fertilizer use.

The reliance on blanket fertilizer recommendations rather than soil test-based approaches has been a common practice in many parts of Ethiopia, including the Sinana District. This approach involves applying uniform rates of fertilizers across different soils and crops, without accounting for site-specific soil fertility conditions and crop nutrient requirements. However, studies like Mulugeta *et al.*, (2022) highlight that this method often leads to inefficiencies, such as over- or under-fertilization, which can either harm the environment or limit crop yields. In contrast, soil test-based fertilizer recommendations are couturier to the specific nutrient needs of the soil and crop, resulting in better nutrient use efficiency, higher yields, and more sustainable agricultural practices. In the case of the Sinana District, using soil test results, especially for phosphorus and nitrogen levels, is crucial for optimizing wheat production as seen in these research efforts.

Soil test-based site-specific nutrient management is indeed considered the most reliable method for replacing blanket fertilizer recommendations, as noted by Mengistu *et al.*, (2022) and Mulugeta *et al.*, (2022). According to Sonon and Zhang (2014), this calibration ensures that nutrient management practices are optimized for the best crop performance and resource use efficiency. The study by Mulugeta *et al.*, (2022) effectively verified the optimum nitrogen rate of 46 kg/ha, a critical phosphorus concentration (Pc) of 22 ppm, 100% Pc from NPS (182 kg ha^{-1}) and a phosphorus requirement factor (Pf) of 5.22 for wheat production in Sinana district.

Even though the introduction of new fertilizer recommendations derived from soil tests, there has been a lack or not conducted pre-extension demonstrations and widespread promotion of the technology for large-scale farming. This study aimed to demonstrate and evaluate the effectiveness of recently recommended phosphorus fertilizers based on soil tests for bread wheat production in the Sinana district. The research sought to create awareness among local farmers, assess the cost-benefit ratio of the recommended practices, and identify the best-performing fertilizer options through farmer participation. The ultimate goal was to recommend the most effective practices for further scaling up and broader application.

MATERIAL AND METHODS

Description of the Study Area

The experiment was carried out in the Sinana District, situated approximately 460 kilometers southeast of the capital city, Addis Ababa. Geographically, Sinana lies between latitude 6°48'20"N and 7°21'40"N, and longitude 39°55'0"E and 40°20'50"E. The district is characterized by a gently undulating plain with elevations ranging from 1,700 to 3,100 meters above sea level (masl). This varied topography and elevation contribute to the region's diverse agro-ecological conditions, influencing agricultural practices and crop performance.

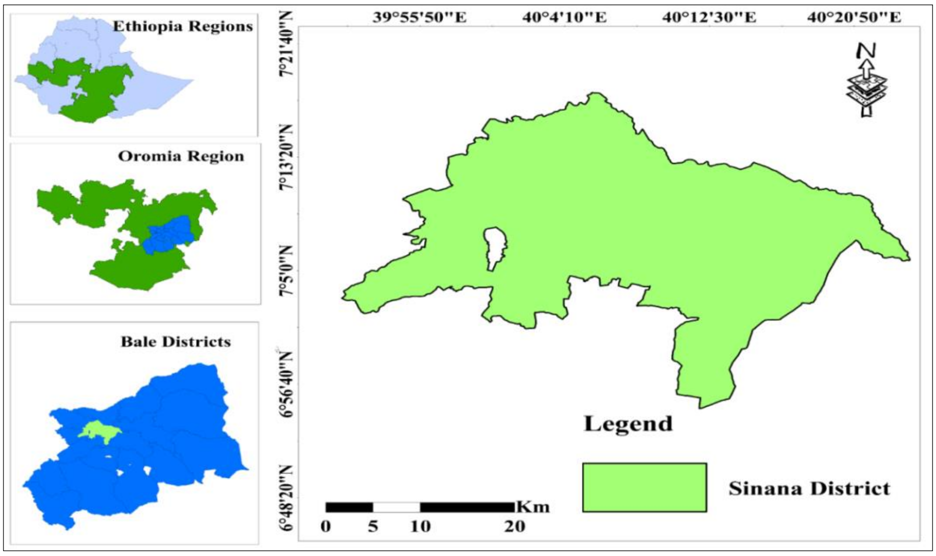

Figure 1: Map the study site

Climate

Sinana District experiences a bimodal rainfall pattern, which is divided into two distinct seasons local named as Bona and Ganna seasons. The Bona season runs from July to late December, while the Ganna season spans from mid-March to August. This bimodal rainfall pattern enables farmers to cultivate crops twice annually. The region has an annual average temperature ranging from 7.8°C to 23.9°C and receives approximately 1,045 mm of rainfall each year (Figure 2).

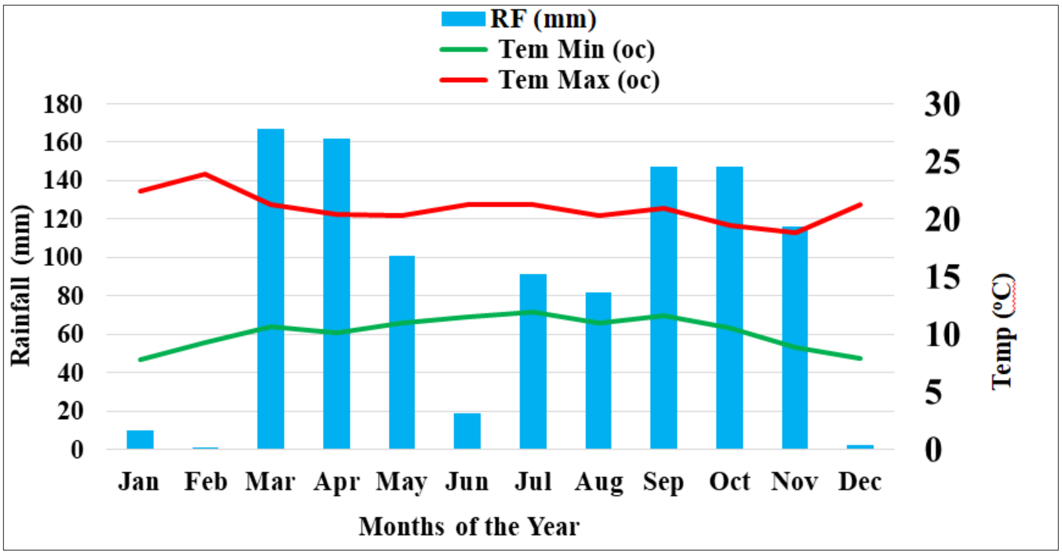

Figure 2: Rainfall and temperature distribution maps of the study area

Site and Farmers' Selection

Site Selection

Sinana District was chosen for this experiment due to its high potential for bread wheat production and the availability of prior soil test-based fertilizer recommendations.

Farmers' Selection

The selection of Farmer Research Group (FRG) members was based on several criteria: willingness to participate, accessibility for supervision, a positive history of group compatibility, and a genuine and transparent approach to sharing innovations with other farmers. As a result, two FRGs were established, each consisting of 15 members having 10 men and 5 women. These groups were formed in the Sinana and Robe areas to ensure diverse and effective engagement in the experimental activities.

Experimental Design and Setup

Two Farmer Research Groups (FRGs), each comprising 15 members (10 men and 5 women), were established in the Sinana and Robe areas to facilitate the implementation and management of the experiment. Optimum Nitrogen (N): 46 kgha$^{-1,}$ bread wheat Galan Varity at 150 kgha^{-1} seed rate, phosphorus requirement factor (Pf); 22 ppm and phosphorus critical level (Pc): 5.24 were used. The trials were carried out on seven farmers' fields, with each treatment applied to 0.25 hectares.

The experiment was conducted with two distinct treatments:

- **Treatment 1 (T1):** Blanket recommendation (farmer practices)
- **Treatment 2 (T2):** Soil test crop response-based fertilizer recommendation (STCRBPR)

Monitoring, Evaluation, and Field Visit

A field visit was organized to raise awareness among farmers, allowing them to share experiences and knowledge. Regular joint monitoring and evaluation activities were conducted throughout the crop growth stages. These follow-up actions were essential for addressing emerging needs, providing technical advice, and ensuring the proper implementation of the experiment. Continuous support and guidance were offered based on the evolving knowledge, skills, and technical requirements observed during the crop development stages.

Data Collected

Both qualitative and quantitative data were gathered using various methods, including focused group discussions (FGD), direct field observations, and measurements. The agronomic data collected included: plant height, number of productive tillers, spike length, seeds per spike, above-ground biomass and grain yield. These data points were recorded to assess the performance of the treatments and their impact on crop growth and productivity.

Farmers' Preferences and Selection Criteria

The demonstrated technologies were evaluated at crop maturity and validated by farmers, agricultural experts, development agents, researchers, and other stakeholders. The evaluation was based on a range of selection criteria, including: number of productive tillers, spike length, seeds per spike, grain yield and others. These criteria helped assess the overall performance of the technologies and their suitability for the farmers' needs and local growing conditions.

Data Analysis

The agronomic data collected during the experiment were analyzed using descriptive statistics in SPSS version 20. Key statistical methods included mean, frequency distribution, and percentages. In addition, farmer preferences were analyzed using a pairwise matrix and ranking methods to identify and select the best-performing technologies for bread wheat production. This approach helped pinpoint the most suitable technologies based on both quantitative data and farmer evaluations.

Yield Advantage Calculation

The yield advantage calculated using the following equation (1)

$$\text{Yield advantage } (\%) = \frac{(\text{STBFR (Kg ha } -1) - \text{BR Kg (ha}-1))*100}{\text{BR Kg (ha}-1)} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (1)$$

RESULTS AND DISCUSSIONS

Yield Performance of the Demonstrated Technology

The descriptive statistical analysis of the mean values from the demonstration of soil test-based fertilizer application revealed significantly better bread wheat parameters compared to blanket recommendations and traditional farmer practices.

Accordingly, the highest mean grain yield of bread wheat (6012.29 kg/ha) was achieved using soil test-based fertilizer recommendations, while the lowest mean yield (4434.61 kg/ha) was observed from traditional farmer practices (Table 1). This highpoints the significant advantage of adopting precise, soil-specific nutrient management strategies over blanket or traditional practices in maximizing wheat productivity. As a result the application of balanced fertilizers, and applied at optimum levels, significantly improves the vegetative growth and yield parameters of bread wheat. Consistent with this finding, Dejene *et al* (2020); Mulugeta *et al.*, (2022); and Mintesinot *et al.*, (2024) reported that the soil test-based fertilizer recommendation gave the highest yield of bread wheat as compared to the blanket recommendation.

The study's results further demonstrated a 35.58% yield advantage from the application of soil test-based fertilizer recommendations over the blanket recommendations. Consistent with this finding, previous research has reported similar yield benefits by Abera *et al.*, (2022) reported a 49.48% yield advantage, while Mintesinot *et al.*, (2024) documented a 17.98% yield improvement using soil test-based phosphorus fertilizer recommendations compared to blanket recommendations.

Table 1: Yield and yield component of bread wheat response to different fertilizer rates

Trt	Descriptive	PH (cm)	NT	SL (cm)	SPS	BM (kg ha^{-1})	GY (kg ha^{-1})
Farmer Particle	Mean	87.27	1.53	4.90	30.29	7642.86	4434.61
	StdDev	4.79	0.30	0.73	3.45	899.74	272.01
	Var	22.98	0.09	0.53	11.89	899.74	73989.66
STBCRFR	Mean	98.61	3.41	8.49	47.23	11142.86	6012.29
	StdDev	1.95	0.26	0.68	2.50	801.78	107.60
	Var	3.82	0.07	0.46	6.25	801.78	11578.29

Where:

Trt = Treatment, STBCRFR = Soil Test-Based Crop Response Fertilizer Recommendation, StdDev = Standard Deviation, Var = Variance, NT = Productive Tiller, SL = Spike Length, SPS = Seeds per Spike, BM = Biomass Yield and GY = Grain Yield.

Farmers training, Feedbacks and Preference

Awareness creation was given to different stakeholders on enhancing soil fertility through soil test-based fertilizer recommendations (Table 2). The field visit was conducted at the vegetative, grain filling, and maturity stages of the crop. Accordingly, farmer research group (FRG) members and others exchanged their experiences, gave feedback, and conducted research on technology preferences. The technology was demonstrated, evaluated at the crop maturity stage, and validated by farmers, agricultural experts, development agents, researchers, and other stakeholders using several selection criteria. These criteria included spike length, seeds per spike, plant height, and crop stand, biomass yield, and overall yield (Tables 2 and 3). Accordingly, the demonstrated soil test-based fertilizer recommendation performed well in all demonstration sites, and the participant farmers also selected the soil test-based fertilizer recommendation based on their own criteria (Table 3).

Table 2: Participant on field training, visit and farmer preference selection

No.	Participants	Male	Female	Total
1	Farmers	40	5	45
2	DA	4	-	4
3	SMS	6	-	6
Total		50	5	55

Where, DA = development agent, SMS = subject matter specialization

Table 3: Rank of Technology demonstrated based on farmers preferences

Treatments	Ranks	Reasons
STBCRFR	1st	Farmers ranked it first due to its high productive tillers, good disease tolerance, large spike length, a high number of seeds per spike, good crop stand, and high grain yield.
Farmer practices	2nd	Farmers did not choose or prefer it due to the relatively low number of productive tillers, limited disease tolerance, shorter spike length, fewer seeds per spike, weak crop stand, and lower grain yield.

Partial Budget Analysis

The partial budget analysis revealed that the most substantial net benefit of 310,563.66 birr, along with an acceptable marginal rate of return (MRR) of 1190.83%, was achieved through soil test-based fertilizer recommendations (see Table 4). This indicates that for each birr invested in bread wheat production using these tailored recommendations, producers can expect an additional net gain of 11.91 birr compared to using blanket fertilizer rates.

Table 4: Partial budget analysis

Trt	GY Kgha^{-1}	AGY Kgha^{-1}	GFB ETB ha^{-1}	TVC ETB ha^{-1}	NB ETB ha^{-1}	MRR (%)
FP	4434.61	3991.149	239468.94	7500.00	231968.94	D
STBCRFR	6012.29	5411.061	324663.66	14100.00	310563.66	1190.83

Where:

Trt= Treatments, FP = Farmer practices; STBCRFR= Soil Test Based Crop Response fertilizer Recommendation, GY= Grain Yield, AGY= Adjusted Grain Yield, GFB=Gross field benefit, TVC =total cost that vary, NB=Net benefit, MRR=marginal rate of return, BR= Blanket recommendation, STBFR= Soil test based fertilizer recommendation

CONCLUSION AND RECOMMENDATIONS

The pre-extension demonstration in the Sinana District aimed to showcase the optimal application rates for nitrogen (46 N kgha^{-1}), the phosphorus requirement factor (5.24), and the critical phosphorus concentration (22 ppm) necessary for successful bread wheat production. Consequently, the mean grain yield of bread wheat was highest (6,012.29 kgha^{-1}) for the soil test-based fertilizer recommendations while the lowest yield (4,434.61 kgha^{-1}) was observed from the blanket recommendations or farmer practices.

The results indicate that soil test-based fertilizer recommendations provide a yield advantage of 35.58% compared to blanket fertilizer applications or farmer practices. The partial budget analysis revealed that the highest net benefit of 310,563.66 birr, along with an acceptable marginal rate of return (MRR) of 1190.83%, was achieved through soil test-based fertilizer recommendations. In conclusion, the study demonstrated that soil test-based crop response fertilizer recommendations outperform both farmer practices and blanket fertilizer applications in terms of yield, net benefits, and marginal rate of return (MRR).

Therefore, it is recommended to adopt soil test-based fertilizer approaches that incorporate optimal nitrogen levels (46 kg N/ha), a phosphorus requirement factor (Pf) of 5.24, a critical phosphorus concentration (Pc) of 22 ppm, and 100% Pc from NPS at a rate of 182 kg/ha for bread wheat production in the Sinana District. Further scaling up and large-scale production should also be considered for sinana and similar soil types and agro-ecologies areas.

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