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Soil Test Based Crop Response Phosphorus Calibration Study for Bread Wheat Production in Sinana District of Bale Zone, Southeastern Ethiopia

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Abstract: Soil fertility decline as results of different factors and blanket fertilizer application throughout the country without considering soil types and agro-ecological are among the bottleneck to obtain sustainable desired yield. Therefore, this calls for site-specific soil nutrients managements and soil test based crop response fertilizer recommendations. Accordingly, soil test based crop response P calibration study for bread wheat production was conducted from 2011-2013 at Sinana district. The objective of the experiment was to determine economically optimum N, and to determine Phosphorus critical (Pc) and Phosphorus requirement factor for bread wheat production at Sinana district. A field trial were conducted in factorial combination of four levels of N (0, 23, 46 and 69 Kg/ha) and Six levels of P (0, 10, 20, 30, 40 and 50 Kg /ha) chemical fertilizer laid out in randomized complete block design with three replications on plot size 3 m x 3 m (9 m^2). Bread wheat (Sanate variety) with a seed rate of 150 kg/ha which had been recommended for area was used. Composite soil sample before plating and intensive soil samples after 21 days of sowing were taken from each plot then subjected to air-dried, prepared and analyzed for selected physicochemical properties following standard laboratory procedures. Phosphorus critical level (Pc) determination was done using C'ate-Nelson diagram method. Agronomic data such as plant height; tiller, seed per spike, biomass, grain yield and thousand kernel weight were collected then subjected to two way factorial analysis of variance (ANOVA) using R software while the partial budget analysis was done using CIMMYT (1998). The results revealed that both N and combined NP fertilizer rates significantly different among agronomic data taken for bread wheat. Accordingly; the optimum nitrogen rate (46 N kg/ha); the critical P (Pc) concentrations (5.24 ppm) and P (Pf) requirement factors (22) for bread wheat production have been determined, at Sinana District. Therefore, application of 46 N kg/ha fertilizer advisable for bread wheat productions in Sinana District as well as other areas having the same soil conditions and agro-ecology. In the feature works; farther verification of the values of Pc and Pf on farm field could be a pre request before disseminating the technology to the end user.

Keywords: Optimum N, Calibration, Critical P Concentration, P requirement Factor

1. Introduction

Crop production is controlled by numerous complex interacting factors which include soil fertility, pests and diseases, climate, and farmers' resourcefulness [7]. Soil fertility decline is one of the principal factors contributing to low crop production and agricultural productivity in which this lead food insecurity in Ethiopia [55]. Soil fertility declines due to removal through crop harvest, leaching, soil erosion by water in the form of surface runoff and cereal based mono cropping are among several restricting factors responsible for low crop yields and agricultural productivity.

Furthermore, Ethiopia is also one of the largest wheat producers in Sub-Saharan Africa in which approximately 80% of the wheat area is covered by bread wheat production [11]. Bread wheat (*Triticumaestivum*L.) is one of the most of the world and particularly in Sub-Saharan Africa like Ethiopia [40]. It is one of the major cereal crops grown that covers an estimated area of 1.69 million hector and production of about 4.5 million tons [20]. Wheat is main staple crops in terms of both production and consumption in Ethiopia particularly Bale highland is known by the wheat belt. It is one of the most important cereals cultivated in Ethiopia [32]. However; these current wheat production is inadequate to fill Ethiopia's needs due to low soil fertility; limited management practices and other factors [40]. Soil fertility degradation has been described as the most bottlenecks to food security in most countries, this indicated without maintaining soil fertility, it is impossible to obtained sustainable yield increment.

Nitrogen (N) and phosphorus (P) are considered as the most deficient nutrients in soils of Ethiopia [5]. Likewise, application of a large amount of N fertilizer has been a method of increasing yield which is costly and can cause environmental pollution [26]. Diammonium phosphate (DAP) and urea have been most of the chemical fertilizers used for crop production with initial understanding that nitrogen and phosphorus are the major limiting nutrients of Ethiopian soils in the form of blanket application. Phosphorus calibration is the way establishing a relationship between a given soil test value and the yield response from adding nutrients to the soil as fertilizer [1]. The calibrations study is specific for each crop type, soil type, soil pH, climate; plant species, and crop variety [3].

Soil test based site specific nutrient management curtail role to overcome the traditional blacken fertilizer application that not considers soil types, crop response and agro. Currently, in Oromia Agricultural Research Institute across Oromia by different centers under soil fertility improvement research team the calibrations study were conducted particularly for major crops such as maize; teff; wheat; food barely to brought our farming community towards site specific fertilizer recommendation. In the study area the blanket recommendations applications rather than exposing farmers to increased production costs cannot contribute toward improve the depletion soils plant nutrients and crop productions in sustainable manners. This calls for site-specific soil test based Crop Response Phosphorus Calibration Study in Sinana District of Bale Zone, Southeastern Ethiopia.

Supported with this idea [35] stated that site specific sound full soil test calibration is essential for successful fertilizer program and crop production. Based on this concept, soil test calibration study was conducted on bread wheat production at Sinana district from 2011 – 2013 with the objectives; to determine optimum N fertilizer, P-critical and P-requirement factor values for bread wheat production and develop soil test based P-recommendation guidelines for bread wheat productions in the Sinana districts.

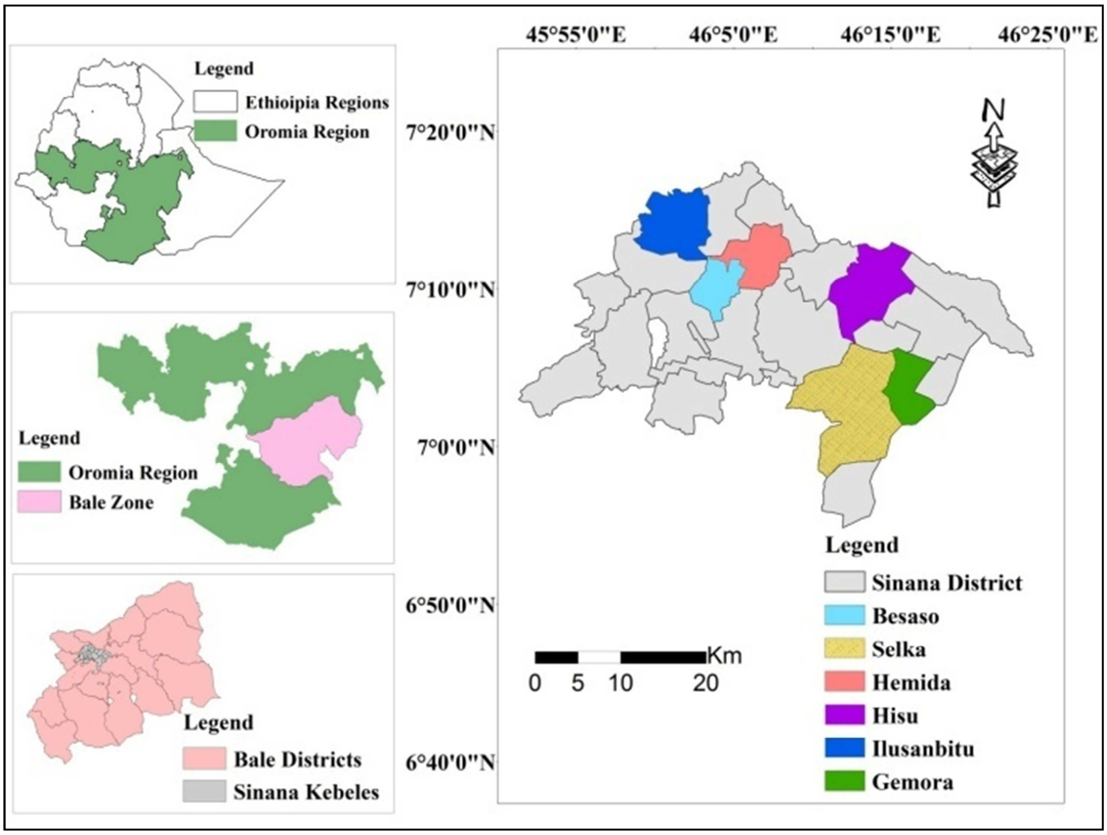

Figure 1. *Map the study site.*

2. Materials and Method

2.1. Descriptions of the Study Area

The study was conducted in Sinana District which is one of the Bale highlands Oromia Regional State, Southeastern Ethiopia. This District is bordered by Goro District in the east, Dinsho District in west, Agarfa and Gassera in the north and northeast and Goba District. Sinana district is located about 460 km from the capital city of Addis Ababa. Geographically, Sinana District is located at 6° 40' 0" to 7° 20' 0" N and 45° 55' 0" to 46° 25' 0" E. Topographically, the area consists of gently undulating plain with average slope gradient of 7%. It extends from 1700 to 3100 mean above sea level (masl).

2.2. Climate and Agro-ecology

Rainfall climatologically patterns of the area follow a bimodal distribution having SH2 (humid sub humid to cool mild highland) agro ecology. The area is characterized by seasonal mean monthly rainfall varies from 8 to 160 mm, annual rainfall totals of between 452.7 mm and 1129.5 mm and mean temperature maximum ranged from 21.9 to 23.5°C while minimum varied from 6.8 to 10.1°C. Agriculture is the main economic practices in the district, from which the major sources of their livelihood income mainly from crop cultivation. Major crops grow in the district include wheat, barley, faba bean, field pea and others.

2.3. Site Selection, Experimental Treatments, Design and Procedures

To obtained representative for experimental sites composite soil samples were collected from 22 farmers' fields in Sinana district, where bread wheat is a dominant crop. Based on available soil P values determined by the Olsen method, fields were categorized into very low, low, and moderate available soil P contents. Based on this classification, sites with low or below critical available P were selected for the experiment in the district.

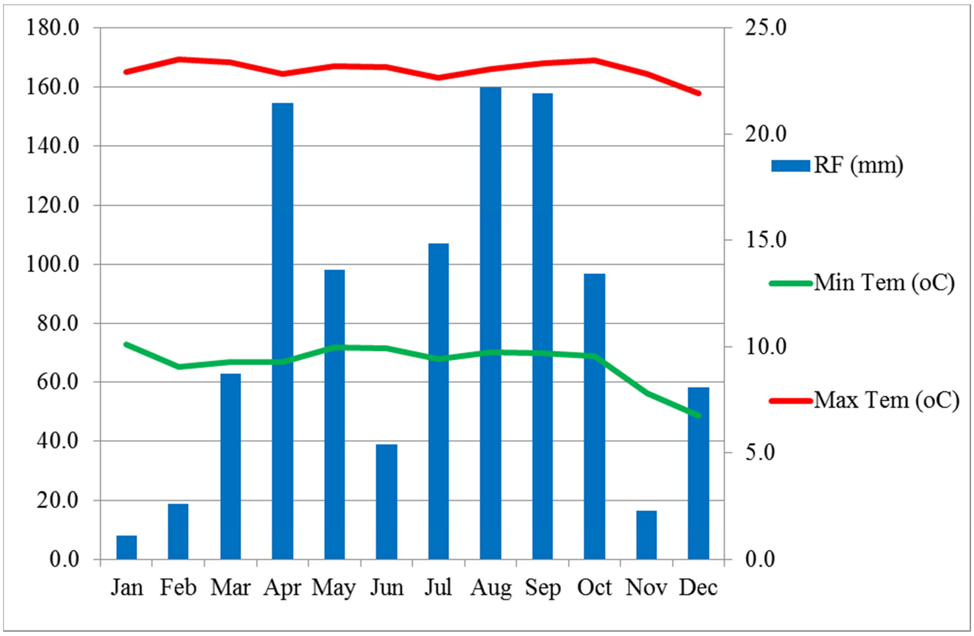

Figure 2. *Mean monthly rain fall (mm), Max and Min Temperature (°C) of three years (2018 to 2020) of Sinana District.*

On-farm field experiments were conducted in Sinana District for the three consecutive year during the main cropping seasons under rainfed (July to December) from 2011 to 2013 E.C In the first year factorial combination of four levels of N rates (0, 23, 46 and 69 Kgha^{-1}) and six rates of P (0, 10, 20, 30, 40 and 50 Kgha^{-1}) to determine optimum N rate as indicated was conducted at six locations as indicated Table 1. In the second and third years single six rates of P (0, 10, 20, 30, 40 and 50 Kg/ha) with recommended N rate (46 Kg/ha) were used to determine Pc and Pf.

Treatments laid out in RCBD with three replications, plot size 3 m x 3 m (9 m^2) using bread wheat (Senate variety) as test crop, N source urea, P source TSP and DAP both in first and second year were used. Land preparation were done both using tractors and oxen while others agronomic managements seed rate (150 kg/ha), hand weeding, herbicide, disease/pest control and row planting in 20 cm according to the recommendations were applied.

Table 1. *Discriptions of treatments in the first year.*

Treatments N: P (Kg/ha)	Treatments N: P (Kg/ha)	Treatments N: P (Kg/ha)	Treatments N: P (Kg/ha)
T1=0: 0	T7=23: 0	T13=46: 0	T19=69: 0
T2=0: 10	T8=23: 10	T14=46: 10	T20=69: 10
T3=0: 20	T9=23: 20	T15=46: 20	T21=69: 20
T4=0: 30	T10=23: 30	T16=46: 30	T22=69: 30
T5=0: 40	T11=23: 40	T17=46: 40	T23=69: 40
T6=0: 50	T12=23: 50	T18=46: 50	T24=69: 50

2.4. Soil Sampling, Preparation and Laboratory Analysis

Soil samples of the experimental sites before and after twenty one (21) days after planting at 0-20 cm soil depth were takenfrom five (5) different auger sampling points then composite soil samples were prepared for each sites and plots. The composite soil samples were labeled with necessary information then air dried, finally crushed using a mortar and pestle to passed through a 2 mm mesh sieve for most soil physicochemical properties except organic carbon and total nitrogen for which the samples further crushed to pass through a 0.5 mm mesh sieve. The analyses were conducted following standard laboratory procedures at Sinana and Melkasa Agricultural Research Center and Haramaya University Soil Laboratory.

Particle size distribution was determined using the Bouyoucos hydrometer method [15]. Finally, the textural class of the soil was assigned using USDA textural triangle classification system [52]. The pH of the soil was measured in the supernatant suspension of a 1:2.5 soil to water ratio using a pH meter [47]. Soil organic carbon and total nitrogen were determined using [54, 16] respectively. Available P was determined following the Olsen method [44] using ascorbic acid as reducing agent.

Total exchangeable bases (Ca^{2+}, Mg^{2+}, K^+ and Na^+) were extracted after leaching the soils with 1N neutral ammonium acetate (NH_4OAc) solution. Exchangeable Ca^{2+} and Mg^{2+} were determined by atomic absorption spectrometry (AAS) while K^+ and Na^+ were determined by flame photometer [43]. Cation exchange capacity (CEC) was determined for the soil samples which were first leached with 1 M ammonium acetate (NH_4OAc), washed with ethanol and the adsorbed ammonium was replaced by Na [17]. Then, the CEC was measured titrimetrically by distillation of ammonia that was displaced by Na. Percent base saturation (PBS) was calculated as follows;

$$\text{PBS }(\%)=\frac{Ca^{+2} + Mg^{+2} + K^{+} + Na^{+}*100}{CEC}$$

The available micronutrients (Fe, Mn, Cu and Zn) were extracted by diethylenetriaminepenta acetic acid (DTPA). Finally, their contents were quantified using AAS at their wave lengths as described by [25].

2.5. Agronomic Data Collection

Agronomic data related to yield and yield components such as plant height, numbers of productive tillers, seed per spike, above ground biomass yield; grain yield and thousand kernel weight were taken then finally subjected to standard statistical analysis.

2.6. Statistical Analysis

The collected bread wheat yield and yield component data was subjected to analyses of variance (ANOVA) using R-software computer software 4.0.3. Significant differences among treatments means were separated by least significant differences (LSD) at 5% level of probability and using linear correlation coefficient matrix. Interpretations were made following the procedure described [28].

2.7. Partial Budget Analysis

On the other hand, partial budget analysis was performed to investigate the economic feasibility of the treatments. Partial budget, dominance, marginal and rate of marginal return analyses were used. The average yield was adjusted downwards to reflect the difference between the experimental plot yield and the yield farmers will expect from the same treatment.

The average grain yield also adjusted by reducing 10% to minimize the over estimation of yield when yield of small plot converted to hectare basis. The average open market price (Birr/kg) of bread wheat, urea (N) and DAP (P) fertilizers were considered for analysis. The minimum acceptable rate of return (MARR) should be 100% [18], which is suggested to be realistic. This enables to make farmer recommendations from marginal analysis.

2.8. Determination of Critical P Concentration

The critical P concentration (Pc) value was determined by the Cate-Nelson diagram method [42]. Where soil test P put on the X-axis and relative yield on the Y-axis based on values obtained trials conducted at 22 sites of Sinana District. A pair of perpendicular lines drawn on it to produce four quadrants displayed the relative yield. The diagram of the results is divided into four quadrants that maximize the number of points in the positive quadrants and minimize the number of points in the negative quadrants.

The observations in the upper left quadrant overestimate the fertilizer P requirement while the observations in the lower right quadrant underestimate the fertilizer requirement. The optimum is indicated by the point where the vertical line crosses the x-axis and critical P value was determined using relative grain yield against the soil test values at different rates of applied phosphorous fertilizer for a given of nutrient rate. The relationship between grain yield response to nutrient rates and soil test P values, relative grain yields in percent were calculated as follows:

$$\text{Relative yield}=\frac{\text{Yield} * 100}{\text{Maximum yield}}$$

2.9. Determination of P Requirement Factor

The P requirement factor (Pf) enables one to determine the quantity of P required per hectare to raise the soil test by 1 mg/kg (1 part per million), and to determine the amount of fertilizer required per hectare to bring the level of available P above the critical level [42]. Finally, the value of P requirement factor (Pf) was calculated using available P values in samples taken from unfertilized and fertilized plots after 21 days starting from sowing date. The phosphorous requirement factor was expressed as:

$$\text{Pf}=\frac{\text{kg P applied}}{\Delta\ \text{soil P}}$$

Finally, using Phosphorus requirement factor, Phosphorus critical level and initial P values (soil P value from composite soil sample before fertilization) rate of P fertilizer to be applied was calculated as follows:

Rate of P fertilizer to be applied=(Pc –P i) × Pf

Where, Pc=critical P concentration, Pi=initial P values and Pf=P requirement factor.

3. Result and Discussions

3.1. Selected Soils Physicochemical Properties Before Planting

The results of particle size distribution of the soil were summarized and presented in Table 2. Accordingly; the values of soil particles size distributions ranged from 14-26%, 16 - 36% and 38 – 66% for percent sand, silt and clay content; respectively. As the rating suggested by [31] low to moderate for both soil percent sand and silt content while moderate to very high for percent clay content. According the USDA soil textural class triangle all soils of experimental site were clay textural class (Table 2).

The pH (pH_H_2O) values of soil of watershed varied from 6. 07 to 6.50 as indicated (Table 2). As per the pH ratings suggested by [33] for pH in soil-water ratio were rated slightly acidic media. The values of soil organic matter (OM) were ranged from 1.55 to 2.65% (Table 2). As per the ratings of [50] OM contents for soils of the experimental sites rated into low to moderate class. The values of total nitrogen (TN) content varied from 0.11 to 0.43% rated as low to moderate as ratings suggested by [37]. The values of available phosphorus (Av. P) ranged from 2.02 to 5.04 mg/kg which rated very low to low based on the critical values as determined by the Olsen method established by [19]. The very low to low categories of these major soils plant nutrients might be due to leaching, continues cereal based monocropping (mostly wheat), low or limited inputs of organic and inorganic sources fertilizers, nutrient fixation and loss as a results of soil erosions.

Table 2. *Selected soils physicochemical properties status of experimental sites of Sinana District.*

Site Name	Soil particle size distributions			Textural Class	PH-H_2O	OM	TN	Av. P (mg/Kg)
	Sand	Silt	Clay					
	(%)				(%)			
Sambitu	14	20	66	clay	6.31	1.55	0.15	5.8
Robe Area	18	16	66	clay	6.50	2.05	0.29	2.94
Amida	18	24	58	clay	6.07	2.26	0.36	4.55
Besaso	14	24	62	clay	6.15	1.75	0.27	4.02
Jafera	26	36	38	clay	6.24	2.26	0.43	2.02
SelkaOda	18	32	50	clay	6.12	2.65	0.33	2.34
Gemora	14	32	54	clay	6.25	2.22	0.11	2.56
Hisu	14	20	66	clay	6.18	2.49	0.11	2.45

Where: OM=soil organic matter, TN=Total nitrogen, Av. P=available phosphorus.

3.2. Cation Exchange Capacity, Exchangeable Bases and Percent Base Saturation

Cation exchange capacity (CEC) values were ranged from 36.4 to 50.2 $cmol_+/kg$ in which as rating suggested by [31] rated into high to very high (Table 3). Exchangeable Bases (Ca, Mg, K and Na) values varied 8.81 to 37.17 $cmol_+/kg$, 0.57 to 1.40 $cmol_+/kg$, 2.13 to 3.49 $cmol_+/kg$ and 0.60 to 70 $cmol_+/kg$ also as the rating stated by [23]. categorized into moderate to very high, low to moderate, low to moderate and moderate for Ca, Mg, K and Na; respectively. The low class of these basic cations might be due to leaching as results of area have relatively high rainfall.

The results indicate that exchangeable bases followed in the order of; Ca > Mg > K > Na for soils of the experiential sits (Table 3). The results indicated the values of exchangeable bases were optimal for crop production it does not mean no need managements. The calculated values of percent base saturation (PBS) for soils of the experimental sites varied from 33.28 to 88.82% and as per the rating set by [31] low to moderate class with having moderately leached (Table 3).

Table 3. *Cation exchange capacity, exchangeable bases and percent base saturation status soils of experimental sites of Sinana District.*

Site Name	CEC	Ca	Mg	K	Na	PBS%
	($cmol_+/kg$)					
Sambitu	50.2	24.23	1.40	3.49	0.60	59.22
Robe Area	47.4	14.87	1.23	3.14	0.62	41.90
Amida	36.4	8.81	1.03	2.13	0.64	34.62
Besaso	49.2	11.01	1.11	3.60	0.65	33.28
Jafera	48	37.17	0.57	2.99	0.67	86.25
SelkaOda	47.2	33.62	0.59	2.89	0.69	80.06
Gemora	46.6	28.15	1.27	3.09	0.70	71.27
Hisu	41.8	31.94	1.01	3.34	0.70	88.82

3.3. Soil Micronutrients

The results of soils analyzed values for Micronutrients (Fe, Mn, Cu and Zn) varied from 6.53 to 13.37 mg/kg, 1.13 to 8.53 mg/kg, 1.54 to 3.40 mg/kg and 0.14 to 0.98 mg/kg and follows in the order of Fe > Mn > Cu > Zn as presented in Table 4. Based on the ratings of [33] rating soils micronutrients (Fe, Mn, Cu and Zn) status of experimental sites categorized as high for Fe, moderate both for Mn and Cu while very low to moderate for Zn (Table 4).

***Table 4.** Soil micronutrients status of experimental sites of Sinana District.*

Site Name	Fe	Mn	Cu	Zn
	mg/kg			
Sambitu	7.77	3.90	1.84	0.14
Robe Area	9.12	6.58	2.34	0.33
Amida	12.75	4.69	2.25	0.21
Besaso	13.37	7.08	2.34	0.36
Jafera	6.53	1.24	1.54	0.24
SelkaOda	6.63	1.13	1.92	0.20
Gemora	9.22	5.90	3.40	0.92
Hisu	12.02	8.53	3.26	0.98

3.4. Determination of Optimum Nitrogen Fertilizer

According to the ANOVA results, there were significant differences among the yield and yield components of bread wheat responses to nitrogen rates (Table 5). The statistical results of each yield and yield components of bread wheat response to nitrogen rates were summered as follows:

3.4.1. Plant Height

The result of analysis of variance for plant height was significant ($p \leq 0.05$) difference due to the main effect of N rates (Table 5). Accordingly, the highest (98.35 cm) and the lowest (70.49 cm) was obtained from 46 Kg/ha and control plot (without fertilizer); respectively. Plant height was increased significantly in response to increasing the rates of N fertilizer except for N rate of 69 $Kgha^{-1}$. Thus, might be due to optimum N applications causes for higher photosynthetic activities, the availability of more nutrients, which helped, in the maximum vigorous growth. This result is also supported by the finding of [29, 30, 22, 27, 14] who stated the increments of plant height with increasing nitrogen rate.

3.4.2. Number of Productive Tillers

The analysis of variance indicated that number of tillers was significant ($p \leq 0.05$) influenced by different N rates (Table 5). The highest mean number of tiller (3.68) was obtained from N fertilizer rate (46 N kg/ha) while the minimum number of tillers (1.94) was recorded from control (with zero nitrogen fertilizer). Thus might be due to optimum N applied played a significant role in plant growth and development that has positive effect on cytokinin synthesis which stimulates formation of new tillers. Several authors like [4, 53, 14, 25, 48, 5] also reported applying optimum N rate was produced highest number of fertile tillers.

***Table 5.** Responses of bread wheat plant height; number of tiller and seed per spike to N fertilizer application at Sinana District.*

N Rates (Kg/ha)	PH (cm)	NT	SPS
0	70.49^{c}	1.94^{d}	24.44^{d}
23	88.99^{b}	2.61^{c}	43.08^{c}
46	98.35^{a}	3.68^{a}	52.68^{a}
69	89.29^{b}	3.37^{b}	45.12^{b}
Mean	86.78	2.63	41.33
LSD (<0.05)	13.52	34.17	15.05
CV (%)	3.14	0.27	1.66

Where, PH: plant height, NT: number of tillers, SPS: seed per spike, CV: Coefficient of Variation, LSD: least significant difference, Means followed by the same letter in the column and rows are not significantly different at 5% level of significance.

3.4.3. Seed Per Spike

The analysis of variance revealed that number of seed per spike was significantly ($p<0.05$) affected by the applications of different N rates fertilizer at the study area. The result showed that number of seed per spike increased as the rate N enhanced from zero to the highest rates of application (Table 5). The highest (52.68 gm) number of seed per spike were recorded at optimum N application (46 kg/ha) while the lowest number of seed per spike (24.44 gm) was recorded by control plot accordingly (Table 5). This result supported with the finding of [48, 5] who reported that number of seed per spikes for bread wheat was significantly influenced and also increased due to different N rates applied.

3.4.4. Total Above Ground Biomass

As the result indicated that biomass yield was significantly ($p \leq 0.05$) influenced by N rate. Accordingly, the highest (11589.27 kg/plot) and the lowest (6182.81 kg/plot) biomass was obtained from 46 N kg/ha and control plot (without fertilizer); Respectively (Table 6). This might be significant increases in plant height, number of tillers, spike length, number of seed per spike and grain yield from optimum N rate application ultimately contributed to the increased crop biomass yield. Several authors [41, 30, 27, 14, 8, 25, 5] reported the significance increased in total biomass yield as compared to treatment received zero nitrogen rate. This means nitrogen enhance the vegetative growth of plants. Similarly, [5] reported that as N rate increased the biomass yield also increased. Additionally, [48] reported optimum N and P increased biomass yield.

3.4.5. Grain Yield

The statistical analysis shows that grain yield values were significant ($p \leq 0.05$) different as influenced by N fertilizer rates (Table 6). The highest grain yield (5657.28 kg/ha) was obtained due to application of 46 kg/ha, whereas the lowest value (2666.41 kg/ha) was recorded from the control treatment. Thus might be due to N significantly enhances the vegetative growth in turn might be the reason for highest grain yield for 46 N kg/ha rate applications. The current result agreement with the achievements of [8, 12, 25] obtained significant highly grain yield as a results of optimum N application.

This highest grain yield at 46 N kg/ha might be due to the ability of N to determine photosynthetic capacity of the crop, and the increased number of seed number per spikes. Overall, grain yield increased as the amount of nitrogen increased from the low level to 46 kg/ha. This result is also supported by the findings of many previous workers [5, 30, 22, 27, 13] who reported significant increases in grain yields of bread wheat with increasing levels of N fertilizer up to optimum rate. This study revealed that nitrogen is more yield limiting factor for bread wheat productions at Sinana District.

The improvements in bread wheat yield and its components under the acceptable increasing N rate (46 N kg/ha) determined for Sinana District. Additionally, [49, 21, 51] reported better grain quality; high grain yield and nutrient use efficiency obtained at 46 N kg/ha for wheat production. The excess application of N might be resulted in lodging of wheat and caused a dramatic yield decrease. This finding also supported by [35, 34] who obtained optimum nitrogen rate (46 N kg /ha) for teff and bread wheat productions; respectively.

3.4.6. Thousand Kernel Weights

The analysis of variance showed that thousand kernel weights had significantly (p ≤ 0.05) affects by different N rates. Accordingly; the highest (47.29 g) and the lowest (30.66 g) thousand kernel weights was found from 46 kg/ha and control plot; respectively (Table 6). The result indicates application of N is responsive to increase the grain size of bread wheat and give better thousand kernel weights. This finding supported by different workers [10, 48, 57, 5].

Table 6. *Responses of bread wheat biomass; grain yield and thousand kernel weight to N fertilizer application at Sinana District.*

N Rates (Kg/ha)	BM (kg/plot)	GY (kg/ha)	TKW (g)
0	6182.81^{d}	2666.41^{d}	30.66^{d}
23	8109.31^{c}	4034.72^{c}	39.71^{c}
46	11589.27^{a}	5657.28^{a}	47.29^{a}
69	10095.64^{b}	5276.29^{b}	42.68^{b}
Mean	8994.00	4409.00	40.08
LSD (<0.05)	28.04	17.38	15.75
CV (%)	674.58	204.98	1.69

Where, BM: above ground biomass, GY: grain yield, TKW: Thousand kernel weights, CV: Coefficient of Variation, LSD: least significant difference, Means followed by the same letter in the column and rows are not significantly different at 5% level of significance.

3.5. Responses of Plant Height, Number of Tillers and Seed Per Spike Component to Combined Applications of Different NP Fertilizer Rates

Plant height was significantly (p ≤ 0.05) affect by the interaction of N P fertilizers rates in which the highest (100.4 cm) and the lowest (62.32 cm) were obtained from applications of 46 N and 40 P kg/ha and control plot (0 N and 0 P); respectively (Table 7). This the significantly highest plant height due to combined application of NP rates than control might be due to the ability of nitrogen and phosphorus enhance vegetative growth and additional P sources fertilizer also increases the efficiency of nitrogen thereby indicating positive effects on bread wheat as compared to unfertilized. Accordingly, [9, 2] state the dramatic response of support the beneficial effects of combined application of optimum N and P fertilizers on yield components and yield of bread wheat. Additionally; thus the highest plant height at 46 N kg/ha and 40 P kg/ha reveled that optimum N supply causes higher photosynthetic activities, vigorous growth and also adequate P enhances many physiological processes and the fundamental processes of photosynthesis, thus, helping inplant growth. Similarly, [13, 5] reported plant height significantly increased with increasing level of NP fertilizers.

Table 7. *Responses of plant height, number of tillers and seed per spike to combined application of different nitrogen and phosphorus levels for bread wheat production at Sinana District.*

Treatments	P Rates (kg/ha)					
N Rates (kg/ha)	0	10	20	30	40	50
	Plant height (cm)					
0	62.32^{m}	72.21^{l}	76.07^{jkl}	74.22^{kl}	69.00^{lm}	69.11^{lm}
23	95.14^{abcde}	96.29^{abcd}	82.90^{ghij}	96.76^{abc}	82.18^{hij}	80.67^{ijk}
46	95.77^{abcde}	97.61^{ab}	99.00^{ab}	99.122^{a}	100.40^{a}	98.18^{ab}
69	87.27^{fghi}	88.53^{efgh}	89.38^{defgh}	89.07^{defgh}	91.77^{bcdef}	89.76^{cdefg}
CV (%)	12.87					
LSD (<0.05)	7.32					
N Rates (kg/ha)	Number of productive Tiller					
0	0.33^{j}	0.89^{ij}	0.97^{i}	1.00^{i}	1.11^{i}	0.90^{ij}
23	2.62^{fgh}	2.40^{h}	2.556^{gh}	2.500^{gh}	2.91^{defgh}	2.68^{efgh}
46	4.51^{b}	3.17^{cdef}	2.86d^{efgh}	3.400^{cd}	5.10^{a}	3.07^{cdefg}
69	3.50^{c}	3.20^{cde}	3.21^{cde}	3.33^{cd}	3.36^{cd}	3.61^{c}
CV (%)	33.13					
LSD (<0.05)	0.57					
N Rates (kg/ha)	Seed Per Spike					
0	20.56^{k}	22.28^{jk}	25.344^{ij}	24.50^{ij}	26.39^{i}	27.57^{i}
23	41.03^{gh}	40.80^{h}	43.68^{fgh}	43.68^{fgh}	44.57^{fg}	44.72^{f}
46	45.29^{f}	49.14^{de}	50.34^{cd}	55.49^{b}	62.22^{a}	53.60^{bc}
69	43.59^{fgh}	44.18^{fgh}	45.36^{f}	45.14^{f}	46.06^{ef}	46.40^{ef}
CV (%)	13.37					
LSD (<0.05)	3.62					

Where, CV: Coefficient of Variation, LSD: least significant difference, Means followed by the same letter in the column and rows are not significantly different at 5% level of significance.

Number of productive tillers was significantly (p ≤ 0.05) affect by the interaction of N P fertilizers rates in which the highest (5.10) and the lowest (0.33) were obtained from applications of 46 N and 40 P kg/ha and control plot (0 N and 0 P); respectively (Table 7). Thus might be due to the fact that optimum combined NP supply played a significant role in plant growth and development, increase in number of grains per spike, number of fertile tillers and grain yield. This result agrees with the findings of [46, 5], who reported that number of productive tillers was significantly affected by NP fertilizer application. In case of interactions between nitrogen and phosphorus, tillers significantly increased with increasing P rates up at all N levels [48]. Higher P rates enhanced tillers survival, emergence and yield, especially for secondary tillers [24]. These results also supported by [39] who stated that phosphorus application positively influenced productive tillers.

Seed per spike had highly significant spike ($p \leq 0.05$) affected by interaction of N and P fertilizers rates. Accordingly; the highest number of seeds per spike (62.22) was recorded for 46 N and 40 P kg/ha while the lowest value (20.56) was recorded for the control treatment (0 N and 0 P); respectively (Table 7). This might be due to combined application attributed to N increases dry matter production and P have also positive effect on number of seed produced per plant. These results are also in accordance [6, 5] reported that highest number of seeds per spike was obtained from optimum combined NP fertilizer application. Additionally, [48] also reported the optimum NP fertilizer increased in number of seed per spikes but beyond the optimum decreased number of seed per spikes.

3.6. Response of Biomass, Grain Yield and Thousand Kernel Weights to Different Nitrogen and Phosphorus Fertilizer Rates

Biomass yield data was statistical significantly ($p \leq 0.05$) different due to interaction effects of NP fertilizer rates. The mean values varied from 4234.81 to 14991.70 kg/plot (Table 8). Differently, [9, 30, 2, 27, 5] reported the dramatic response of support the beneficial effects of combined application of optimum N and P fertilizers on yield components and yield of bread wheat.

Grain yield values were statistical significantly ($p \leq 0.05$) influenced by the interactions of N and P fertilizers rates. Accordingly; the highest (7018.57 kg/ha) obtained at 46 N kg/ha and 40 kg/ha P while the lowest (1989.92kg/ha) obtained from the control plot (Table 8). This might be due to NP fertilizer induced vigorous vegetative growth, which in turn, resulted in increased biological yield. This result supported with the finding of [45, 39, 48] who stated applications of optimum NP fertilizer enhanced grain yield. Additionally, [48] also obtained the decline grain yield and yield components due to application NP fertilizer beyond optimum rate. The mean grain yield of bread wheat response to optimum NP fertilizer application was 71.65% as compared to the unfertilized control mean. Hence, N and P fertilizers should be applied in proper proportion to get higher crop productivity. Thus, result supported by different authors [35, 49, 21, 34, 51] who reported 46 N kg/ha for better grain quality; high grain yield, nutrient use efficiency and economically acceptable.

Thousand kernel weights values had significantly ($p \leq 0.05$) influenced by interaction of N and P fertilizer application. Accordingly; the highest (56.02 g) and the lowest (26.06 g) thousand kernel weights was obtained at 46 N 40 P kg/ha and control; respectively (Table 8). This means nitrogen enhance the vegetative growth of plants. Different authors [48, 5] stated that highest level of P in combination with an optimum N rate contributed maximum to transfer physiological attributes and assimilates towards the yield attributes.

Table 8. *Responses of biomass, grain yield and thousand kernel weight to combined application of different nitrogen and phosphorus levels for bread wheat production at Sinana District.*

Treatments	**P Rates (kg/ha)**					
N Rates (kg/ha)	**0**	**10**	**20**	**30**	**40**	**50**
	Biomass (kg/plot)					
0	4234.81^{o}	5500.76^{no}	6495.99^{mn}	6693.65^{lmn}	6777.63^{klmn}	7394.02^{jklm}
23	7509.34^{jklm}	7770.75^{ijklm}	7939.56^{ijklm}	8210.19^{ijk}	8672.24^{ghij}	8553.79^{hij}
46	9173.61^{fghi}	10011.74^{efg}	10525.42^{def}	12884.64^{b}	14991.70^{a}	11948.49^{bcd}
69	8052.44^{ijkl}	9042.64^{ghi}	9934.30^{efgh}	10835.99^{cde}	12172.14^{bc}	10536.31^{def}
CV (%)	24.56					
LSD (<0.05)	1447.28					
N Rates (kg/ha)	Grain Yield (kg/ha)					
0	1989.92^{m}	2503.76^{l}	2783.61^{kl}	2847.58^{kl}	2893.4^{k}	2980.18^{k}
23	3556.44^{j}	3605.82^{j}	3867.402^{ij}	4025.32^{hi}	4348.80^{gh}	4804.53^{f}
46	4568.73^{fg}	5246.11^{de}	5410.94^{cd}	5999.88^{b}	7018.57^{a}	5699.46^{bc}
69	4421.31^{g}	4880.62^{ef}	5280.75^{d}	5519.56^{cd}	5892.10^{b}	5663.41^{bc}
CV (%)	12.86					
LSD (<0.05)	371.60					
N Rates (kg/ha)	Thousand kernel weight (g)					
0	26.06^{j}	28.44^{ij}	31.73^{hi}	32.00^{hi}	32.38^{h}	33.35^{h}
23	37.23^{g}	37.05^{g}	39.03^{fg}	39.59^{fg}	44.04^{cd}	41.33^{def}
46	40.22^{efg}	42.43^{cdef}	45.22^{c}	50.15^{b}	56.02^{a}	49.70^{b}
69	41.04^{def}	41.62^{cdef}	41.41^{def}	43.86^{cd}	44.66^{cd}	43.46^{cde}
CV (%)	13.81					
LSD (<0.05)	3.63					

Where, CV: Coefficient of Variation, LSD: least significant difference, Means followed by the same letter in the column and rows are not significantly different at 5% level of significance.

3.7. Partial Budget Analysis for Optimum Nitrogen for Bread Wheat Productions

The results of partial budget analysis showed that highest net benefit of 74573.28 (Birr ha^{-1}) was obtained from the treatment that received 46 N $Kgha^{-1}$ while the lowest net benefits of 35996.54 (Birr ha^{-1}) was obtained from the treatment that received0 N $Kgha^{-1}$ or control plot (Table 3). Thus, application of nitrogen fertilizer for bread wheat had positive net benefit over the control treatment (zero nitrogen) which implies that improvement in crop nutrient management strategy increase in farmers' income. Therefore, application of 46 N $Kgha^{-1}$ is economically profitable and recommended for farmers in Sinana district and other areas with similar soil types and agro-ecological conditions.

Table 9. *Partial budget analysis for optimum nitrogen rate determination for bread wheat productions at Sinana District.*

N rates ($Kgha^{-1}$)	UGY ($Kgha^{-1}$)	AGY ($Kgha^{-1}$)	GB (Birr ha^{-1})	TVC (Birr ha^{-1})	NB (Birr ha^{-1})	MRR (%)
0	2666.41	2399.769	35996.535	0.00	35996.54	0.00
23	4034.72	3631.248	54468.72	900.00	53568.72	1952.47
46	5657.28	5091.552	76373.28	1800.00	74573.28	2333.84
69	5276.29	4748.661	71229.915	2490.00	68739.92	

Where, UGY=unadjusted grain yield, AGY=adjusted grain yield, GB=Gross benefit; TVC=Total variable cost; NB=Net benefit; MRR=Marginal rate of return..

3.8. Critical P Concentration (Pc) for Bread Wheat

The correlation between relative bread wheat grain yield response and soil P measured with Olsen method is indicated in Figure 3. The critical P concentration (Pc) was determined from the scatter diagram drawn using relative grain yields of bread wheat and the subsequent soil test P values for all P rates (0-50 kg P ha^{-1}). The Pc defined by the Cate Nelson method in this study was about 22 mg/kg, with mean relative yield response of about 57% (Figure 3).

3.9. P Requirement Factor (Pf) for Bread Wheat

Calculated phosphorus requirement factor (Pf), which is the amount of P in kg needed to raise the soil test P by 1ppm bread wheat production at Sinana District was 5.24 (Table 10). These Phosphorus requirement factor enables to determine the quantity of P required per hectare to raise the soil test by 1 ppm, and to determine the amount of fertilizer required per hectare to bring the level of available P above the critical level (Table 10). This implies that P fertilizer application could be recommended for a buildup of the soil P to this critical value, or maintaining the soil P at this level for sustainable crop productions.

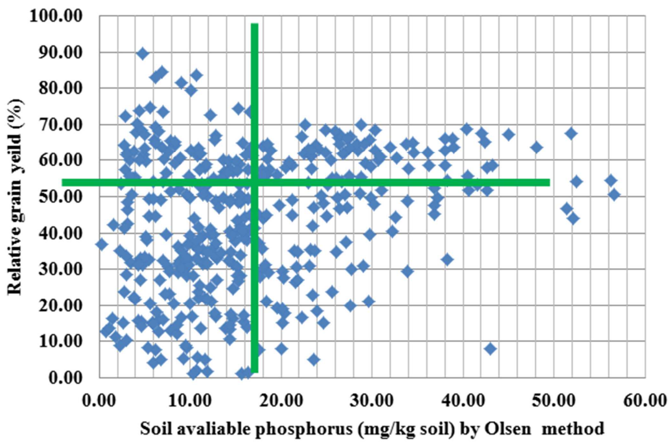

Figure 3. *Relationships between soil extractable P measured using Olsen method and relative grain yield of bread wheat according to this Nelson and Anderson graphical method critical limit determined was 22 P mg /kg.*

Table 10. *Determination of P requirement factor (Pf) for bread wheat production at Sinana.*

Phosphorus Rate	Available P Olsen Method in mg/kg			P increases over control	Pf
kg/ha	Range		Average	(PI)	
0	0.30	24.69	12.49		
10	1.50	30.85	16.18	3.68	2.72
20	2.69	31.01	16.85	4.36	4.59
30	2.89	33.93	18.41	4.36	6.89
40	2.50	36.43	19.46	6.97	5.74
50	2.84	38.07	20.46	7.96	6.28
Average					5.24

4. Conclusion and Recommendations

In order to solve the problem of crop production and soil productivity decline because of recommendations fertilizer application site specific soil test based crop response phosphorus calibration study was conducted for three consecutive years (2019-2021) in Sinana District. Accordingly, the optimum nitrogen rate (46 N kg/ha) determined during this studied advisable for bread wheat productions in Sinana district as well as other areas having the same soil conditions and agro-ecology recommended.

Phosphorus critical (pc) concentration (5.24 ppm) and Phosphorus requirement factor (pf) with the value (22) were determined for bread wheat production during this soil test based crop response phosphorus calibration study. Therefore; farther verification of the result on farmer's field could be a prerequisite before disseminating the technology to the end users.

Generally, soil test crop response based fertilizer application particularly a determined optimum nitrogen and phosphorus calibration study significantly improve bread wheat production in Sinana District since both are the most yield limiting nutrients in the study area.

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