

# Determination of NPS fertilizer rates based on Pc and Pf for yield and yield components of bread wheat (*Triticum Aestivum* L.) in Negelle Arsi District, West Arsi Zone of Oromia, Ethiopia

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Received 9th February, 2021; Accepted 26th March, 2021

**ABSTRACT:** The study was conducted for two years on farmers' fields in Nagelle Arsi District in 2018/19 to 2019/20 to evaluate the effect of rates of NPS fertilizer on growth, yield and yield components of bread wheat and to determine economically appropriate rate of NPS fertilizer for bread wheat production. The experiments were laid out in randomized complete block design (RCBD) with two replications with a plot size of 5 m x 4 m accommodating 20 rows each spaced 20 cm. Spacing of 1.0 m and 0.5 m were maintained in between adjacent blocks and plots, respectively. The treatments consist of 100% Pc from TSP fertilizer and 100, 75, 50, 25% Pc from NPS fertilizer and control (no fertilizer application) on a bread wheat variety Ogolcho with seed rate of 150 kg ha<sup>-1</sup>. Weed and yellow rust were managed by pallas and rexcido, respectively. The effects of NPS fertilizer rate on mollic andosols was highly significant with phosphorus critical and requirement factors ( $p < 0.01$ ) on plant height, aboveground dry biomass and grain yield whereas spike length, seed per spike and thousand kernels weight were not significant. Also, the effects of NPS fertilizer rate on eutric vertisols was highly significant with phosphorus critical and requirement factors ( $p < 0.01$ ) on spike length, seed per spike, aboveground dry biomass and grain yield whereas the plant height and thousand kernels weight were not significant. The highest grain yield was obtained in 100% pc TSP with recommended rate of 46 kg N ha<sup>-1</sup> followed 100% pc NPS with recommended rate of 46 kg N ha<sup>-1</sup>. The lowest yield (2468 kg ha<sup>-1</sup>) was obtained in control. The partial budget analysis showed that the maximum net benefit with an acceptable marginal rate of return (MRR) was obtained from 75% pc NPS fertilizer and supplemented rate of 69 kg N ha<sup>-1</sup> application on eutric vertisols and 100 % pc NPS fertilizer and supplemented rate of 46 kg N ha<sup>-1</sup> application on mollic andosols.

**Keywords:** Benefit, eutric vertisols, fertilizers, mollic andosols, NPS, rate.

## INTRODUCTION

Bread wheat (*Triticum aestivum* L.) is one of the most important cereal crops globally and is a main food for about one third of the world's population (Hussain et al., 2002). This is particularly true to the major food crops grown total grain crop area, 81.39% (10,358,890.13 hectares) was under cereals. Wheat took up 13.73% (1,747,939.31 hectares) of the grain crop area. Likewise, cereals in Ethiopia contributed 87.97% (about 277,638,380.98 quintals) of the grain production and the wheat 15.33%

(48,380,740.91 quintals) of the grain production (CSA, 2019). Wheat provides more protein than any other cereal crops (Hussain et al., 2006). In Ethiopia, wheat grain is used in the preparation of a range of products such as: the traditional staple pancake ("injera"), bread ("dabo"), local beer ("tella"), and several others local food items (i.e., "dabokolo", "ganfo", "kinche"). Besides, wheat straw is commonly used as a roof thatching material, and as a feed for animals. It accounts for about 11% of the national

calorie intake (Demeke and Marcantonio, 2013).

Low soil fertility, especially nitrogen (N) deficiency, is one of the major constraints limiting wheat production in Ethiopian highlands (Teklu and Hailemariam, 2009). In Ethiopia, erratic seasonal rainfall, inadequate availability of other nutrients, nitrate leaching during the short but heavy rainy seasons, ammonia volatilization and continuous removal in the cereal mono cropping systems of the highlands are the major factors that result in inefficient use of N fertilizer (Tanner et al., 1993). According to the soil fertility map made over 150 districts, most of the Ethiopian soils lack about seven nutrients (N, P, K, S, Cu, Zn and B) (EthioSIS, 2013). Moreover, Hailu et al. (2015) reported that, soil analysis data of wheat fields in central highland vertisols of Ethiopia showed deficiency in the levels of N, P, S, Zn, Mo and B. Moreover, the plant analysis data from the same sites indicated that wheat plants will be deficient in N, P, Zn and K.

Grain yield, plant height, effective tiller number/m<sup>2</sup> and biomass yield of bread wheat variety increase linearly with planting density and N/P<sub>2</sub>O<sub>5</sub> fertilizer rate. Moreover, it also reported that grain yield and yield components of wheat 100% fully responded to applied nitrogen, 72.3% showed response to sulfur and 78% showed response to applied phosphorus on eighteen fields studied in central high lands of Ethiopia (Menna et al., 2015). According to Habtegebrail et al. (2013), the optimum grain yield for two bread wheat varieties was found at 100 kg N ha<sup>-1</sup>; couple with 20 kg S ha<sup>-1</sup>, beyond which the yield increase was non-significant, suggesting that higher N rates are to be avoided. Depending upon available sulfur levels, the wheat yield can increase from 0 to 42% (De Ruiter and Martin, 2001) usually obtaining the best response with sulfur application between 10 and 20 kg ha<sup>-1</sup> (McGrath et al., 1996). Due to these, new fertilizers such as NPS (19% N, 38% P<sub>2</sub>O<sub>5</sub> and 7% S) are currently being used by the farmers in Ethiopia including the study area. In addition to this, the amount of N in the NPS is small as compared to the requirement of bread wheat. Therefore, this study was undertaken with the following objectives to assess the effect of NPS fertilizer rates and to determine economically appropriate NPS fertilizer rate on yield and yield components of bread wheat.

## MATERIALS AND METHODS

### Description of the experimental site

The experiment was conducted on a farmers' field in Nagelle Arsi District which is located in West Arsi Zone of Oromia Regional Estate in the central highlands of Ethiopia. Geographic location of the district is 7° 17' to 7° 66' N latitude and 38° 43' to 38° 81' E longitudes. The elevation is 500 to 2000 masl; the area is characterized by erratic type of bimodal rainfall pattern according to National Meteorological Services Agency (NMSA) which

varied between 20 to 180 mm per month during cropping season and mean annual minimum and maximum temperatures of 8.14 and 27.89°C, respectively. In general, the average monthly maximum and minimum temperatures and rainfall distribution are suitable for wheat production. The environment is seasonally humid and major soil type of the trial sites are eutric vertisols and mollic andosols (Figure 1).

### Treatments and experimental design

The experiment was laid out in randomized complete block design (RCBD) with two replications. The details of the treatments are shown in Table 1 and 2 for two soils type separately. The gross plot was 4 m x 5 m (20 m<sup>2</sup>) accommodating 20 rows each spaced 20 cm. Spacing of 1.0 m and 0.5 m were maintained in between adjacent blocks and plots, respectively. The treatments were based on already determined phosphorous critical and requirement factor and consisting of 100% Pc from TSP fertilizer and 100, 75, 50, 25% Pc from NPS fertilizer and control (no fertilizer application).

Applied P = (Critical P - P<sub>o</sub>) \* P<sub>f</sub>. Whereas P<sub>c</sub> = 19 ppm and 18 ppm; P<sub>f</sub> = 4.72 and 3.63 ppm on two major soil types mollic andosols and eutric vertisols of bread wheat in the district (Kefyalew et al., 2016). Nitrogen fertilizers in the form of urea were used according to the recommended optimum rate of 46 and 69 kg N ha<sup>-1</sup> on soil types of mollic andosols and eutric vertisols respectively. Moreover, the available phosphorus was determined by extraction with 0.5 M NaHCO<sub>3</sub> according to the methods of Olsen et al. (1954).

### Experiment managements

The experimental field was prepared following the conventional tillage practice which includes four times plowing before sowing of the crop. As per the specification of the design, a field layout was prepared; the land was leveled and made suitable for crop establishment. Sowing was done in July 2019 using seed rate of 150 kg ha<sup>-1</sup>. Full dose of NPS and TSP as per the treatment and one-third of N alone was applied at sowing time. The remaining two-third of N alone was top dressed at the mid-tillering crop stage. While conducting the experiment others necessary management practices such as fungicide (Tilt) sprayed for yellow rust were carried out uniformly for all treatments.

### Data collection

Agronomic data collected were plant height, biomass yield, grains per spike, spike length, 1000 kernel weight (TKW) and grain yield. All agronomic parameters were average of 5 plants. A total biomass and grain yields recorded on plot

**Table 1.** Rates of fertilizers treatment used with their nutrient contents in kg for the experiment on mollic andosols.

No	Treatments	Fertilizer source	Kg P ha <sup>-1</sup> = (Pc - Po)* Pf. Pc= 19 ppm and Pf = 4.72 ppm	kg N ha <sup>-1</sup>
1	Control	-	0	0
2	100% Pc	DAP	(19- Po) x 4.72	46
3	100% Pc	NPS	(19- Po) x 4.72	46
4	75% Pc	NPS	(14.25- Po) x 4.72	46
5	50% Pc	NPS	(9.5- Po) x 4.72	46
6	25% Pc	NPS	(4.75- Po) x 4.72	46

Whereas Pc = phosphorus critical, Pf = phosphorous requirement factor, Po = initial soil phosphorus.

**Table 2.** Rates of fertilizers treatment used with their nutrient contents in kg for the experiment on Eutric Vertisols.

No	Treatments	Fertilizer source	Kg P ha <sup>-1</sup> = (Pc - Po)* Pf. Pc= 19 ppm and Pf = 4.72 ppm	kg N ha <sup>-1</sup>
1	Control	-	0	0
2	100% Pc	DAP	(18- Po) x 3.63	69
3	100% Pc	NPS	(18- Po) x 3.63	69
4	75% Pc	NPS	(13.5- Po) x 3.63	69
5	50% Pc	NPS	(9- Po) x 3.63	69
6	25% Pc	NPS	(4.5- Po) x 3.63	69

Whereas Pc = phosphorus critical, Pf = phosphorous requirement factor, Po = initial soil phosphorus.

basis were collected and converted to kg ha<sup>-1</sup> for statistical analysis.

### Partial budget analysis

Partial budget analysis was employed and calculates the marginal rate of return (MRR) (CIMMYT, 1988) manual. Total variable cost was cost incurred due to application of NPS fertilizers rate with Pc and Pf of both soils which were mollic andosols and eutric vertisols from 25, 50, 75 and 100% Pc of NPS and 100% Pc TSP for bread wheat and the grain yield was adjusted by 10% to reduce the exaggeration of small plot management.

### Data management and analysis

All agronomic which were collected across locations was properly managed using the EXCEL computer software. It was subjected to ANOVA using GLM procedures of statistical analysis system of computer software (SAS, version 9.1.3, 2004) and LSD was used for mean comparison.

## RESULTS AND DISCUSSION

Soil test based crop response phosphorus calibration study was executed on two major soil types (mollic andosols and eutric vertisols) in Arsi Negelle for the

determination of optimum nitrogen, P-critical (Pc) and phosphorus requirement factor (pf). Economically optimum nitrogen rate for mollic andosols and eutric vertisols were 46 and 69 N kg ha<sup>-1</sup>, respectively. While determined P critical (Pc) concentrations and P (Pf) requirement factors on mollic andosols and eutric vertisols for bread wheat in Arsi Negelle District were 18 ppm and 3.63, and 18 ppm and 4.72 respectively.

### Yield and yield components of bread wheat on mollic andosols

The main effects of NPS fertilizer rate mollic andosols highly significant with phosphorus critical and requirement factors ( $p < 0.01$ ) effect on plant height, aboveground dry biomass and grain yield. However, the spike length, seed per spike and thousand kernels weight were not significant. The highest grain yield was obtained due to the application of 100% Pc TSP with recommended 46 kg N ha<sup>-1</sup> and flowed by rate of 100% Pc NPS ha<sup>-1</sup> with recommended 46 kg N ha<sup>-1</sup> (Table 3). The highest grain yield (4818 kg ha<sup>-1</sup>) and (4530 kg ha<sup>-1</sup>) was obtained in response to application of 100% Pc TSP and 100% Pc of NPS fertilizers, respectively. While the lowest grains yield (2468 kg ha<sup>-1</sup>) was obtained in response to control (Table 3). This study is in line with the study of Tagesse et al. (2018). Use of higher blended NPS fertilizer with supplemental N rates is the realistic approach to address the problem of low productivity of bread wheat. Therefore, combined application of 200 kg NPS ha<sup>-1</sup> supplemented

**Table 3.** Effect of NPS fertilizers rate on yield and yield components on mollic andosols.

Treatments	Plant height (cm)	Spike length (cm)	Seed per spike	Biomass ton ha <sup>-1</sup>	Grain yield (Qt ha <sup>-1</sup> )	TKW (gm)
No appl	85.05b	7.50	45.68	6.53c	24.68e	40.62
25 % pc	92.00ab	8.32	49.11	10.00b	38.01d	41.00
50 % pc	95.17a	8.06	46.81	10.37ab	41.10cd	38.73
75 % pc	95.58a	8.15	49.26	10.94ab	42.41bc	40.61
100 % pc NPS	97.05a	8.38	48.92	10.97ab	45.30ab	39.43
100 % pc TSP	97.85a	7.91	47.20	11.03a	48.18a	40.19
Lsd (0.05)	7.10	NS	NS	0.97	3.78	NS
CV (%)	7.51	9.27	9.38	9.69	9.39	18.48

Means followed by the same letter with in the same column of the respective treatment are not significantly different ( $P \leq 0.05$ ) according to fishier Test, PC= Phosphorus Critical, CV = Coefficient of variation, LSD = Least Significant differences, NS = not significant.

**Table 4.** Effect of NPS fertilizers rate on yield and yield components on eutric vertisols.

Treatments	Plant height (cm)	Spike length (cm)	Seed per spike	Biomass ton ha <sup>-1</sup>	Grain yield (Qt ha <sup>-1</sup> )	TKW (gm)
No appl	79.33	6.57b	27.99b	6.30c	25.08d	38.48
25 % pc	87.43	7.61a	36.13a	8.58b	34.72c	37.39
50 % pc	89.82	7.87a	36.92a	9.92a	39.45bc	37.63
75 % pc	91.82	7.81a	35.28a	9.63ab	42.95ab	37.76
100 % pc NPS	91.17	7.76a	37.81a	9.33ab	41.72ab	37.46
100 % pc TSP	93.00	7.76a	40.60a	9.38ab	45.93a	37.99
Lsd (0.05)	NS	0.79	6.40	1.21	6.18	NS
CV (%)	8.95	8.81	15.19	11.60	13.68	15.24

Means followed by the same letter with in the same column of the respective treatment are not significantly different ( $P \leq 0.05$ ) according to fishier Test, PC= Phosphorus Critical, CV = Coefficient of variation, LSD = Least Significant differences, NS = not significant.

rate of 46 kg N ha<sup>-1</sup> are recommended to achieve sustainable bread wheat in the study area.

#### Yield and yield components of bread wheat on eutric vertisols

The main effects of NPS fertilizer rate on eutric vertisols highly significant with phosphorus critical and requirement factors ( $p < 0.01$ ) effect on spike length, seed per spike, aboveground dry biomass and grain yield (Table 4). However, the plant height and thousand kernels weight were not significant. The highest grain yield was obtained due to 100 % Pc TSP with recommended 69 kg N ha<sup>-1</sup>, and flowed by the rate of 75 % pc NPS ha<sup>-1</sup> fertilizer with recommended 69 kg N ha<sup>-1</sup>. The highest grain yield (4593 kg ha<sup>-1</sup> and 4295 kg ha<sup>-1</sup>) were obtained in response to application of 100% Pc TSP and 75% Pc of blended NPS fertilizers, respectively. While the lowest grains yield (2508 kg ha<sup>-1</sup>) was obtained in response to control. This study is in line with the study of Ishete, and Tana (2019). The main effect of blended NPS fertilizer significantly ( $p < 0.05$ ) influenced plant height and grain yield. Therefore, increasing the rate of blended NPS fertilizer from 100 to

200 kg ha<sup>-1</sup> increased grain yield and the highest grain yield (5274 kg ha<sup>-1</sup>) was obtained at the highest (200 kg ha<sup>-1</sup>) of blended NPS fertilizer.

#### Economic analysis for mollic andosols

The partial budget analysis showed that the maximum net benefit with an acceptable MRR was obtained from 100% Pc TSP and 100% Pc NPS fertilizer and supplemented with 46 kg N ha<sup>-1</sup> application (Table 5). The net benefit obtained by the use of improved bread wheat with rates of 100% Pc NPS ha<sup>-1</sup> fertilizer were found to be greater than the benefit of applying 75% Pc NPS and 50% Pc NPS rates. Therefore, the net positive benefit obtained with application of 100% Pc NPS ha<sup>-1</sup> + 46 kg N ha<sup>-1</sup> to bread wheat are economically profitable application rates and can be recommended for farmers on mollic andosols of the study area and other areas with similar agro-ecological conditions. This study is in line with the study of Tagesse et al. (2018) who use 200 kg blended NPS ha<sup>-1</sup> supplemented with 46 kg SN ha<sup>-1</sup> produced highest grain yields, together with the best economic benefit or profitability with results of the economic analysis showed

**Table 5.** Partial budget analysis for NPS fertilizers rate of bread wheat on mollic andosols.

Treatments	Gy (Qt ha <sup>-1</sup> )	AGY (Qt ha <sup>-1</sup> )	GFB (ETB ha <sup>-1</sup> )	TVC (ETB ha <sup>-1</sup> )	NB (ETB ha <sup>-1</sup> )	MRR (%)
No application	24.68	22.21	39426.30	0.00	39426.30	0
25 % pc	38.01	34.21	60720.98	2264.55	58456.43	840.35
50 % pc	41.10	36.99	65657.25	3066.21	62591.04	515.76
75 % pc	42.41	38.17	67749.98	3620.84	64129.14	277.32
100 % pc NPS	45.30	40.77	72366.75	4175.44	68191.31	732.45
100 % pc TSP	48.18	43.36	76967.55	4769.32	72198.23	674.70

ETB= Ethiopian birr; GFB = gross field benefit; TVC = total variable cost; NB = net benefit; MRR = marginal rate of return, PC = Phosphorus critical, FP = Farmer Practice, GY = grain yield, AGY= adjusted grain yield.

**Table 6.** Partial Budget analysis for NPS fertilizers rate of bread wheat on eutric vertisols.

Treatments	Gy (Qt ha <sup>-1</sup> )	AGY (Qt ha <sup>-1</sup> )	GFB (ETB ha <sup>-1</sup> )	TVC (ETB ha <sup>-1</sup> )	NB (ETB ha <sup>-1</sup> )	MRR (%)
No appl	25.08	22.57	40065.30	0.00	40065.30	0.00
25 % pc	34.72	31.25	55465.20	2360.11	53105.09	552.51
50 % pc	39.45	35.51	63021.38	2763.28	60258.10	1774.19
75 % pc	42.95	38.66	68612.63	3166.45	65446.18	1286.82
100 % pc NPS	41.72	37.55	66647.70	3567.85	63079.85	D
100 % pc TSP	45.93	41.34	73373.18	4113.46	69259.72	1132.65

ETB= Ethiopian birr; GFB = gross field benefit; TVC = total variable cost; NB = net benefit; MRR = marginal rate of return, PC = Phosphorus critical, FP = Farmer Practice, GY = grain yield, AGY= adjusted grain yield.

that the maximum net return was obtained due to the application of 200 kg NPS ha<sup>-1</sup> + 46 kg N ha<sup>-1</sup>.

### Economic analysis for eutric vertisols

The partial budget analysis showed that the maximum net benefit with an acceptable MRR was obtained from 100% Pc TSP and 75% Pc NPS fertilizer and supplemented with 69 kg N ha<sup>-1</sup> application (Table 6). The net benefit obtained by the use of improved bread wheat with rates of 75% Pc NPS ha<sup>-1</sup> fertilizer were found to be greater than the benefit of applying 100% Pc NPS and 50% Pc NPS rates. Therefore, the net positive benefit obtained with application of 75% Pc NPS ha<sup>-1</sup> + 69 kg N ha<sup>-1</sup> to bread wheat are economically profitable application rates and can be recommended for farmers on eutric vertisols of the study area and other areas with similar agro-ecological conditions. This study is in line with the study of Ishete, and Tana (2019) of which the economic analysis revealed that for a treatment to be considered worthwhile to farmers (100% marginal rate of return), application of 100 kg NPS ha<sup>-1</sup> with 69 kg N ha<sup>-1</sup> supplementation are profitable and recommended for farmers in Arsi Negelle district. This study is in line with the study of Molla (2018) which indicated that the application of 167/45 kg N/P ha<sup>-1</sup> was more economical (79.7 to 134.1% marginal return) and is suggested to be promoted for bread wheat production following tef and lentil precursors on both types of vertisols

of the test locations and similar areas in the central highlands of Ethiopia.

### Conclusion

In conclusion, the net positive benefit obtained with application of 100% pc NPS ha<sup>-1</sup> + 46kg N ha<sup>-1</sup> on mollic andosols and 75% pc NPS ha<sup>-1</sup> + 69 kg N ha<sup>-1</sup> on eutric vertisols were recommended for farmers of the study area. Research institute and ministry of agriculture should work and harmonize on the transfer of the technology to farmers or end users.

### CONFLICT OF INTEREST

The authors declare that they have no conflict of interest.

### ACKNOWLEDGEMENTS

The authors would like to thank Oromia Agricultural Research Institute and Batu Soil Research Center for funding the research and providing all the necessary facilities required for the research, respectively. Appreciation also goes to all staff members, especially to laboratory analysis team of Batu Soil Research Center for their support and unreserved effort to provide reliable samples analysis data on time.

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