**Plant**
2022; 10(4): 105-110
http://www.sciencepublishinggroup.com/j/plant
doi: 10.11648/j.plant.20221004.13
ISSN: 2331-0669 (Print); ISSN: 2331-0677 (Online)

# Determination of NPS Fertilizer Rate Based on Calibrated Phosphorus for Maize in Dabo Hana District, Buno Bedele Zone, Western Oromia

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**To cite this article:**
Dagne Chimdessa. Determination of NPS Fertilizer Rate Based on Calibrated Phosphorus for Maize in Dabo Hana District, Buno Bedele Zone, Western Oromia. *Plant*. Vol. 10, No. 4, 2022, pp. 105-110. doi: 10.11648/j.plant.20221004.13

**Received**: October 17, 2022; **Accepted**: November 12, 2022; **Published**: December 29, 2022

**Abstract:** Periodic assessment of soil fertility status and plant nutrients requirement of a given area has vital role in enhancing sustainable crop production. A study was conducted in Dabo Hana district on twelve farmers' fields during 2018 and 2019 main cropping seasons to determine NPS fertilizer rate based on calibrated phosphorus for maize. The experimental design was completely randomized block design in three replication. Five rates of Phosphorus critical level (Pc) (0, 25, 50, 75 and 100%) calculated from NPS fertilizer and previously recommended 100% Pc calculated from DAP fertilizer was included as check were tried on hybrid maize (BH 661) for yield and yield component. Results showed that all Pc rates significantly increased the plant above ground bio mass, grain yield, thousand grain weight and hasten maturity of hybrid maize over control. Phosphorus critical level rate of 100% Pc from NPS gave maximum biomass yield (31.0 t $ha^{-1}$), grain yield (8.7t $ha^{-1}$) and thousand grain weight (480.0 g) followed by 100% Pc from DAP, while a partial budget analysis result also revealed that fertilizer application rate of 100% Pc from NPS offered net return of 27340 ETB $ha^{-1}$ followed closely by 100% Pc from DAP (24971 ETB $ha^{-1}$) which were substantially greater than the rest of the fertilizer treatments. Hence, fertilizer application rate of 100% Pc from NPS and DAP fertilizers appear the most appropriate for intensification of maize production in Dabo Hana district.

**Keywords:** BH 661, Nitrogen, NPS, P-Critical Level, Phosphorus, Sulfur

## 1. Introduction

Balanced supply of essential nutrients is one of the most important factors in increasing yields of annual crops. Hence, knowledge of interaction of a nutrient with other nutrients is an important factor in improving efficiency of this element and consequently improving crop yields. By using the relationships for yield decline with cumulative nutrient loss for different levels of management, it is possible to predict yield changes over time [1]. Nutrient interaction in crop plants is measured in terms of yield level. Application of a particular nutrient may increase, decrease, or have no effect on uptake of other essential plant nutrients. Similarly, yield level of a crop may increase, decrease, or experience no change with the increase of two nutrient levels in the growth medium. Hence, nutrient interactions may be positive, negative, or neutral. In mineral nutrition, the nutrient interactions are designated as synergistic (positive), antagonistic (negative), or neutral. Therefore, knowledge of fertilizer elementsand their interaction of a nutrient with other nutrients in the soil is very important to increase crop production.

Nitrogen (N) is an abundant element on earth that accounts for 78.1% of Earth’s atmosphere and is an essential nutrient for all forms of life [2, 3] It is also the most common growth-limiting nutrient in agricultural production systems. The N absorbed by crops is primarily derived from soil. It is a vital plant nutrient and a major yield determining factor required for maize production [4]. It is a component of protein and nucleic acids and when N is sub-optimal, growth is reduced. Its availability in sufficient quantity throughout the growing season is essential for optimum maize growth [5]. Grain yield was increased significantly with different levels of nitrogen applications in maize plants [6]. Combined with carbon, hydrogen, phosphorus and sulfur, it functions as a structural constituent of a wide variety of organic nitrogenous compounds of plants like proteins, nucleotides, porphyrins and alkaloids. In order to be incorporated into organic structures and to fulfill its essential functions as a plant nutrient, nitrogen has to be reduced to ammonium.

Phosphorus plays a key role in energy transfer and is essential for photosynthesis and other chemico-physiological processes in plants [7]. The different NP combinations significantly affected the plant height, cob bearing plants, number of grains/cob, 1000-grain weight and grain yield [8, 9]. The plant available forms of phosphorus are limited primarily to solution $HPO_4^{-2}$ and $H_2PO_4^-$, with the dominant form determined by the soil pH. It is also firmly bound in soils, due to precipitation of P with calcium ions in calcareous soil, and due to adsorption of P by Fe- and Al- oxides in acidic soil [10]. As a result, only a relatively small fraction of soil P is available to plants. To realize a sustainable P use in agriculture, it is important to optimize soil P management to achieve optimal crop yield and to decrease P losses simultaneously by improving soil P status in P deficient soils and by limiting the accumulation of soil P to certain target levels [11]. Even though, these target or critical level was determined for maize in Dabo Hana district [12], it is very important to know the interaction effect of soil P in combination with other plant nutrients like, N and Sulfur.

Sulfur interaction with nitrogen is very common, and S requirements of crops are enhanced with the increase of N in the growth medium. The main reason for the interaction of S with N may be a significant increase in growth of plants with N addition, which may cause dilution of S in plants [13]. It is an important component of two amino acids, cysteine and methionine, which are essential for protein formation. Since animals cannot reduce sulfate, plants play a vital role in supplying essential S-containing amino acids to them [14]. The need for S fertilization should be particularly related to the amount of N being applied since both nutrients are required for protein formation. One part S was required for every 12 to 15 parts N to ensure maximum production of both dry matter and protein in wheat, corn, and beans [15]. There are increasing reports that application of S in combination with N and P increases crop yields, suggesting an increased need for inputs of these nutrients as N and P deficiencies are alleviated [16]. The application of high-analysis fertilizers (urea and TSP) without S, can with continuous cropping, lead to S deficiencies [17].

Maize crop has high yield potential in Dabo Hana district. Despite its high yield potential, it is giving low yields because of improper fertilizer management practices due to lack of appropriate information on N, P and S nutrient elements management. Increasing productivity per unit area through plant nutrient management is one of the most important strategies to increase the production of maize. Therefore, the proper management of these three nutrient elements is very important for good maize production. As the soils of the area are known to be poor in nitrogen and phosphorus, this study was conducted to determine optimum NPS fertilizer rate based on calibrated phosphorus for maize in Dabo Hana district, western Oromia.

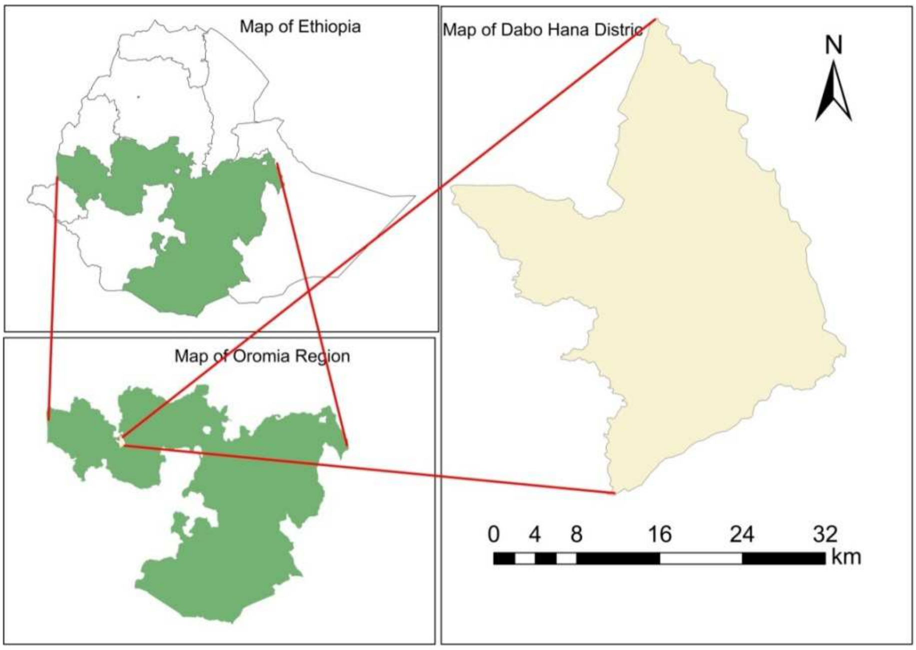


***Figure 1.*** *Map of the study area (Dabo Hana district).*

## 2. Materials and Methods

### *2.1. Description of the Study Area*

Geographically, the study area (Dabo Hana district) is located in Oromia National Regional State, western Ethiopia, in 08°30'28.7" to 08°41'34.6"N and 036°26'19.2" to 036°30'41.1" E with altitude ranging from 1791 to 1990 masl (Figure 1). The long-term weather information at nearby study area (Ethiopian Metrology Agency Bedele District Branch) indicated that a uni-modal rainfall pattern with average annual rain fall of 1945 mm. The rainy season covers April to October and the maximum rainfall is received in the months of June, July and August. The minimum and maximum annual air temperatures are 12.9 and 25.8°C, respectively, The predominant soil type in Southwest and Western Ethiopia in general and the study area in particular, is Nitisols according to the soil classification system [18]. Its vernacular name is "*Biyyee Diimmaa*" meaning red soil. On the average, the soil is deep and relatively highly weathered, well drained, clay in texture and strongly to moderately acidic in reaction. Nitisols are highly weathered soils in the warm and humid areas of the west and southwest Ethiopia [19].

### *2.2. Soil Sampling and Analysis*

Twelve composite surface soil samples (0-20) cm depth were collected from each experimental sites before planting to analyze soil pH ($H_2O$), exchangeable acidity, available P, OC (%), CEC, and textural class during site selection. The collected soil samples were prepared and analyzed following standard laboratory procedures at soil analysis laboratory of, Bedele Agricultural Research Center.

laboratory analysis result indicated that, soil pH was strongly acidic in reaction, low in available P and OC content (Table 1). The low contents of available P observed in the study area agreed with the results of similar study [20]. The low available P in most Ethiopian soils can be attributed to P fixation, crop harvest. soil erosion and low rate of P sources application. The OC content of the soil was low [21]. Most cultivated land soils of Ethiopia are poor in their organic matter content due to the low amount of organic materials applied to soil and complete removal of biomass from farm land [22]. As a result, the major source of organic matter in cultivated soils below ground plant biomass has little contribution to increasing OM [23].

Soils CEC values were low to moderate and and soil textural class was ranged from Silty clay loam to clay (Table 1). The observed CEC values of the soils generally showed similar trend with that of soil OC (Table 1). This indicated that CEC was more influenced by OM than clay content [24].

***Table 1.*** *Initial soil data before planting in Dabo Hana district.*

| Sites | pH ($H_2O$) | Exch.A (cmol (+)/kg soil) | Av. P (ppm) | OC (%) | CEC (cmol (+)/kg soil) | Textural Class |
|---|---|---|---|---|---|---|
| 1 | 5.0 | 0.1 | 2.0 | 2.6 | 17.8 | Loam |
| 2 | 4.7 | 0.4 | 1.1 | 1.5 | 15.3 | Sity clay loam |
| 3 | 4.5 | 0.5 | 2.2 | 2.3 | 16.3 | Silty clay loam |
| 4 | 5.0 | 0.3 | 1.5 | 1.9 | 17.6 | Silty clay loam |
| 5 | 5.1 | 0.3 | 3.1 | 4.6 | 15.1 | Silty loam |
| 6 | 4.7 | 0.4 | 1.2 | 2.2 | 15.5 | Silty loam |
| 7 | 4.3 | 1.6 | 0.9 | 1.2 | 18.9 | Clay |
| 8 | 4.4 | 0.3 | 2.0 | 2.2 | 14.7 | Clay |
| 9 | 4.4 | 0.4 | 1.1 | 2.3 | 15.0 | Clay |
| 10 | 5.2 | 0.1 | 1.7 | 4.2 | 19.3 | Clay |
| 11 | 4.7 | 0.2 | 1.1 | 3.6 | 21.9 | Clay |
| 12 | 5.1 | 0.4 | 2.0 | 4.1 | 17.2 | Clay Loam |

Av. P=Available Phosphorus = CEC= Cation Exchange Capacity, Exch. A =Exchangable acidity, OC= Organic Carbon, P=Phosphorus.

### *2.3. Treatments, Experimental Design and Procedures*

The treatments consisted of five (0, 25, 50, 75 and 100%) P critical levels (Pc) calculated from NPS fertilizer and one previously recommended P critical level (100% Pc) calculated from DAP fertilizer was included, which was used as check, that means the total number of treatment were six. The experiment was laid out in RCBD design with three replications. The gross plot size was $12m^2$ (3m x4m). Maize variety (BH 661) was used as a test crop. Phosphorus rate was calculated and applied according to the formula, P (kg $ha^{-1}$) = (Pc – Po)*Pf, where Pc= Phosphorus critical level, Po = initial soil Phosphorus in the soil and Pf= Phosphorus requirement factor. Recommended N (138 kg N $ha^{-1}$) determined during Phosphorus calibration study for maize in the district was used. The experimental fields were prepared by using oxen plow in accordance with conventional farming practices followed by the farming community in the area where, the fields were plowed four times., and treated with lime for soil pH less than 5.5, and the amount of lime needed per hectare was calculated based on exchangeable acidity. Full dose of phosphorous as per the treatment and one-half of N was applied at sowing. The remaining one-half of N was top dressed at 35 days after planting in the form of urea. The field was kept free of weeds by hand weeding during the period of the experiment. All other recommended agronomic management practices disease and insect pest control was done. Finally biomass yield, days to 50% tasseling, grain yield, and thousand grain weight data were collected. Data were subjected to analysis of variance (ANOVA) using General Linear Model (GLM) procedures of SAS 9.1.3 [25]. Differences among treatment means were compared using Least Significant Difference test at 5% level of significance.

### *2.4. Economic Analysis*

Costs that vary among treatments were also assessed using the CIMMYT partial budget analysis [26]. The cost of NPS, DAP, UREA, the cost of labor required for the application of fertilizer, and cost for shelling were estimated by assessing the current local market prices. The price of NPS (1548.87ETB 100 $kg^{-1}$), DAP (1997 ETB 100 $kg^{-1}$), UREA (1394 ETB 100 $kg^{-1}$), daily labors (35 ETB per one person day based on governments' current scale in the study area) and the cost of maize shelling (1 ETB $kg^{-1}$) were considered to get the total cost that vary among the treatments. Time elapsed during NPS application for some plots of each treatment was recorded to calculate daily labor required for one hectare. One person per day was estimated based on eight working hours per day. Maize grain yield was valued at an average field price of 6 ETB $kg^{-1}$. However, other non-varied costs were not included since all agronomic managements were equally and uniformly applied to each experimental plot. Before calculating gross revenue, maize grain yields obtained from each experimental plot were adjusted down by 10%. Finally, gross revenue was calculated as total yield obtained multiplied by field price that farmers receive for the sale of the crop. The net benefit and the marginal rate of return (MRR) were also calculated as per standard manual [26].

# 3. Results and Discussion

### *3.1. Effects of NPS Fertilizer on Yield Components and Yields of Maize*

The data (Table 2) showed significant differences among different treatments for maize biomass yield. Maximum biomass yield (31.0 t $ha^{-1}$) was recorded for 100% Pc from NPS against minimum (7.8 t $ha^{-1}$) in case of unfertilized maize plants with significant difference. The results are in conformity with those Dagne Chimdessa *et al*. [12] who observed the significant effect of NPS fertilizer on maize yield and yield component. The data also showed significant effect of NPS application on days to tassling and grain yield of maize. The highest maize grain yield (8.7 t $ha^{-1}$) was recorded for 100% Pc from NPS followed by 100% Pc from DAP (8.3 t $ha^{-1}$) with non-significant difference. This is in agreement with the findings of Benti Tolessa [27] who stated that, although adoption of new varieties especially maize hybrid is moving fast in Ethiopia, fertilizer management techniques need to supplement the existing potential of the varieties. The data (Table 2) also showed significant effect of NPS application on thousand grain weight. Maximum thousand grain weight (480.7 g) was obtained in 100% Pc from NPS and minimum (272.2 g) was for the control plot. These results are in accordance with those of Fareed, M. K, Maqsood, M., A *et al*. [28, 29] who also observed an increase in thousand grain weight with increase in NP application.

***Table 2.*** *Mean Bio Mass Yield, Days to Tassling, Grain Yield and Thousand Grain Weight of Maize in Dabo Hana district.*

| Treatments | BMY (t $ha^{-1}$) | DT (days) | GY (t$ha^{-1}$) | TGW (g) |
|---|---|---|---|---|
| Without fertilizer | 7.8$^{d}$ | 96.7$^{a}$ | 1.8$^{e}$ | 272.2$^{d}$ |
| 25%Pc from NPS +Rec N | 16.8$^{c}$ | 91.4 $^{b}$ | 4.4$^{d}$ | 342.7$^{c}$ |
| 50%Pc from NPS +Rec N | 21.1$^{b}$ | 90.3 $^{b}$ | 6.1$^{c}$ | 400.0$^{b}$ |
| 75%Pc from NPS +Rec N | 21.5$^{b}$ | 89.9 $^{b}$ | 7.1$^{b}$ | 407.3$^{b}$ |
| 100% Pc from NPS+Rec N | 31.0$^{a}$ | 89.0 $^{b}$ | 8.7$^{a}$ | 480.7$^{a}$ |
| 100% Pc from DAP+Rec N | 30.3$^{a}$ | 89.6 $^{b}$ | 8.3$^{a}$ | 473.2$^{a}$ |
| Mean | 21.4 | 91.1 | 6.0 | 396.0 |
| CV (%) | 25.5 | 6.3 | 15.7 | 6.6 |
| LSD | 3.6 | 2.6 | 0.5 | 17.3 |

BMY= Bio mass yield, DAP=di ammonium phosphate, CV= coefficient of variation, DT= days to teslling, GY= grain yield, LSD= least significant differences, NPS= nitrogen, phosphorus and sulfur, Pc= phosphorus critical level, PLH= plant height, Rec N= recommended nitrogen, TGW= thousand grain weight.

### *3.2. Economic Analysis*

The economic analysis of maize in relation to nutrient management practices is presented in (Table 3). The total variable cost ranged between 3360 ETB to 20029ETB $ha^{-1}$, The gross return oscillated between 9600ETB and 46800 ETB $ha^{-1}$ different treatments. Application of 100% Pc from NPS offered net return of 27340 ETB $ha^{-1}$ followed closely by 100% Pc from DAP (24971 ETB $ha^{-1}$) which were substantially greater than the rest of the fertilizer treatments (Table 3). The least net return of 6240 ETB $ha^{-1}$ was received from unfertilized control, elucidating the importance of NPS fertilizer in enhancing the net return. The highest (263%) marginal rate of return (MRR) was obtained with application of 100% Pc from NPS followed by application of 100% Pc from DAP for maize production.

***Table 3.*** *Partial budget analysis for NPS fertilizer fates on maize in Dabo Hana district.*

| Treatments | Av. GY (t $ha^{-1}$) | Adj. GY (t $ha^{-1}$) | TVC (ETB) | Gross Benefit (ETB) | Net Benefit (ETB) | D.A | MRR (%) |
|---|---|---|---|---|---|---|---|
| Without fertilizer | 1.8 | 1.6 | 3360.00 | 9600.00 | 6240.00 | | - |
| 25%Pc from NPS +Rec N | 4.4 | 4.0 | 12056.50 | 24000.00 | 11943.50 | | 66 |
| 50%Pc from NPS +Rec N | 6.1 | 5.5 | 15381.00 | 33000.00 | 17619.00 | | 171 |
| 75%Pc from NPS +Rec N | 7.1 | 6.4 | 17145.50 | 38400.00 | 21254.50 | | 206 |
| 100% Pc from NPS + Rec N | 8.7 | 7.8 | 19460.00 | 46800.00 | 27340.00 | | 263 |
| 100% Pc from DAP+ Rec N | 8.3 | 7.5 | 20029.00 | 45000.00 | 24971.00 | D | - |

Adj.GY=adjusted grain yield to 10%, Av.GY=average grain yield. D= dominated, DA= dominancy analysis, MRR= marginal rate of return, TVC= total variable cost.

## 4. Conclusion and Recommendation

Information on soil fertility status and crop response to different soil fertility management is very important to come up with sustainable crop production**.** Accordingly, The study confirmed the role of nitrogen, phosphorous and sulfur fertilizers in increasing growth and grain yield in maize production. The results conclude that maximum grain yield, the highest net benefit and acceptable MRR were recorded for 100% Pc from NPS fertilizer, whereas the lowest were recorded for the treatment without fertilizer. Accordingly NPS fertilizer increased maize productivity in the study area; which indicated that maize productivity in the study sites were reduced due to high demand for external nutrient inputs. Therefore, maize growers in Dabo Hana district are advised to use NPS fertilizer for higher yield.

## Acknowledgements

I acknowledge Oromia Agricultural Research Institute (IQQO)) for granting research fund and technical advice.

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