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Determination of NP Fertilizer Requirement for Newly Released Medium Maturing Maize Varieties at Jimma Zone, Southwestern Ethiopia

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ABSTRACT

The field experiments were carried out in two sites of Omonadaworeda, Jimma Zone for three consecutive years 2016-2018 main cropping seasons. The treatments consisted of factorial combinations of four Nitrogen and Phosphorous fertilizer rates (69/52, 92/69, 115/86 and 138/104 kg ha^{-1}) and three maize varieties (BH547, BH546 and SPRH 1) laid down in a randomized complete block design (RCBD) with three replications. The analysis of data showed that all parameters of maize were significantly affected by NP fertilizer rates and maize varieties except harvest index, plant height and logging percentage were not affected by NP fertilizer rates. Maximum grain yield (7.11 t ha^{-1}), biomass yield (10.46 tha^{-1}) and harvest index (0.724) were recorded from BH546 variety and grain yield (7.11 t ha^{-1}), biomass yield (9.54 tha^{-1}) and harvest index (0.742) were recorded from 138/104 NP fertilizer rates. Thus the previous recommendation of 92 kg N ha^{-1} is insufficient for those new hybrid versions like BH456 due there high response to inorganic fertilizers. The grain and biomass yield were significantly increased from 6.21 to 7.11 t ha^{-1} and 8.39 to 9.54 t ha^{-1} which means increased by 12.32% and 11.71% over control respectively from the application of 92/69 NP kg ha^{-1}.In conclusion, Partial budget analyses showed that BH546 maize variety gave highest net benefit (25,006 EtB) with acceptable MRR (160%) and also application of 138/104 kg NPha-1gave highest net benefit (21,445 EtB) with acceptable MRR (120%) but sensitive or not withstand price changes. Therefore, application of 138/104 kg NP ha^{-1} to improve grain yield of medium maturing maize BH546 variety might be more profitable in and around the study area.

Keywords: *Maize; BH547; BH546; SPRH 1; Nitrogen and Phosphorous fertilizer rates*

INTRODUCTION

Maize is the primary staple crop in Ethiopia and plays an important role in the livelihood of the people of Ethiopia. Its availability and abundance determine the level of welfare and food security in the country. In Ethiopia, future increases in maize production to meet domestic demand will have to rely on improvements in yield per hectare rather than on the expansion of maize production area. Enhanced maize productivity can be achieved by increased use of modern production techniques such as the adoption of hybrid maize varieties in line with the use of fertilizer application and appropriate crop management practices.

Some soil types in Ethiopia contain enough amounts of essential nutrients for the plant's development. But the majority of soils in the country contains low to medium total N and found inherently low in available P. This could be due to long term cultivation practice that depletes plant nutrients and soil resource degradation as a result of soil erosion and run-off and this becomes a threat to agricultural productivity in Ethiopia. Thus to produce some crop yields the application of mineral fertilizers has been mandatory that previous fertilizer recommendation for most potential maize production areas were found to vary from 90 - 110 kgha^{-1} N and 20 - 35 kgha^{-1}P Tolessa et al.,(2002). However, current observation in maize production field show multi-nutrient deficiencies even in plots where farmer attempted to apply fertilizers at rates they claim optimal for expected yield levels. Thus, NP fertilizers must be applied at rates that can provide better nutrient use efficiencies of some maize varieties or hybrid can be coupled with optimum plant population and fertilizer application methods and rates that coincide with peak need by the crop.

Therefore, it is an appropriate period to propose fertilizer studies for lately released medium maturing maize varieties that have been developed and ready for use in different agro-ecologies of Ethiopia. Hence, an effort made to study the effect of different fertilizer rates on the growth and yield of newly released medium maturity maize varieties.

Materials and Methods

Description of the Study Area

The current field experiments were conducted in at two sites for three consecutive main cropping seasons of Omonadaworeda, Jimma Zone Southwestern Ethiopia at farmers' fields. The sites were located on 7º46' N and 36º 00'E and laid at an altitude of 1753 m.a.s.l. with soil type of the area is Upland: Chromic Nitosol and Combisol. The average maximum and minimum temperature are 9ºC and 28ºC respectively and reliably receive good rains 1561 mm per annum cropping season.

Experimental Treatment and Procedures

The recently released medium maturing varieties BH546, BH547 maize hybrid and SPRH 1 storage pest resistant maize are well adapted to low-mid altitude (1000-1800 m.a.s.l) areas. They were white-colored and used for experiment to maximize yield potential of smallholder farmers. The combination of four Nitrogen and Phosphorous fertilizer rates (69/52, 92/69, 115/86 and 138/104kg ha^{-1}) twelve treatments were laid out in a randomized complete block design (RCBD) with three replications. Blocks were separated from each other by 1.5 m wide-open space, while experimental plots within replications were separated by 1 m apart from each other. The gross size of each plot was 4.0m length by 5.25m width (21 m2) accommodating 8 rows. The inner 6 rows used for data collection. Nitrogen and phosphorus fertilizers were applied, respectively per stand or hill base. To increase the nitrogen use efficiency, it was split into two equal rates and applied at planting time and knee height stages.

The experimental field was prepared following the conventional tillage practice and furrow opened by using oxen. Two maize seeds were planted per hill and thinned after establishment to maintain a single healthy plant per hill. All other agronomic practices like three times hand weeding were applied uniformly to both experimental plots as per their respective recommendations for maize in the study area.

Soil Sampling and Analysis

A composite surface soil (0-30 cm depth) sample was collected from both sites with a gauge auger before planting; the experimental field was blocked into three parts depending upon land uniformity. Plant residues on the sampling soil surface were removed. The investigated soil properties are shown in Table 1.

Table1. *Physiochemical properties of the experimental soil (0-30 cm depth) before sowing*

	Omonada	Rating	Source
pH 1:2.5 (H_2O)	5.03	Strongly acid	Batjes(1995)
Organic matter (%)	3.52	Medium	Tekalign (1991)
Total N (%)	0.17	Medium	Tekalign (1991)
Organic carbon	2.04	medium	Berhanu, (1980)
Available P (mg kg^{-1})	9.45	Low	Cottenie, 1980

Source: *Jimma agricultural research center soil laboratory.*

Data collection

The data collected were growth, yield, yield related and other agronomic data were collected.

Economic Analysis

To assess the costs and benefits associated with different treatments (inter and intra row spacing), the partial budget technique as described by CIMMYT (1988) was applied. Economic analysis was done using the prevailing market prices for inputs at planting and outputs, at the time the crop was harvested. All costs and benefits were calculated on ha-basis of Ethiopian Birr (EtB). The inputs and/or concepts used in the partial budget analysis were the mean grain yield of each treatment in the three years, the field price of QPM Hybrid maize grain (sale price grain yield minus the costs of fertilizer, planting, seed), the gross field benefit (GFB) ha^{-1}(the product of field price of the mean yield for each treatment), the field price of Seed rate kg ha^{-1}, fertilizer and wage rate, the total costs that varied (TCV) which included the sum of field cost of seed, fertilizer and its wage for planting and application. The net benefit (NB) was calculated as the difference between the GFB and the TCV. Actual yield was adjusted downward by 10% to reflect the difference between the experimental yield and the yield farmers could expect from the same treatment. There were optimum plant population density, timely labor availability and better management (e.g. weed control, rainfall) under the experimental conditions CIMMYT, (1988). The dominance analysis procedure as detailed in CIMMYT (1998) was used to select potentially profitable treatments from the range that was tested. The discarded and selected treatments using this technique were referred to as dominated and undominated treatments, respectively. The undominated treatments were ranked from the lowest to the highest cost. For each pair of ranked treatments, the percent marginal rate of return (MRR) was calculated. The MRR (%) between any pair of undominated treatments was the return per unit of investment in fertilizer. To obtain an estimate of these returns the MRR (%) was calculated as changes in NB divided by changes in cost. Thus, the MRR of 100% was used indicating for every one EtB expended there is a return of one EtB for a given variable input.

Data Analysis

Analysis of variance (ANOVA) for all collected data was computed using SAS software version 9.3. The significance of differences between samples was separated using the least significance difference (LSD) at 5% level of significance.

Results and Discussion

The combined analysis of variance (ANOVA) for the effects of NP fertilizer rates and maize varieties both location and three seasons were did not show significant (P <0.05) interaction all parameters. Grain, and biomass yield were significantly (P <0.01) influenced by both NP fertilizer rates maize and varieties (Table 6) and Plan height, logging percentage and harvest index were showed significantly (P <0.05) only influenced by maize varieties (Table 1 and 2), While Plan height, logging percentage and harvest index were not showed significantly (P <0.05) influenced NP fertilizer rates (Table 2).

Plant Height

The plant height was significantly (P<0.05) influenced by the main effects maize varieties at both locations and three seasons and not significantly (P<0.05) influenced by NP fertilizer rates and interaction effect (Table 2). The SPRH 1 variety had the highest plant height 282.06 cm, followed by BH546 variety with a height of 27.85cm. Among varieties, BH547 variety had the shortest 250.48cm height (Table 2). The result showed the plant height and growth were vary with varieties even though they were a similar group of maturity and variety SPRH 1 had the highest plant height 282.06 cm than all tested varieties. Similarly, Tolera A. et al., (1999) reported that breeders should select maize varieties that combine high grain yield and desirable stover characteristics because of large differences that exist between cultivars. The highest plant height 266.58 cm and followed by 265.56 cm were recorded from 138/104 and 115/86 NP kg ha^{-1}fertilizer rates respectively. While the shortest 258.56 was recorded from lowest 69/52 NP fertilizer rates. There was an increase in plant highest with an increase in N rate. The current result was in agreement with Rashid et al. plant height was linearly increased with increasing levels of N fertilization. Similarly, Harris P. (1995) reported plant height, on each treatment with an increase of NKP rate and animal manure application.

Table2. *Across season and location main effects of NP and medium maturing maize varieties on yield and yield component parameters at Omonada*

Varieties	Plant height (cm)	Logging percentage
BH547	250.48	32.66
BH546	257.85	15.97
SPRH1	282.06	41.89
LSD (0.05)	**10.81**	**6.04**
NP (P_2O_5 kg/h^{-1}) fertilizer rates		
69/52	258.56	30.53
92/69	263.17	29.32
115/86	265.56	30.41
138/104	266.58	30.44

Mean	**263.47**	**30.17**
LSD (0.05)	**Ns**	**Ns**
CV (%)	**12.48**	**20.88**

Where, LSD (0.05) =Least Significant Difference at 5% level; CV=Coefficient of Variation.

Logging Percentage

The highest Logging percentage of 41.89 was recorded from the SPRH 1 variety and followed by 32.66 from BH547 variety. While the lowest 15.97 was recorded from the BH546 variety. It was significant differences (P<0.01) effect only due to varieties but didn't show the interaction effect and influenced by NP fertilizer rates (Table 2). The varietal difference shows that the variety SPRH 1 gave the highest plant height and logging percentage. So, these highest logging percentage was may be resulted due to the highest plant height even though there were other factors like wind. Similarly, Odeleye and Odeleye (2001) reported that maize varieties differ in their growth characters, yield and its components.

The biomass yield was significant differences (P<0.01) effect due to NP fertilizer rates and maize varieties (Table 3). The highest biomass yield 10.46 and 9.54 t ha-1 was recorded from the BH546 and 138/104 respectively from the highest NP rate. On the contrary, the lowest 7.02 and 8.39 t ha^{-1} from the BH547 and 69/52 respectively from the lowest NP rate (Table 2). The highest 138/104 kg ha^{-1}NP rate of biomass yield was significantly increased from 8.57 to 9.54 t ha^{-1} which means increased by 11.71% over control from the application of 92/69 NP kg ha^{-1} (control). The result shows that an increase in biomass yield with increasing NP rate. These result in agreement with Tariku B. e al (2018) reported that application of higher nitrogen increased the dry matter of plants.

Biomass Yield

Table3. *Across season and location main effects of NP and medium maturing maize varieties on yield and yield component parameters at Omonada*

Varieties	Grain yield tone ha^{-1}	Biomass yield t ha^{-1}	Harvest Index
BH547	6.83	9.18	0.739
BH546	7.82	10.46	0.746
SPRH1	5.10	7.02	0.724
LSD (0.05)	**0.48**	**0.59**	**0.126**
NP (P_2O_5 kg/h^{-1}) fertilizer rates			
69/52	6.21	8.39	0.736
92/69	6.33	8.57	0.733
115/86	6.68	9.06	0.734
138/104	7.11	9.54	0.742
Mean	**6.58**	**8.89**	**0.736**
LSD (0.05)	**0.56**	**0.69**	**Ns**
CV (%)	**20.45**	**20.35**	**5.19**

Where, LSD (0.05) =Least Significant Difference at 5% level; CV=Coefficient of Variation.

Grain Yield

Grain yield was significantly (P<0.01) affected by the effect of NP fertilizer rates and maize varieties and doesn't show the interaction effect (Table 3). The results of ANOVA showed that the highest mean grain yield (7.82 t ha^{-1}) was recorded from BH546 variety and followed by (7.11 t ha^{-1}) were recorded in the highest 138/104 NP fertilizer rates. While the lowest grain yield (6.21 t ha^{-1}) and biomass yield (7.02 tha^{-1}) were recorded in SPRH 1variety and the lowest 69/52 NP fertilizer rates. The highest 138/104 kg ha^{-1}NP rate of grain yield was significantly increased from 6.33 t ha^{-1} to 7.11 tha^{-1} which means increased by 12.32% over control from the application of 92/69 NP kg ha-1 (control). Thus the previous recommendation of 92 kg N ha-1 is insufficient for those new hybrid versions like BH456 due there high response to inorganic fertilizers. This is similar to the findings of Ghimire S. et al. (2016) reported that grain yield was significantly affected by crop varieties sown. Irrespective of fertilizer dose and irrigation maximum grain yield ranging from (3.17 to 7.25 t ha^{-1}) and (1.60 to 6.32 t ha^{-1}) was produced by Rajkumar in improved practice and farmers practice of cultivation respectively. Also supported by Obi (1999), Kim (1997) and Udoh (2005) who reported that some hybrid maize varieties have a yield advantage over other maize varieties because they possess such special qualities as high yield, disease resistance, and early maturity uniformity in flowering and ear placement, harvester.

Harvest Index

The harvest index was significantly (P<0.001) influenced by varieties and not significantly (P<0.05) influenced by the application of NP fertilizer rates (Table 3). Significantly higher harvest index of 0.746 was obtained from BH546 variety and while the lowest was 0.724 from SPRH 1 variety. The second highest harvest index 0.742 was obtained from the application of the highest 138/104 kg ha^{-1}NP fertilizer rate. The result showed that there was an increase in harvest index with an increase in N rate. In line with this result, Lawrence (2008) reported that the harvest index in maize increased when nitrogen rates increased. Similalry, Orkaido (2004) reported that increasing N level from 0 to 120 kg N ha^{-1} increased harvest index of maize.

Economic Viability of Maize Varieties and NP Fertilizer Rates

Analysis of variance (Table 1) showed that verities and NP had a significant (P = 0.001) effect on the grain yield of QPM Hybrid, BHQPY546 maize whereas interaction was not significant. An economic analysis of the combined results using the partial budget technique was thus appropriate (CIMMYT, 1988). The result of the partial budget analysis and the data used in the development of the partial budget are given in (Tables 3 and 4). It was performed by considering fertilizer cost, application cost, and labour as main input, mean grain yield obtained across season and location. The total costs of fertilizers (NPS = 15.90 EtB/kg and urea = 12.65 EtB/kg and sale of grain maize at Omonada open market average price (4.00 EtB/kg).

Dominance analysis (Table 3) led to the selection of treatments only BH547 and BH546 from varieties and 69/52, 115/86 and 138/104 NP kg ha-1 from NP rates were ranked in increasing order of total costs that vary. The treatments having MRR below 100% was considered and unacceptable to farmers; thus, SPRH-1 variety and 92/69 NP kg ha-1 were eliminated (CIMMYT, 1988) (Table 3). This was because such a return would not offset the cost of capital (interest) and other related deal costs while still giving an attractive profit margin to serve as an incentive. partial budget analysis based on the field prices of inputs and maize grain yield showed that, The BH546 gave the highest net benefit (25006 EtB ha-1) with acceptable MMR (160%) and also application of 138/104 kg NP ha-1 gave the high net benefit (21445 EtB ha-1) and acceptable MMR (120%) (Table 4). This might suggest the use of inputs that result inmaximum net benefits Bekele, (2000).

Market prices are ever changing and as such a recalculation of the partial budget using a set oflikely future prices i.e., sensitivity analysis, was essential to identify treatments which maylikely remain stable and sustain satisfactory returns for farmers despite price fluctuations. Thesensitivity analysis study indicates an increase in the labour price of the total variable costs, and a fall in the price of maize grain of Birr 0.5 per kg which represented a price variation of 15%. The price changes are sensitive under market conditions prevailing at OmonadaBH546 variety and application of 138/104 kg ha-1 NP gave (92%)and (15%) MRR., respectively which were below the minimum acceptable (Table 5).

Therefore, this investigation remained with BH546 with application 138/104 NP kg ha-1give aneconomic yield response and also sustained acceptable even under a projected worsening trade conditions or for farmers with high net benefit even though unacceptable MMR in Omonada. The results of this study can be used to make tentative recommendations, which can be refined through multi-location.

Table3. *Partial budget with dominance to estimate net benefit for application of medium maturing maize varieties and NP fertilizer rates at current prices*

Varieties	Grain yield tone ha^{-1}	Adjusted Grain Yield tone ha^{-1}	GFB (EtB)	TCV (EtB/ha)	NB (EtB/ha	Dominance analysis
BH547	6.83	6.15	24,588	1776	22,812	U
BH546	7.82	7.04	28,152	3146	25,006	U
SPRH 1	5.10	4.59	18,360	3851	14,509	D
NP fertilizer rates (kg ha^{-1})				-		
69/52	6.21	5.59	22,356	2076	20,280	U
92/69	6.33	5.70	22,788	2761	20,027	D
115/86	6.68	6.01	24,048	3446	20,602	U

138/104	7.11	6.40	25,596	4151	21,445	U

TCV= total cost that varied, Retail price of grain =Birr 4.00 per kg; EtB = Ethiopian Birr; Fertilizers urea = Cost of Birr 12.65, per kg; NPs =Cost Birr 15.90 per kg; MMR= Marginal Rate of Return;GFB=Gross FieldBenefit; NB = Net benefit;

Table4. *Partial budget with estimated marginal rate of return (%) for varieties and NP rates at current prices*

Varieties	TCV(EtB/ha)	NB (EtB/ha	Raised cost	Raised benefit	MRR (%)
BH547	1776	22,812	----	----	----
BH546	3146	25,006	1,370	2,194	160
NP fertilizer rates(kg ha^{-1})					
69/52	2076	20,280	----	----	----
115/86	3446	20,602	1,370	322	23
138/104	4151	21,445	705	843	120

TCV= total cost that varied, Retail price of grain =Birr 4.00 per kg; EtB = Ethiopian Birr; Fertilizers urea = Cost of Birr 12.65, per kg; NPs =Cost Birr 15.90 per kg; MMR= Marginal Rate of Return; NB = Net benefit;

Table5. *Sensitivity analysis of maize production after different practices based on a 15% rise in total cost and maize price of gross field benefit fall*

Varieties	**TCV (EtB/ha)**	**NB (EtB/ha**	Raised cost	Raised benefit	MRR (%)
BH547	2042	18857	---	---	---
BH546	3618	20311	1576	1454	92
NP fertilizer rates(kg ha^{-1})					
69/52	2387	16616	---	---	---
138/104	4774	16983	2387	367	15

TCV= total cost that varied, Retail price of grain =Birr 3.50 per kg; EtB = Ethiopian Birr; Fertilizers urea = Cost of Birr 12.65, per kg; NPs =Cost Birr 15.90 per kg; MMR= Marginal Rate of Return; NB = Net benefit;

Summary and Conclusion

From all, the most important parameters were significant (P = 0.001) for the effects of maize varieties and NP fertilizer rates. The highest biomass yield 10.46 and 9.54 t ha-1 was recorded from the BH546 and 138/104 respectively from the highest NP rate. The highest mean grain yield (7.82 t ha-1) was recorded from BH546 variety and followed by (7.11 t ha-1) were recorded in the highest 138/104 NP fertilizer rates. Thus the previous recommendation of 92 kg N ha-1 is insufficient for those new hybrid versions like BH456 due there high response to inorganic fertilizers. While the lowest grain yield (6.21 t ha-1) and biomass yield (7.02 t ha-1) were recorded in SPRH1variety and the lowest 69/52 NP fertilizer rates (Table 2). The highest 138/104 NP rate of grain yield was significantly increased from 6.33 t ha-1 to 7.11 t ha-1 which means increased by 12.32% over control from the application of 92/69 NP kg ha-1 (control). The partial budget analysis based on the field prices of inputs and maize grain yield showed that, The BH546 gave the highest net benefit (25006 EtB ha-1) with acceptable MMR (160%) followed by and application of 138/104 kg ha-1 NP net benefit (21445 EtB ha-1) and acceptable MMR (120%) and The price changes are sensitive under market conditions prevailing at OmonadaBH546 variety and application of 138/104 kg ha-1 NP gave (92%) and (15%) MRR, respectively which were below the minimum acceptable, so it implies sensitive to changing price(Table 5).Hence, the farmers at and around Omonada site, (Jimma zone) could use rates of nutrients (138/104 NP kg ha-1for BH546 medium maturing maize variety) in order to achieve economic grain yield under rain fed conditions. Therefore, in the light of the significant response of maize to NP fertilizer and variety, further studies aimed at promoting fertilizer recommendation based on soil and plant tests over locations will be useful.

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