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Growth and Yield of Maize (Zea Mays L) as Affected by Nitrogen Fertilization in Denba Gofa, Southern Ethiopia

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Abstract:
Background: *Maize is an important food crop in southern Ethiopia. However, its productivity is constrained by inadequate nitrogen supply and use of low yield potential cultivars. Therefore, a field experiment was conducted during 2016 with objective of determining optimum nitrogen rates for two maize varieties adapted to agro-ecology of Denba Gofa woreda.*
Materials and Methods: *The graded levels of nitrogen tried were 0, 50, 100, 150 and 200 kg ha^{-1} and varieties were Pioneer jabi 3253 and BH 540. Experiment was laid in randomized complete block design with ten treatments (combinations of five nitrogen levels and two varieties) and three replications. The crop was raised under rainfed conditions.*
Results: *There was significant effect of nitrogen fertilization on different growth and yield contributing parameters and grain and biomass yields of maize. Nitrogen rate of 200 kg ha^{-1}produced significantly higher grain and biomass yields than all other rates and increased grain yield by about 78 % over control. The variety Pioneer jabi 3253 responded significantly better than BH 540 to fertilization; grain yield being 10 % higher in the former than the latter. All growth and yield contributing parameters showed highly significant correlations with grain and biomass yields. The linear N-response function for grain and biomass yields showed very high values of R^2 (0.97-0.99), further signifying marked response of maize to nitrogen fertilization. Partial budget analysis indicated benefit of fertilization (over control) at 200 kg N ha^{-1} to the tune of 60 % for Pioneer jabi 3253 and 48 % for BH540.*
Conclusion: *The N level of 200 kg N ha^{-1} and variety Pioneer jabi 3253, giving better yield and economic benefits, may be recommended for cultivation in Denba Gofa woreda.*
Key words: *Denba Gofa; Maize varieties; N rate; Growth and yield; Economic yield.*

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I. Introduction

Maize (*Zea mays* L) is the third most important cereal crop in the world next to rice and wheat, serving as a potential source of food for humans in South America, Africa and China. Africans consume maize for making of bread and as a starchy base in a wide variety of porridges, pastes, grits, and beer. Green maize grain is eaten parched, baked, roasted or boiled and plays an important role in filling the hunger gap after the dry season. In sub-Saharan Africa, maize is a staple food for an estimated 50 % of the population and provides 50 % of the basic calories [1], while in Ethiopia, it constitutes more than 60% of the caloric intake of a typical household [2]. Its cultivation is largely by smallholder farmers, comprising some 80 percent of Ethiopia's population and producing over 95% of the total maize. Obviously, the crop has great significance in the livelihood of most Ethiopians.

Maize is grown mostly at lower altitudes along the country's western, southwestern, and eastern peripheries both under irrigated and rain fed systems. It ranks second after Teff (*Eragrostis tef*) in area coverage among the principal grain crops in Ethiopia (the share of teff, maize, sorghum, wheat and barley being 30, 22, 20, 17, and 11 %, respectively), and first in total production [3]. Currently, it occupies an area of about 2 million ha and records average production of about 6.7 million tonnes [4]. The national average yield of maize is about 3.39 t ha^{-1} [5], which is far below the world's average yield of about 5.2 t ha^{-1} [4]. Poor soil fertility and low-yielding cultivars are some of the principal factors limiting maize productivity in Ethiopia [2, 6, 7]. There is still huge potential to increase the existing national average yield to a level of 8 to 12 t ha^{-1} under well-managed farm practices [2, 8].

Majority of Ethiopian soils are inherently poor in soil fertility, particularly in respect of nitrogen [9, 10, 11, 12]. The nutrient availability in soils could be enhanced with more use of organic manures and chemical fertilizers. The organic manures are still in short supply with most of the small holder farmers, as animal dung and crop residues are largely used as sources of energy for domestic purposes. Use of chemical fertilizers, therefore, should be a mainstay of maintaining adequate nutrient supplies in soils and enhancing crop productivity. The role of mineral fertilizers in promoting the accelerated growth in maize productivity in Ethiopia has been demonstrated very well for a period of 10 years from 2004-2013 by Abate et al. [13].

The fertilizer use on maize is still inadequate in Ethiopia in terms of area coverage and rates as revealed by the study by Abate et al. [13]. The requisite data for the study were accessed from the Central Statistical Agency, Ethiopia (www.csa.gov.et). Although the total consumption of fertilizer (urea and diammonium phosphate) in maize production grew three-fold between 2004 -2013 (from 20,000 to 68,000 MT), the area that received some amount of mineral fertilizer remained between 56 to 69 %. The SNNPR region, where Denba Gofa woreda is located, showed 61 % area coverage. As for fertilizer rates, the NP consumption was 16 kg ha^{-1} in 2004, which increased to 34 kg ha^{-1} in 2013. The fertilizer rate, however, was far from the national recommendation of about 120 kg ha^{-1} of NP. Taking N:P consumption ratio of 2:1 from this study [13], the N application rate worked out to be only 11-23 kg ha^{-1} in contrast to national recommendation of about 80 kg ha^{-1}. The low fertilizer use was, obviously, one of the factors for low productivity of maize, especially in the context of fertilizer responsive hybrids/varieties of maize.

Therefore, determining the precise fertilizer N rates for the optimum yields of the high yielding hybrids/varieties based on the actual field experiments, should be central to the overall farm strategy of increasing productivity of maize. The present study on determination of N fertilizer response and its optimum level for two maize hybrids adapted to the agro-ecology of Denba Gofa woreda was, therefore, taken up with the perspective of raising farm productivity employing sound fertilizer management.

II. Materials and Methods

Description of the study area

The experiment was conducted at Denba Gofa Woreda of Gamo Gofa zone in southern Ethiopia. This Woreda is one of the 17 Woredas in Gamo Gofa Zone located at 530 km from Addis Ababa and 300 km from the regional capital Hawassa. The geographical coordinates of the site are 6^{O}18'N longitude, and 36^{O} 54'E latitude and the altitude of 1343m above sea level. The area receives rainfall of 900-1100 mm and has a temperature of 27- 38^{0}C. The major crops cultivated in the Woreda include maize, teff, haricot bean, groundnut, sesame, sorghum and various root crops (potato, cassava, taro, yam). The soil of the experimental site was clay loam in texture and had pH of 7.0 and organic matter content of 2.8% [14]

Experimental materials

Plant materials - The high yielding maize hybrids, viz., BH 540 and PHB Jabi 3253 adapted to the agro-ecology of the area were used for the study. BH 540 has a wider adaptability and grows well at altitudes ranging from 1000-2000 meters above sea level with rainfall of 1000-1200mm. It needed 145 days for maturity and grain yield on a research field. The variety PHB Jabi 3253 grows best on altitude of 1400-2000 meters above sea level with rain fall of 500-1000mm. It also needs about 133 days for maturity.

Fertilizer materials - Urea (46 % N) and triple superphosphate (48-0-0) were used as sources of nitrogen and phosphorus, respectively.

Experimental design, layout and treatments

The experiment was laid out in RCBD (Randomized Complete Block Design) with three replications. There were 10 treatments consisting of combinations of five nitrogen levels (0, 50, 100, 150, and 200 kg N ha^{-1}) and two maize hybrid varieties (BH 540 and PHB Jabi 3253). The number of total plots were 30. The space between the plots and blocks was 1m and 1.5 m, respectively. There were six rows of maize plants in a plot, spaced at 75 cm. The number of plants in a row was ten spaced at 30 cm. Accordingly, the plot size was 13.5 m^2. The gross area was 784 m^2 (56m x 14 m).

Field activities

The whole amount of P at the recommended rate of 46 kg P_2O_5 ha^{-1} and one-half of N at the given rate for the respective treatments were applied at the time of planting in furrows below the seed. The fertilizer was raked into the soil properly to avoid direct contact of seed with fertilizer. Sowing was done on 23rd April, 2016. The remaining half of nitrogen was top dressed at the knee-high stage of crop growth. The experiment was conducted under rainfed condition. All cultural practices were followed in a specified manner ensuring high level of crop management. Weeding and earthing–up operations were done manually. The crop was harvested on 15th August, 2016 from the central net plot area of 13.5m^2.

Growth and yield parameters

Leaf area index - Leaf area at 50% silking was determined by multiplying leaf length and maximum breadth and adjusted by a correction factor of 0.75 (i.e. 0.75 x leaf length x maximum breadth) as suggested by Francis et al. [15]. Leaf area index was calculated by dividing leaf area per sample ground area [16].

Number of green leaves per plant - Total number of green leaves per plant at tasseling were counted from five randomly taken plants and their averages were taken as the number of green leaves per plant .
Plant height - Measured as the height from the soil surface to the base of the tassel of five randomly taken plants from the net plot area at physiological maturity.
Days to physiological maturity - Recorded as the number of days after sowing to the formation of a black layer at the point of attachment of the kernel with the cob.
Number of Cobs per plant - Recorded as average count of five randomly taken plants in the central net plot area.
Cob height - It was measured from ground level to the node bearing the top useful cob.
Cob length - It was measured from the point where the cob was attached to the stem to the tip of the cob.
Number of kernels per cob - Computed as the average number of kernels of five randomly taken cobs from the central net plot area.
Thousand kernels weight - It was determined from 1000 randomly taken seeds from each plot
Grain yield - Plants from the net plot area were harvested and grain weight obtained.
Grain yield per hectare was calculated as follows:

$$\text{Grain Yield} = \frac{Grain\ weight\ (g) X\ 10{,}000\ m2}{Harvested\ \ plot\ area\ (m2)}$$

Above ground biomass yield - It was recorded after harvesting plants from the net plot area at physiological maturity and weighing after sun drying. The biomass yield was calculated as for grain yield.

Data analysis

Analyses of variances for the data recorded were conducted using the SAS procedure. Least significant difference (LSD) test at 5% probability was used for mean separation. Pearson's correlation coefficients (r) between growth and yield parameters were determined. The data on yield were regressed on N rates to develop nutrient response functions.

Economic analysis

Mean grain yield under treatments was used for partial budget analysis employing CIMMYT procedure [17]. The gross benefit was calculated by multiplying the adjusted grain and biomass yields (kg/ha) with the prevailing selling prices of the produce. Total variable cost was computed considering prevailing market price of urea fertilizer as well as labor cost to apply it. Net benefit was calculated by subtracting total variable cost from the gross benefit. The farm gate prices used for analyses were 6.0 ETB/kg of grain and 200 ETB/ton of straw of maize; and 11.53 ETB/kg of urea fertilizer. The marginal rate of return analysis of non-dominated grain yield responses for different N fertilizer rates was done following the method used by Nasreen and Farid [18].

$$\text{Marginal rate of return (MRR \%)} = \frac{Marginal\ \ increase\ \ in\ net\ benefit}{Marginal\ \ increase\ \ in\ variable\ \ cost}\ X\ 100$$

III. Results and Discussion

Effect of N rates and varieties on growth parameters

The fertilizer N rates influenced significantly different growth parameters, viz., leaf area index, number of leaves per plant, plant height, cob height and days for physiological maturity (Table 1). Although, the low level of N application, i.e 50 kg ha^{-1}, did not show a significant increase over control in number of leaf per plant, plant height and cob height, it was quite marked for all the growth parameters at higher levels of 150 and 200 kg N ha^{-1}. The increase over control with highest level of 200 kg ha^{-1} was 21.7, 12.4, 15.4, 22.9 and 11.4 percent for leaf area index, number of leaf per plant, plant height, cob height and physiological maturity, respectively. Similar to our results, the increasing nitrogen fertilizer rates have been reported to increase leaf area index [19], plant height [20, 21], and cob height [22]. It was quite obvious as more availability of nitrogen under higher rates had increased the photosynthetic activity, having positive effect on different growth parameters. Moreover, increased nitrogen supply had extended vegetative growth period, that increased photosynthetic assimilate production and its partitioning to stems, exerting favorable impact on cob height of maize. It was interesting to note that the successive levels of N application significantly increased the physiological maturity of the crop. The days taken to maturity were about 105, 110, 112, 115 and 117 with the N application rates of 0, 50, 100, 150 and 200 kg ha^{-1}, respectively. It was so, as maize crop required accumulation of more heat units (thermal time) to physiological maturity with increasing rate of nitrogen [22].
As for varieties, Pioneer jabi 3253 gave significantly higher leaf area index, number of leaf per plant, plant height and cob height compared to BH 540, registering an increase of 10.8, 9.9, 6.7 and 5.0 percent,

respectively. The varieties did not show a significant difference in maturity period, both maturing in112 days. The N fertilizer rates and varieties did not show a significant interaction for growth parameters.

Table 1. Effect of N levels and varieties on growth parameters of maize

Treatment	Leaf area index	Number of leaf per plant	Plant height (cm)	Cob height (cm)	Physiological maturity (days)
N level (kg ha^{-1})					
0	3.64^{b}	13.93^{c}	225.16^{c}	145.5^{c}	104.94^{e}
50	3.97b^{a}	14.43b^{c}	231.83^{c}	152.49^{c}	109.83^{d}
100	3.96^{b}	14.83^{b}	241.66^{b}	162.49^{b}	112.33^{c}
150	4.08^{a}	15.43^{a}	253.66^{a}	171.66^{a}	114.99^{b}
200	4.43^{a}	15.66^{a}	259.83^{a}	178.83^{a}	117.33^{a}
LSD (0.05)	0.46	0.59	8.76	7.65	1.85
Variety					
Pioneer Jabi 3253	4.22^{a}	15.55^{a}	250.33^{a}	166.19^{a}	111.91
BH 540	3.81^{b}	14.15^{b}	234.53^{b}	158.19^{b}	111.86
LSD (0.05)	0.29	0.37	5.54	4.84	NS
Interaction	NS	NS	NS	NS	NS
CV (%)	9.5	3.2	4.75	3.9	1.3

The means in the columns followed by the same letters are not significantly different from each other

Effect of N rates and varieties on yield contributing characters

The analysis of variance revealed significant ($p<0.01$) effect of nitrogen fertilizer application rates on yield contributing characters. Like growth parameters, the values for yield contributing characters, viz number of cobs per plant, cob length, number of kernels per cob and one-thousand kernel weight were also significantly higher under higher N rates of 150 and 200 kg ha^{-1} compared to control (Table 2). The increases under 200 kg N ha^{-1} were 23.0, 22.3, 49.1 and 17.9 percent, respectively for cobs per plant, cob length, kernels per cob and thousand kernel weight. A significant increase in number of cobs per plant and number of kernels per cob with increasing N rates has also been reported by Selassie [23] for Alfisols of Northwestern Ethiopia and Mitiku and Asnakech [21] for Decha District of SNNPR. Similarly, Increase in cob length with increasing rate of fertilizer N application has been reported by Singh *et al.* [24], Sharifi and Taghizadeh [25] and Kandil [20]. Increase in cob length under higher N rates was as a result of more photosynthetic activity of the plants on account of adequate supply of nitrogen, which is essential requirement for cob growth. Better development of cob length was considered to be a better index of economic yield of maize crop [26]. Increased kernel weight with increasing nitrogen levels might be due to more vegetative growth resulting in production of more carbohydrates in the source to be translocated to the sink (the grain). Also, increasing N rates increase the enzyme activity in maize which may result in higher kernel weight. The increased kernel weight in maize with higher rate of N has also been reported by Raja [27], Miao *et al.* [28], Khaliq *et al.* [29], Abera [30] and Ngosong et al. [31].

Table 2 . Effect of N levels and varieties on yield contributing parameters of maize

Treatment	Number of cob per plant	Cob length (cm)	Number of kernel per cob	Thousand kernel weight (g)
N level (kg ha^{-1})				
0	1.0^{c}	13.11^{d}	416.9e	424.5^{d}
50	1.06^{c}	14.08^{c}	494.27d	447.83^{c}
100	1.09^{c}	14.81^{b}	533.93c	469.33^{b}
150	1.2a^{b}	15.59^{a}	572.73b	481.00a^{b}
200	1.23^{a}	16.04^{a}	621.68a	500.50^{a}
LSD (0.05)	0.12	0.51	30.21	20.10
Variety				
Pioneer Jabi 3253				
	1.13	14.82	573.04^{a}	468.2
BH 540	1.10	14.64	482.76^{b}	461.06
LSD (0.05)	NS	NS	19.12	NS
Interaction	NS	NS	NS	NS
CV (%)	8.6	2.8	2.87	3.5

The means in the columns followed by the same letters are not significantly different from each other

The variety Pioneer jabi 3253 produced significantly higher number of kernels per cob (573) than BH 540 (483). The differences were, however, insignificant for other yield contributing characters. There was no significant effect of interaction between N rates and varieties on yield contributing characters.

Effect of N rates and varieties on grain and biomass yields

There was marked effect of addition of fertilizer N on grain and biomass yields of maize (Table 3). The fertilization increased grain yield from 4648.3 kg ha^{-1} in control to 8251.8 kg ha^{-1} with N level of 200 kg ha^{-1}, an increase of the order of 77.5 %. While there was no significant difference between mean yields of control and N level of 50 kg/ha, the successive N levels influenced grain yields significantly. The yields increased by 20.6, 15.1 and 14.5 % when N level was increased from 50 to 100, 100 to 150 and 150 to 200 kg ha^{-1}, respectively. Likewise, the biomass yield increased from 25332.7 kg ha^{-1} in control to 37481.2 kg ha^{-1} with N level of 200 kg ha^{-1}, registering an increase of almost 50 percent. The biomass yield increased significantly with each successive level of N from 0 to 200 kg ha^{-1}. The percent increases were 16.4, 11.6, 5.9 and 7.7 as N increased from 0 to 50, 50 to 100, 100 to 150 and 150 to 200 kg ha^{-1}, respectively.

The varieties too differed in their response to application of fertilizer N. Pioneer jabi 3253 gave significantly higher grain yield of 6605.7 kg ha^{-1} compared to 6014.7 kg ha^{-1} of BH 540, an increase of 9.8 % in the former than the latter. Likewise, Pioneer jabi 3253 gave significantly higher biomass yield (33066.2 kg ha^{-1}) than BH 540 (30932.9 kg ha^{-1}), an increase of 6.9 percent.

Table 3. Effect of N levels and varieties on yield of maize

Treatment	Grain yield (kg ha^{-1})	Biological yield (kg ha^{-1})
N level (kg ha^{-1})		
0	4648.3^{d}	25332.7^{e}
50	5189.0^{d}	29481.2^{d}
100	6258.0^{c}	32888.3^{c}
150	7204.0^{b}	34814.3^{b}
200	8251.8^{a}	37481.2^{a}
LSD (0.05)	575.61	1354.1
Variety		
Pioneer Jabi 3253	6605.7a	33066.2a
BH 540	6014.7^{b}	30932.9^{b}
LSD (0.05)	364.05	856.4
Interaction	NS	NS
CV (%)	7.5	3.5

The means in the columns followed by the same letters are not significantly different from each other

The marked yield response of maize to nitrogen fertilization at Denba Gofa was further evidenced by the linear N-response functions with very high and significant values of R^2 (0.97 to 0.99) for grain and biomass yields (Figures 1& 2). As the maize hybrids, responding greatly to fertilization, have still not reached their yield maxima, there is scope for obtaining still higher yields with N rates beyond 200 kg N ha^{-1}.
A significant effect of N rates on yield of maize has been reported earlier by several workers [29, 32, 33, 34].
The recent studies on N fertilization of maize in different parts of Ethiopia further corroborate our findings.
There was a significant effect of fertilizer N rates upto 90 kg N ha^{-1} on Alfisols of north-western Ethiopia [23],

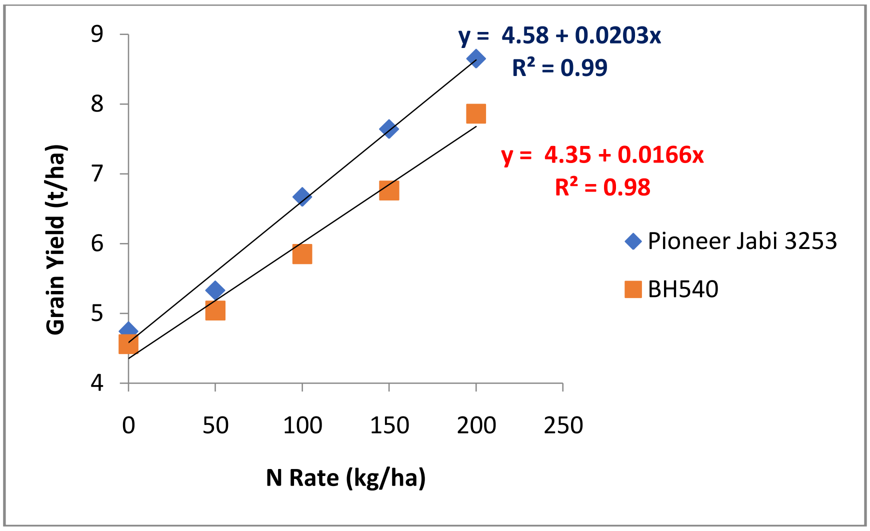

Figure 1. Effect of N rate on grain yield of maize varieties

upto 69 kg ha^{-1} at Decha [21] and Arba Minch [35] of SNNPR State and upto 92 kg ha^{-1} at Bako, West Shoa [36]. However, the response of maize to N fertilization was quite spectacular, continuing upto 200 kg N ha^{-1}

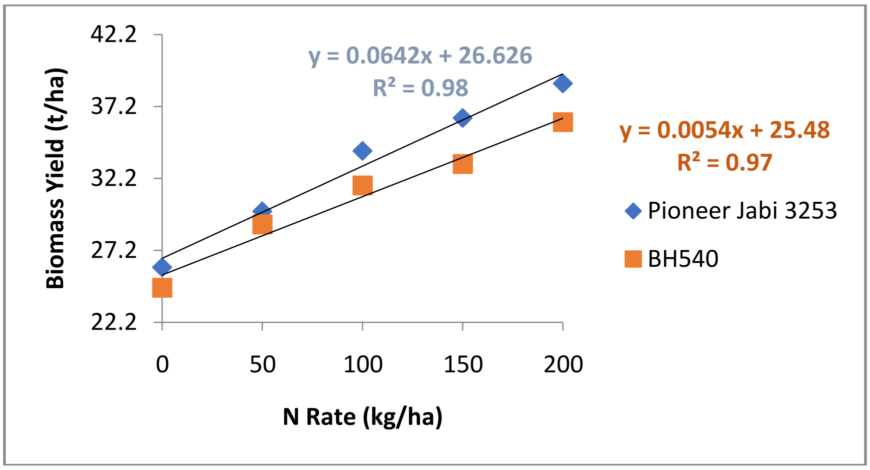

Figure 2. Effect of N rate on biomass yield of maize varieties

at Denba Gofa in our study. This could be probably due to more N-responsive soil and maize hybrids. The soil of the experimental area testing low in organic matter content (2.8 %) as per ratings given by Ethiosis [37], should be deficient in available N content and more responsive to N fertilization. A similar effect of N fertilization on grain yield of maize was noticed on a low N volcanic soil of Buea, Cameroon, where higher N rate of 150 - 200 kg N ha^{-1} produced the highest grain yield of 10.3 t ha^{-1}[31]. This indicated the need for ascertaining the site specific fertilizer recommendations to obtain higher yields even in a particular region.

The higher rate of N application maintained optimum supply of nitrogen through vegetative and reproductive phases, influencing favourably the final yields of maize. This was evidenced by highly significant correlations of grain and total biomass yield with different growth and yield contributing parameters of maize (Table 4). The number of kernel per cob and cob length, showing higher values of correlation coefficients (r) with grain yield (0.86*** and 0.88***, respectively) and biological yield (0.88*** and 0.91***, respectively), indicated relatively better relationship with maize yield among the yield influencing characteristics.

Table 4. The correlations matrix between different growth and yield parameters of maize

	LAI	**NLPP**	**NCPP**	**NKPC**	**PH**	**PMD**	**CH**	**CL**	**TKW**	**GY**	**BY**
LAI	1	0.6***	0.51**	0.64***	0.63***	0.55***	0.59***	0.53**	0.62***	0.53**	0.60***
NLPP		1	0.55**	0.86***	0.84***	0.61***	0.76***	0.60***	0.53**	0.71***	0.76***
NCPP			1	0.59***	0.64***	0.70***	0.68***	0.70***	0.71***	0.67***	0.65***
NKPC				1	0.83***	0.74***	0.82***	0.81***	0.72***	0.86***	0.88***
PH					1	0.80***	0.96***	0.78***	0.79***	0.74***	0.84***
PMD						1	0.87***	0.91***	0.87***	0.81***	0.90***
CH							1	0.86***	0.84***	0.79***	0.88***
CL								1	0.83***	0.88***	0.91***
TKW									1	0.81***	0.83***
GY										1	0.91***
BY											1

LAI = Leaf area index, NLPP = Number of leaf per plant, NCPP = Number of cob per plant, NKPC = Number of kernel per cob, PH = Plant height, PMD = Physiological maturity days, CH = Cob height, CL = Cob length, TKW = Thousand kernel weight, GY = Grain yield, BY = Biological yield

Economic analysis of N fertilization

Based on partial budget analysis [17], the Pioneer jabi 3253 gave maximum relative net return of 46224.2 Eth Birr ha^{-1} at the rate of 200 kg N ha^{-1}, followed by the rate of 150 kg N ha^{-1} (42045.7 Eth Birr ha^{-1}) (Table 5). Likewise, for BH 540, the maximum relative net return was at the rate of 200 kg N ha^{-1} (41650.6 Eth Birr ha^{-1}) followed by the rate of 150 kg N ha^{-1} (36873.7 Eth Birr ha^{-1}). None of the fertilizer N rates was cost dominated, where net benefit was less than that of the preceding treatment (Table 6). The marginal rate of return was more than 100 for all the N rates, suggesting that N application was economic at all the application rates.

Table 5. Partial budget analysis of maize production as related to fertilizer N rates and varieties

N rate (kg ha^{-1})	Grain yield adjusted by 10% (kg/ha)	Gross income (@ 6birr/kg	Stalk yield adjusted by 10% (t/ha)	Stalk gross yield income(@200 birr /ton)	Total gross income (Eth. birr/ha	Variable cost (cost of fertilizer + application	Net benefit Birr/ha)
			Pioneer jabi 3253				
0	4266.0	25596.0	19.2	3840.0	29436.0	0.0	29436
50	4799.4	28796.6	22.1	4420.0	33216.6	1470.6	31746
100	5999.7	35998.0	24.7	4940.0	40938.0	2941.3	37996
150	6879.6	41277.6	25.9	5180.0	46457.6	4411.9	42045
200	7781.1	46686.8	27.1	5420.0	52106.8	5882.6	46224
			BH 540				
0	4101.0	24606.2	18.0	3600.0	28206.2	0.0	28206
50	4540.8	27244.6	21.6	4320.0	31564.6	1470.6	30094
100	5264.7	31588.4	23.3	4660.0	36248.4	2941.3	33307
150	6087.6	36525.6	23.8	4760.0	41285.6	4411.9	36873
200	7072.2	42433.2	25.5	5100.0	47533.2	5882.6	41650

Grain price = ETB 6/ kg, Urea =11.53 Birr/ kg and labor cost for fertilizer application = ETB 200 /100 kg Urea.

Table 6. Marginal rate of return for N rate in maize production

N level (kg ha^{-1})	Benefit margin (Birr/ha)	Variable cost (Birr/ha)	Marginal increase in benefit margin (Birr/ha)	Marginal increase in variable cost (Birr/ha)	Marginal rate of return, MRR(%)
			Pioneer Jabi 3253		
0	29436.0	0	-	-	-
50	31746.0	1470.64	2310.0	1470.64	157.1
100	37996.7	2941.32	6250.7	1470.64	425.0
150	42045.7	4411.92	4049.0	1470.64	275.3
200	46224.2	5882.56	4178.5	1470.64	284.1
			BH 540		
0	28206.2	0	-	-	-
50	30094.0	1470.64	1887.8	1470.64	128.4
100	33307.1	2941.32	3213.1	1470.64	218.5
150	36873.7	4411.92	3566.6	1470.64	242.5
200	41650.6	5882.56	4776.9	1470.64	324.8

IV. Conclusion

Maize is an important cereal crop of Ethiopia, serving as a source of food and income to the smallholder farmers. Its productivity is, however, low due to a number of soil, crop and environmental factors. Inadequate soil nutrient availability, particularly of nitrogen, and use of low-yield potential cultivars are prominent factors limiting maize productivity in Denba Gofa Woreda of Gamo Gofa Zone, southern Ethiopia. Accordingly, a field experiment was conducted under rainfed conditions during Meher season of 2016 to determine the optimum rates of fertilizer N to two high yielding varieties/hybrids of maize well suited to the agro-climatic conditions of the area. The treatments consisted of combinations of five fertilizer N rates (0, 50, 100, 150, 200 kg N ha^{-1}) and two varieties, namely Pioneer Jabi 3253 and BH 540. The experiment was laid out in randomized complete block design with three replications.

The fertilizer N rates influenced significantly the growth parameters (leaf area index, number of leaves per plant, plant height, cob height, days to physiological maturity), yield contributing characters (cob length, number of kernel per cob, thousand kernel weight) and grain and biomass yields. The N rate of 200 kg ha^{-1} was significantly superior to all other rates in terms of grain yield, total biomass yield, 1000 grain weight and number of kernels per cob. The N fertilization increased grain yield from 4648.3 kg ha^{-1} in control to 8251.8 kg ha^{-1} with rate of 200 kg ha^{-1}, an increase of about 78 %. The variety Pioneer jabi 3253 responded significantly better than BH 540 to N fertilization. The grain yield increased by about 10 % in the former than the latter. The interaction between N rates and varieties was not significant for any of the parameters studied.

All the growth and yield components showed highly significant correlations with the grain and biomass yields. The regression analyses showed the relationship between N rates and grain and biomass yields as linear with very high values of R^2 (0.97-0.99).

The partial budget analysis indicated benefit of fertilization at 200 kg N ha^{-1} to the tune of 60 % for Pioneer jabi 3253 and 48 % for BH540 over no fertilization. Therefore, N rate of 200 kg ha^{-1} and variety Pioneer jabi 3253, giving better yield and economic benefits, may be recommended for cultivation in Denba Gofa Woreda. The recommendation may be validated further by conducting verification trials on farmers' fields for its scaling up to other areas with similar agro-climatic situations.

Conflicts of Interest

The authors declare no conflicts of interest regarding the publication of this paper.

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