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Effect of N Fertilizer Level and Plant Density on Grain Yield of Newly Released Maize Variety

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Abstract

Number of plants per unit area and the nitrogen nutrient in the soil are the most leading factors for Maize production as it lacks tillering capacity to adjust available spaces and its highly responsiveness to available nitrogen. Thus, improving of these factors to optimum level significantly increases the grain yield of the crop. Particularly, BH-546 is recently released maize hybrid which has narrow leaf area and erected leaf architecture that needs modification of plant population with optimum nitrogen level to fully exploit its yield potential. Based on this perspective, a field experiment was conducted at three locations for three consecutive years (2016-2018) to determine the optimum plant density and nitrogen level for high yield. The experiment was laid out in a Randomized Complete Block Design in factorial arrangement with three replications. Three plant density viz., 44444, 53333, 62500 and 66666 with five nitrogen levels viz. 69, 92, 115, 138 and 161kg ha^{-1} were combined by factorial combinations and tested in the experimental plots to select the optimum level for high yield. Based on the results, the maximum grain yield (7713.3kilo gram per hectare) was obtained when the hybrid was sown at the highest plant density (66666 plants per hectare) with application of 115 kilo gram nitrogen per hectare. This result showed 20.2% and 20.7% yield advantages compared to the standard check and satellite check respectively. Similarly, application of 115kg N ha^{-1} under 66666 plant density was the most profitable compared to other combinations. Thus, the highest plant population (66666 plants per hectare) with application of 115kg N ha-1 is suitable for the higher yield of hybrid maize BH546 during main seasons for all locations.

Keywords: BH546; Nitrogen level; Plant density; Grain yield

Introduction

Maize (*Zea mays L.*) is one of the most widely distributed cereal crops in the world. It is successfully grown in diverse ecologies for various benefits of human beings. In Ethiopia, maize is one of the top priority food crops selected to achieve food security, particularly in the major maize producing regions, western, north western and southern parts of the country. Currently, maize covers large cultivated area (2,128,448.91 hectares), next to teff, and coming first of all cereals in production and productivity in this country [1]. Maize is one of an important source of food and income generation on which 10573934 people depend on it for their livelihood [1]. It is used for household diet in different forms. Bread, muffin, boiled grain, enjera, local beer (tela), green cob and porridge are the most common prepared forms for direct use [2].

The importance of maize particularly in the food security attracted the attention of government to select it as one of the national commodity crops to satisfy the food self-sufficiency program of the country [3]. This situation leading various researchers to emphasized on improvement of maize production through continual practical research work. Due to these continue efforts various hybrids with high yield potential and different morphological characters were released through breeding. However, these hybrids cannot exploit their yield potential fully under limited nitrogen fertilizer as well as under scattered or too dense population. Besides this the dynamic nature of soil (continuous degradation of soil fertility through erosion, leaching and uptake) the recommended amount of fertilizer in the past several years ago cannot be sufficient for the current production. Similarly, the previously recommended plant population cannot be appropriate for newly released maize hybrids of modified architecture to exploit their yield potential. Thus, to achieve maximum economic yield of maize hybrid BH546 determination of plant population per hectare with appropriate N-fertilizer rate was needed. Keeping this in view the study was conducted with objective: To evaluate the effect of plant population and N fertilizer level on yield potential of maize under various locations.

Materials and Methods

The experiment was conducted at three locations for three consecutive seasons, 2016-2018, (Table 1).

Table 1: Physical characteristic of the three experimental sites.

Physical Characteristics	Experimental Cites		
	Bako	Tibe	Hawassa
Altitude (m)	1650 above sea level	1670 above sea level	1689 above sea level
Latitude (North)	9º 06' N	9°01'	7°03'
Longitude (East)	37º 09' E	37°14'	38°30'
Average Annual Rainfall (mm)	1237.9	1283.3	1001
Soil Type	Nitosol	Ultisols	Vitric Andosols
Average Maximum Temperature (°C)	28.1	27.5	27.3
Average Minimum Temperature (°C)	13.3	12.5	12.6
Agro ecology	Mid Altitude Sub-Humid	Mid Altitude Sub-Humid	Mid Altitude

Experimental materials

Maize variety: Hybrid maize variety BH-546 was used for the study. BH-546 is intermediate maturing variety released in 2013, performing well in agro-ecological range of 900-1800 meter above sea level with rainfall range of 900-1200mm. It can give 8500-9500 and 5500-7000 kg ha^{-1} grain yield on-station and on-farm experiments, respectively. It matures at about 145 days with plant height of 250-260cm.

Fertilizer: Nitrogen fertilizer in the form of urea (46% N) and NPS fertilizer in the form of (19% N, 38% P_2O_5, and 7% S) were used as a source of nitrogen and Phosphorus respectively. Nitrogen fertilizer was used for the experiment. It was applied at different rates to each treatment

Table 2: Number of rows per plot and Plant density for each treatment.

Spacing (cm)	Plant Density/ha	Remark
75 x 20	66666	One seed per hill
75 x 25	53333	One seed per hill
75 x 30	44444	One seed per hill
80 x 40	62500	Two seed per hill

Treatment setup: The hybrids BH546 was treated under five rates of Nitrogen (69Nkg/ha, 92N/ha, 115N kg/ha, 138N kg/ha and 161N kg/ha) and four plant population densities as indicated in Table 2. The treatment set up that contains 44444 plants ha^{-1} with application of 92kg N ha^{-1} was used as a standard check. One satellite check plot having plant density (62, 500) with 150kg NPSBZn blended fertilizer application was added as a second check.

Experimental design

The experiment was laid out as a randomized complete block design (RCBD) in factorial arrangement with three replications. The gross plot size was 4.8m × 6m (28.8m^2) with row length of 4.8m, but the net plot size 4.8m × 4.5m (21.6m^2) was used for harvesting to minimize the border effects on the grain yields. The treatments were randomly assigned to the experimental unit within a block. The blocks were separated by 2m wide space.

Experimental procedures

Land preparation was done three times from March to May in each location by using tractor plough at Bako and Assosa; and by using oxen plough at Tibe. Planting time was varied from location to location and from year to year, but all planting times were done in between May 17 to June 20. Planting was done with one additional seed per hole, 1seed + required seed number for each hole. Two weeks after planting, seedlings were thinned to required plant per plot by keeping a good stand seedling for each treatment.

Full dose of phosphate fertilizer in the form of NPS at the national recommended rate of 69kg P_2O_5 ha^{-1} was applied uniformly to all plots at the time of sowing. Half dose of nitrogen fertilizer as per the treatments was applied at sowing time and half dose of nitrogen fertilizer was applied four weeks after sowing and immediately covered with soil. Any weeds were removed just before the second split urea fertilizer application. The other crop management practices were applied as per the recommendation for maize. Finally, maize plants in the central net plot area were harvested at harvesting maturity stage for the next work and analysis.

Soil analysis

Table 3: some physical and chemical properties of soil of the study cites before planting in each experiment year.

Cites	Year	pH (1:2.5) H_2O	% OC	%OM	%TN	Available P (ppm)	Exchangeable Mg	Exchangeable Ca
Bako	2016	5.78	1.61	2.77	0.14	23.08	15	25
	2017	5.58	1.41	2.44	0.12	13.08	5	15
	2018	4.86	0.63	1.09	0.05	16.08	10	25
Tibe	2017	5.38	1.8	3.11	0.16	12.08	10	30
	2018	5.05	1.9	3.28	0.16	11.08	5	20
Assosa	...	...	...	...	...	...	...	...

Where OC = organic Carbone, OM = Organic Matter, P (ppm) = Phosphorus part per million, Mg = magnesium, Ca = Calcium and '...' = Not available data

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A representative Soil samples were taken 0 to 30cm depth using an auger in a diagonal pattern among each 5m interval before planting from each cite in each experimental year. Then the soil samples were analyzed at soil laboratory for physical and chemical properties (texture, soil pH, organic carbon, total N, available phosphorus and cation exchange capacity (CEC) using standard laboratory procedures (Table 3).

Crop data collection and measurement

Grain Yield was the targeted data and in all cites and in each year grain yield data was taken

Statistical analysis

Analyses of variances for the data recorded were conducted using the SAS version 9.3. Least significant difference (LSD) test at 5% probability was used for mean separation if the analysis of variance indicated the presence of significant treatment differences.

Economic analysis

Economic analysis was performed to investigate the economic feasibility of the treatments. The price of maize that farmers received from sale was calculated based on current market price of maize. The total variable costs including the cost of fertilizers, improved seed and labors were also calculated based on the current price. The net return was calculated by subtracting total variable cost from the gross benefit. The Gross benefit was calculated with that grain yield (kg ha^{-1}) and stalk yield multiplied by field price that is money gained from sale of the grain and stalk. Finally, to assess the cost and benefit associated with different treatments, the partial budget analysis technique of CIMMYT [4] was applied.

Results

Appendix Table 1: Mean square values of ANOVA for grain yield of maize that affected by nitrogen rates and plant density.

Source	DF	Grain Mean Square		
		Bako	Tibe	Hawassa
Year	2	408673183.60***	91164736.70**	109191405.00**
Rep	2	30592727.20**	4621524.10*	6109324.80**
Bloc	18	10636933.00**	2584027.40**	3165741.00**
Entry	20	4081489.50*	3329071.70**	1013347.20ns
Year*Entry	40	2484137.3ns	1035434.8ns	1679797.40*
Error	106	2187055	1181303	822783
CV		18.38	19.2	14.87

There was a significant difference among treatments at Bako and highly significantly difference at Tibe. In all location the year had highly significant effect on grain yield. But the interaction between treatment and year at Bako and Tibe and; among treatments at Hawasa had not shown any significant difference (Appendix Table1)

The combined results of analysis showed that highly significant (P<0.01) effect of year, location, block, entry and interaction among year location and entry on the grain yield. However, the interaction effects of year and location; and the year and entry were not significant on grain yield of maize (Appendix Table 2).

Appendix Table 2: Mean square values of combining analysis of ANOVA for grain yield of maize that affected by nitrogen rates and plant density.

Source	DF	Grain Mean Square
Year	2	193577731.90**
Loc	2	353940182.70**
Rep	2	628840.10ns
Bloc (Rep)	25	10411095.00**
Entry	20	5906161.40**
Year*Entry	40	1756097.10ns
Loc*Entry	40	2288983.30ns
Year*Loc*Entry	63	10575003.40**
Error	309	1880669
CV		20.58

Maximum grain Yield 9859 kg ha^{-1} was recorded at higher plant density (66666 plants ha^{-1}) with application of 161kg N ha^{-1} at Bako. But statistically similar grain yield was recorded under application of 115 and 138kg N ha^{-1} in the same plant density and 161kg N ha^{-1} under 53333 plants ha^{-1}. In case of Tibe Maximum grain Yield 6891.1kg ha^{-1} was recorded at higher plant density (66666 plant ha^{-1}) with application of 115kg N ha^{-1}. But statistically similar grain yield was recorded under 66666 and 53333 plants ha^{-1} with application of either of N rate except 69kg application on 53333 plants per hectare. But at Hawassa Grain yield had not shown any significant differences among treatments.

In combined analysis, maximum grain yield (7713.3kg/ha) was obtained under 66666 plant ha^{-1} with application of 115kg N ha^{-1}. However, statistically similar grain yield was also obtained with increasing N rate at the same plant density and with highest N rate under 53333 plants ha^{-1} (Table 4). But the maximum economic return was achieved under treatment of 66666 plants ha^{-1} with application 115kg N ha^{-1} compare to other treatments (Table 5).

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Table 4: Effect of N rate and plant density on grain yield of BH-546 at Bako, Tibe and Hawasa, and combination effect of them in three consecutive years (2016-2018).

N-Level	P. Density	Grain Yield kg/ha			
		Bako	Tibe	Hawassa	Combined
69	66,666	7132.60^{cde}	6170.10^{abcde}	6277.80^{abc}	6558.00^{cde}
92	66,666	7711.30^{bcde}	6407.20^{abc}	6479.00^{abc}	6914.20^{bcd}
115	66,666	8999.20^{ab}	6891.10^{a}	7017.70^{a}	7713.30^{a}
138	66,666	9059.40^{ab}	6147.00^{abcde}	5146.80^{e}	6989.10^{abcd}
161	66,666	9859.00^{a}	6685.10^{ab}	5794.80^{bcde}	7652.80^{ab}
69	53,333	7771.60^{bcde}	5818.90^{bcdefg}	5725.00^{bcde}	6527.70^{cde}
92	53,333	8160.90^{bcde}	6393.90^{abc}	6446.50^{abc}	6872.30^{cd}
115	53,333	8161.80^{bcde}	6043.10^{abcdef}	5208.20^{de}	6628.90^{cde}
138	53,333	8079.80^{bcde}	6124.30^{abcdef}	5590.80^{cde}	6724.30^{cde}
161	53,333	8735.70^{ab}	6352.00^{abcd}	6560.30^{abc}	7298.00^{abc}
69	44,444	7844.40^{bcde}	4801.20^{ghi}	6025.50^{abcde}	6248.50^{def}
92	44,444	7687.20^{bcde}	5188.00^{efgh}	6341.00^{abc}	6413.50^{de}
115	44,444	8391.30^{bcd}	5092.00^{fghi}	5859.50^{bcde}	6521.10^{cde}
138	44,444	8002.40^{bcde}	6051.80^{abcdef}	6253.00^{abcd}	6833.60^{cd}
161	44,444	8358.90^{bcd}	5744.60^{bcdefg}	6468.50^{abc}	6905.90^{bcd}
69	62,500	6920.30^{e}	4106.10^{i}	5984.00^{abcde}	5630.90^{f}
92	62,500	7044.40^{de}	4995.10^{ghi}	5745.70^{bcde}	5951.30^{ef}
115	62,500	8181.80^{bcde}	5406.10^{cdefg}	5824.20^{bcde}	6551.50^{cde}
138	62,500	8491.60^{abc}	5145.20^{efgh}	6184.50^{abcde}	6659.90^{cde}
161	62,500	7181.60^{cde}	4470.70^{hi}	6444.20^{abc}	5980.60^{ef}
150NPSBZn	62,500	7186.90^{cde}	5349.20^{defg}	6760.50^{ab}	6391.20^{def}
LSD		1382.2	1038.9	1046.5	778.91
CV		18.38	19.53	14.87	20.58

Table 5: Partial budget analysis of nitrogen fertilizer rates and plant densities on BH-546 maize hybrid during 2016-2018 cropping season.

N kg ha^{-1} * Densty	GY (kg ha^{-1})	AGY (kg)	SY (kg ha^{-1})	ASY (kg)	GYR (Birr)	SYR (Birr)	TR (Birr)	TVC (Birr)	NR (Birr)
69*66,666	6558	5902.2	10736.8	9663.1	32462.1	2898.9	35361	3801.8	31559.3
92*66,666	6914	6222.8	11264.8	10138.3	34225.3	3041.5	37266.8	4412.8	32854
115*66,666	7713	6942	11970.3	10773.3	38180.8	3232	41412.8	5023.8	36389.1
138*66,666	6989	6290.2	12029.2	10826.3	34596	3247.9	37843.9	5634.8	32209.2
161*66,666	7653	6887.5	12411.8	11170.6	37881.4	3351.2	41232.5	6245.8	34986.8
69*53,333	6528	5874.9	11215.6	10094	32312.1	3028.2	35340.3	3408	31932.3
92*53,333	6872	6185.1	11663.2	10496.9	34017.9	3149.1	37166.9	4019	33147.9
115*53,333	6629	5966	11670	10503	32813.1	3150.9	35964	4630	31334
138*53,333	6724	6051.9	11556.3	10400.7	33285.3	3120.2	36405.5	5241	31164.5
161*53,333	7298	6568.2	11633.6	10470.2	36125.1	3141.1	39266.2	5852	33414.2
69*44,4444	6249	5623.7	11218.1	10096.3	30930.1	3028.9	33959	3145.5	30813.5
92*44,4444	6414	5772.2	10488.5	9439.7	31746.8	2831.9	34578.7	3756.5	30822.2
115*44,444	6521	5869	10948.8	9853.9	32279.4	2956.2	35235.6	4367.5	30868.1
138*44,444	6834	6150.2	11171	10053.9	33826.3	3016.2	36842.5	4978.5	31864
161*44,444	6906	6215.3	11830.7	10647.6	34184.2	3194.3	37378.5	5589.5	31789
69*62,500	5631	5067.8	11335.4	10201.9	27873	3060.6	30933.5	3672.5	27261
92*62,500	5951	5356.2	9839.8	8855.8	29458.9	2656.7	32115.7	4283.5	27832.2

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115*62,500	6552	5896.4	11643.7	10479.3	32429.9	3143.8	35573.7	4894.5	30679.2
138*62,500	6660	5993.9	11177.5	10059.75	32966.505	3017.925	35984.4	5505.5	30478.9
161*62,500	5981	5382.5	10367.7	9330.93	29603.97	2799.279	32403.2	6116.5	26286.7
150NPSBZn*62,500	6391	5752.1	10693.9	9624.51	31636.44	2887.353	34523.8	3714.5	30809.3

Discussion

The grain yield of maize increased with increasing plant density. Maximum grain yield was obtained under highest plant density (66666 plants per hectare) at all locations. Similarly, Grain yield was also increased with increasing nitrogen rate up to optimum. The combined analysis showed that maximum Grain yield (7713.3kg ha^{-1}) under 66666 plant density with application of 115kg N ha^{-1}.

Compared to the standard control of 44444 plant ha^{-1} with the application of 92kg N ha^{-1}, the mean grain yield was increased by 1299.8kg ha^{-1} or 20.2% when the maize hybrid sown at 66666 plants ha^{-1} with application 115kg N ha^{-1}. Similarly, the results surpassed the satellite check plot by 20.7% (Table 4).

In general, the grain yield ha^{-1} was increased with the increase plant density and N rate, although, economically faceable grain yield was achieved at 115kg N ha^{-1}. The positive relationship between grain yield and plant density was due to the high number of plants per unit area. The increased in maize grain yield under high plant density might be due to efficient utilization of available resources like nutrient, water, air and solar radiation. Maize hybrids can be grown up to 76500 plant ha^{-1} with no adverse effect on yield or grain quality [5]. Leaf area index and light interception increased with increasing in planting density [6]. Farnia et al. [7] reported that plant shortage per unit area prevents maximum usage of production parameters while over density can increase the competition and decrease the yield. Higher grains yield at higher nitrogen levels might be due to the lower competition for nutrient and positive effect of N on plant growth, leaf area expansion and thus increase solar radiation use efficiency which indirectly increases dry matter production for grain filling that ultimately increases in grain yield [2]. These results are in line with many workers [8,9].

Summary and Conclusion

The grain yield of BH 546 maize hybrid tends to increase with increasing plant population and N fertilizer level. Maximum grain yield ha^{-1} (7713.3kg) was obtained under plant density of 66,666 plant ha^{-1} with the application of 115kg N ha^{-1}. This grain yield result exceeds by 20.2% and 20.7% compared to the grain yield of standard check and satellite check respectively. Similarly, application of 115kg N ha^{-1} under 66666 plant density was the most profitable compared to other combinations. Thus, this hybrid should be sown with 66,666 plants ha^{-1} (75cm x 20cm spacing) with application of 115kg N to ascend its production by 20% from current production status.

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