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Research Article

Impact of Nitrogen Rate and Intra Row Spacing on growth parameters and Yield of Maize at Bako, Western Ethiopia

Abstract

The yield of maize is highly sensitive to nitrogen fertilizer rates and plant spacing. The space of plant is also varied depend on crop architecture and available resources. Some recent hybrids have erected and narrow leaf nature so that providing space for growing additional crop stands to increase yield per unit area. Hybrid BH-546 is among such hybrids which has erected and narrow leaf nature, but its optimum nitrogen rate and spacing has not been determined yet. Thus, a field experiment was conducted at Bako research farm in the year 2017 to determine the optimum rate of nitrogen fertilization and intra row spacing. The experiment was laid out in a Randomized Complete Block Design in factorial arrangement with three replications. Three intra row spacing viz., 75x40 cm, 75x30 cm and 75x20 cm accommodating 33, 333, 44,444 and 66, 666 plants ha-1 respectively, with six nitrogen levels viz. 0, 23, 46, 69, 92 and 115 kgha-1 were assigned to the experimental plot by factorial combinations. Based on the results, the maximum grain yield (10,207.8 kgha-1) was obtained when the hybrid was sown at the closest intra row spacing (20 centimeters) with application of the highest rate of nitrogen (115 kgha-1). This result showed 8.9% yield advantages compared to the standard check. However, statistically similar grain yield (9887 kgha-1) was also obtained under application of 92 kilo gram nitrogen per hectare in the same intra spacing (20 cm). But application of 115 kgNha-1 on maize hybrid planted at 20 cm intra row spacing was the most profitable as compared to other combinations. However, as this experiment was conducted for one season and in one location, the comprehensive recommendation could be drawn by investigating at more locations over years for this hybrid maize.

Introduction

Maize is grown in a wide range of agro climatic condition and plays an important role in the food security of Ethiopia [1]. Though maize adapts in wide ranges of agro-climate condition and plays critical role in food security, the production and productivity of maize is highly influenced, among several factors, by Nitrogen rate and plant density [2,3]. The importance of nitrogen for plant growth and productivity is increasingly being recognized, and in many cases it is considered as the most growth and yield limiting factor. In addition, yield potential of maize is highly dependent on the amount of intercepted solar radiation, water, and nitrogen supply [4]. The photosynthetic efficiency of leaves depends on nitrogen concentration in leaves [5,6]. N-fertilization provides sufficient nutritional requirements of maize plants and hence promotes its grain production [7].

Beside plant nutrients, plant spacing significantly affects the crop yield as maize does not have tillering capacity to adjust to variation in plant stand. Plant reduction per unit area prevents maximum use of production parameters while excessive density can increase the competition and decrease the yield [8]. Thus, yield increment was observed with increasing plant density up to optimum for a maize genotype grown under a set of particular environmental and management conditions [2,9,10].

However, there is no single recommendation for all conditions because optimum density varies depending on resource availability and the tolerance of a hybrid to intra-specific competition [11,12]. Some modern maize hybrids withstand stresses better than the earlier cultivars, and are grown at higher plant populations to maximize the interception of solar radiation [13]. The newly released hybrid, BH 546 is one of such cultivars which could be managed at higher densities to exploit its yield potential as it possesses semi erected leaf nature and narrow leaf size (BNMRS, 2014). However, this opportunity of leaf architecture for increasing yield by increasing plant density is not determined yet at study area. Thus, to achieve potential economic yield of BH-546 variety modification of plant spacing with appropriate N-fertilizer rate should be determined. Keeping this in mind this study was designed with the objective of determining the optimum intra-

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row spacing and N- fertilizer level for BH-546 maize variety at Bako agro ecological conditions.

Materials and Methods

Description of experimental site

The experiment was conducted at the research site of Ethiopia Institute of Agricultural Research, Bako, located at 9° 06' N and 37° 09' E, with altitude of 1650 m.a.s.l, in western Ethiopia, in the year 2017. The soils of the area are dominantly nitosol. The site represents a mid altitude sub-humid agro ecological zone. Monthly mean rainfall and relative humidity, and temperature in 2017/2018 cropping season was as shown in the figures 1,2 below respectively, with maximum precipitation being from May to August.

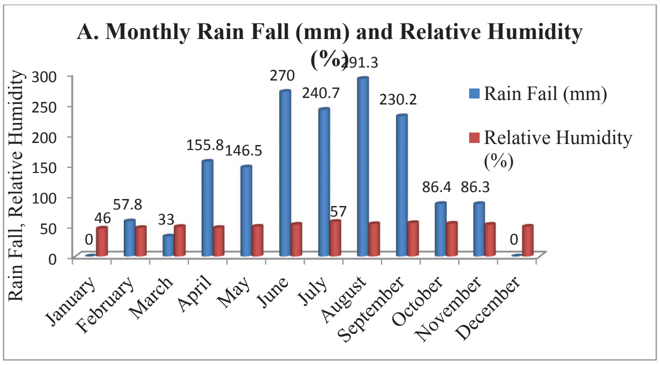

Figure 1: Monthly mean rainfall (cm) and relative humidity (%) at Bako during 2017/2018 cropping season.
Source: Bako agricultural Research Center weather data, Bako, West Shewa, Ethiopia.

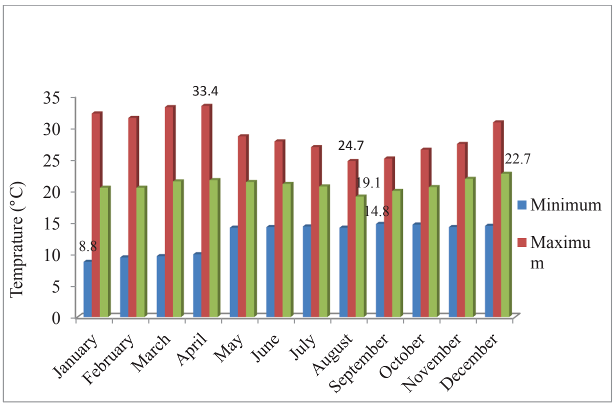

Figure 2: Monthly maximum, minimum and average temperatures (°C) at Bako during 2017/2018 cropping season.
Source: Bako agricultural Research Center weather data, Bako, West Shewa, Ethiopia.

Experimental materials (maize variety and fertilizers)

Hybrid maize variety BH-546 was used for the study. BH-546 is intermediate maturing variety released by Bako national maize research center (BNMRC) in 2013. It gives 8500-9500 and 5500-7000 kg ha-1 grain yield on-station and on-farm experiments, respectively (BNMRC, 2014). This hybrid has narrow and erected leaf architecture which makes it unique compared to the previously released hybrids. Nitrogen fertilizer in the form of urea (46% N) and phosphorous fertilizer in the form of Triple Superphosphate (46% P2O5) were used for the experiment.

Treatments and experimental design

The treatments consisted of six rates of nitrogen (0, 23, 46, 69, 92 and 115 kg N ha-1), fixed inter row spacing of 75 cm, and three intra row spacing of 40 cm, 30 cm, and 20 cm with corresponding plant population of 33,333, 44,444 and 66,666 plant ha-1, respectively. The treatment set up that contain 75 x 30 cm spacing with 92 kg N ha-1 was used as a standard check whereas 0 kg N ha-1 was used as negative control. The experiment was laid out in Randomized Complete block Design (RCBD) in factorial arrangement with three replications. The gross plot size was 4.8 m× 3.0 m (14.4 m2) with row length of 4.8 m, and net plot size 4.8m × 1.5 m (7.2m2) was used for harvesting. The treatments were randomly assigned to the experimental unit within a block (replication). The blocks were separated by 2 m wide space.

Soil sampling and analysis

A representative soil samples were taken from 0 to 30 cm depth in a diagonal pattern among each 5 m interval before planting by vertical insertion of an auger. The sample soil was analyzed at soil laboratory for physical and chemical properties of soil using standard laboratory procedures and the result is summarized in table 1. The experimental field was used for maize cultivation for the last five consecutive cropping seasons. Due to this reason the laboratory result of soil analysis indicated that lower amount of organic carbon, organic matter and total nitrogen as well as reduction in pH value (Table 1).

Experimental procedures

Land preparation was done by plowing three times using tractor plough during March to May 2017. Planting was done in June 2017. Full dose of phosphate fertilizer in the form of Triple Superphosphate (TSP) at the national recommended rate of 69 kg P2O5 ha-1 was applied uniformly to all plots at the time of sowing. Half dose of N fertilizer as per the treatments was applied at sowing time and the remaining half dose of N fertilizer was applied 4 weeks after sowing. Weeding and others crop management practices were applied uniformly to all plots as per the experience of the farm. Finally, maize plants in the central net plot area were harvested at harvest maturity stage for the analysis.

Crop data collection and measurement

Data were collected from ten randomly taken samples per plot for parameters of plant height (cm), stem diameter (cm) and leaf area index. All maize plants from the net plot area were mowed at the ground level, at harvesting maturity and weighed after sun drying to a constant weight to obtain above ground dry biomass. The total numbers of ears in the net plot were harvested and the field weight was measured using electronic balance after removing the husk. Grains were shelled

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from center of some ears of each plot and their moisture content was immediately measured using moisture tester. The measured values were adjusted to the standard moisture content of 12.5 [14], and then multiplied by field weight and shelling percentage/0.8/ to determine the adjusted yield of the plot on hectare basis using the following formulas.

Correction factor = (100-Actual moisture content)/(100-12.5)

Grain Yield kg plot-1 = (100-Actual Moisture Content)/87.5 x Field weight x shelling percentage

Grain Yield kg ha-1 = (Yield/ kg/ plot x 10000)/(plot size)

Statistical analysis

Analyses of variances for the data recorded were conducted using the SAS version 9.3. Least significant difference (LSD) test (5%) was used for mean separation if the analysis of variance indicated the presence of significant treatment differences. Correlation analysis was made to examine the association among the response variables.

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 at Bako near the experimental site. The total variable costs including the cost of fertilizers, improved seed and labors were also calculated based on the current price. Costs and benefits were calculated for each treatment. 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 (1988) was applied.

Results and Discussion

Growth parameters of maize

The analysis of variance revealed that main effect of nitrogen application was highly significantly ($P < 0.01$) affected plant height and stem diameter, and significantly ($P< 0.05$) influenced leaf area index. Similarly, intra row spacing had significant ($P<0.01$) effect on the stem diameter and leaf area index, and significant ($P< 0.05$) effect on plant height. But the interaction of N rate with intra row spacing did not show significant effect ($P> 0.05$) on growth parameters during the experiment period.

Plant height

Mean values for nitrogen rates showed that plant height increased with increased in nitrogen rate and the maximum plant height (267.59 cm) was recorded under application of 115 kg N ha-1. However, statistically similar plant height (265.26 cm) was obtained under application of 92 kg N ha-1. The shortest plant (250.07) was obtained under control (treatment with no N application), but application of 23 and 46 kg N ha-1 have also as similar effect as the control (Table 2). The increase in plant height with increase in the rate of nitrogen application could be attributed to positive effect of N on vigorous vegetative growth and inter-nodal extension due to more availability of N throughout the growing period. This increase in plant height in response to higher rates of nitrogen has been confirmed by the previous findings of Wajid et al. [15], GÖKMEN et al. [16], Woldesenbet and Haileyesus [17].

The intra row spacing in table 2 showed that the tallest plants (260.87 cm) were observed when the maize plant was raised at 20 cm intra row spacing (66,666 plants ha-1), but with no significant difference compared to the plant height (259.66 cm) that obtained at 30 cm plant spacing (44, 444 plants ha-1). The minimum plant height (254.81) was recorded from the treatment planted at 40 cm intra row spacing (33,333 plants ha-1), but this was also statistically at par with plant height obtained under 30 cm intra row spacing. The increase in the plant height at narrowest spacing may be due to strong competition among the plants for light. These results are in line with the findings of Mahmood et al. [18], Sener et al. [19], and Khan et al. [20].

Stem diameter

Nitrogen fertilizer applications enhanced plant development and, as a result, the stem diameter was increased with increasing nitrogen rates. The maximum stem diameter (2.76) was obtained from application of highest N rate (115 kg N ha-1), however, statistically similar stem diameter were recorded under application of 46, 69 and 92 kg N ha-1. The thinnest stem diameter (2.44) was obtained under no N application, but statistically similar stem diameter (2.50) was also recorded

Table 1: The results of soil physical and chemical properties before planting at Bako Research Center during 2017/2018 cropping season.

	Chemical characteristic of soil						Texture		
Characteristic of soil	pH (1:2.5H_2O) suspension	%OC	%OM	%TN	AP (ppm)	CEC (cmol/100g soil)	Clay	Silt	Sand
Value	5.01	0.88	1.51	0.05	13.33	17.17	43	8	49
Test Method	potentiometer	Walkley Black	Walkley- Black	From %OC	Bray II	Ammonium acetate Method	Hydrometer		
Rating	strongly acid	Low	Low	Low	Medium	Moderate	--		
Textural class	--	--	--	--	--	--	Sandy Clay		

Where, OC = organic carbon, OM = Organic matter, TN = Total nitrogen, CEC = cat ion exchange capacity, AP = available Phosphorus pH = the negative logarithm of the hydrogen ion activity and ppm = part per million.

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under application 23 kg N h-1 (Table 2). The increase in stem diameter with increasing in nitrogen rate might attributed to the more increasing of cell size and growth due to nitrogen application, as it is a general truth that N enhances plant growth. This result was in accordance to Gözübenli [2] and Iqbal et al. [21].

Intra row spacing had significant and positive effect on stem diameter. The highest value (2.79 cm) was obtained at the widest intra row spacing of 40 cm while the lowest value (2.38cm) was recorded at the narrowest intra row spacing (20 cm) (Table 2). Even though the reducing intra row spacing led to thinner plants, which were also characterized by a taller plant height, none of the compared treatments displayed a lodging tendency throughout the growing period. Reducing in stem diameter at closest intra row spacing might be due to higher plant competition for available resources like solar radiation, nutrients, water, air and space. This result was in agreement with those of Sener et al. [19] and Carpici et al. [22].

Leaf area index

The data in table 2 showed that the maximum LAI (3.92) was attained from application of 92 kg N ha-1. However this result was statistically similar with LAI of (3.73, 3.87 and 3.85) which obtained under application of 46, 69 and 115 kg N ha-1 respectively. The minimum LAI (3.50) was recorded under 23 kg N ha-1 applications, but statistically similar LAI were also obtained under 0 and 46 kg N ha-1 (Table 2).

Leaf area index showed a positive response to N rates. However, increasing the application rates of N fertilizer from 92 kg N ha-1 to 115 kg N ha-1 showed slight numerical reduction. This may be due to susceptibility of leaves to down bending and over competition among leaves and other part of the plant for others growth factors under over dose of N. But LAI increase with increasing in N rate up to optimum amount.

Table 2: Effect of different nitrogen rates and plant spacing on growth and development of maize during 2017/2018 cropping season.

Treatments	Plant height (cm)	Stem diameter (cm)	Leaf area Index
Nitrogen levels (kg/ha)			
0	250.07^{d}	2.44^{c}	3.51^{b}
23	251.39^{d}	2.50^{bc}	3.50^{b}
46	256.61^{cd}	2.61^{ab}	3.73^{ab}
69	259.76^{bc}	2.65^{ab}	3.87^{a}
92	265.26^{ab}	2.73^{a}	3.92^{a}
115	267.59^{a}	2.76^{a}	3.85^{a}
LSD (0.05)	7.01	0.15	0.33
Intra row spacing (cm)			
20	260.87^{a}	2.38^{c}	4.95^{a}
30	259.66^{ab}	2.68^{b}	3.59^{b}
40	254.81^{b}	2.79^{a}	2.65^{c}
LSD (0.05)	4.95	0.11	0.23
CV (%)	2.83	6.02	9.09

Means followed by the same letter within column are not significantly different (P<0.05).

These increases in LAI can possibly the result of improved leaf expansion in plants due to optimum nitrogenous fertilizers. These results coincided with the findings of Moosavi [23] and Imran et al. [24].

In case of intra row spacing, the LAI ranged from 2.65 to 4.95 and the highest LAI (4.95) was recorded from intra row spacing of (20 cm) while the lowest LAI (2.65) was observed from the widest intra row spacing of (40 cm) (Table 2). Generally, consistent increments in LAI were observed with reducing in intra row spacing. This dramatic increase in LAI with reduced intra row spacing or with increase in the plant population density indicates occupation of more unit area by green canopy of the plants. Similarly Abuzar et al. [25] reported that LAI was significantly affected and increased in linear fashion with increase in plant population. However, other workers found results which opposed this finding. Imran et al. [24] reported that maximum LAI from the lowest planting density and minimum LAI from the highest plant density.

Grain yield

The ultimate goal of crop production is increasing economic yield. Maximum grain yield ha-1 (10207.80 kg) was achieved at the intra row spacing of 20 cm with the application of 115 kg N ha-1, but it was statistically similar with (9886.90 kg) that produced under the rate of 92 kg N ha-1 application for the same intra row spacing (20 cm). The minimum grain yield (6358.80) was obtained under 0 kg N ha-1 at 20 cm intra row spacing, but statistically similar grain yield were obtained under application of 0 and 23 kg N ha-1 at all intra row spacing including 46 kg N ha-1 application in case of 40 cm intra row spacing (Table 3). Compared to the standard control of the intra row spacing 30 cm (44444 plant ha-1) with the application of 92 kg N.ha-1, the mean grain yield was increased by 8.90% when the maize hybrid sown at intra row spacing of 20 cm with application 115kg N ha-1.

The increased in maize grain yield under decreased spacing might be due to efficient utilization of available resources (nutrient water and light). 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 that ultimately increases in grain yield. These results are in line with that of Gozubenli [2], Shrestha [3].

Above ground dry biomass yield

Application of 115 kg N ha-1 to maize hybrid planted at intra row spacing of 20 cm gave the highest AGDBM yield (26805.6 kg ha-1) followed by (25833.3 kg ha-1) which obtained under application of 92 kg N ha-1 in the same intra row spacing. The lowest AGDBM yield (18138.9 kg ha-1) was obtained at the widest intra row spacing (40 cm) without N fertilizer application, but this was statistically similar with 18250.0 kg ha-1 which harvested under 40 cm intra row spacing with application of 23 kg N ha-1. Application of 115 kg N ha-1 to maize hybrid planted at intra row spacing of 20 cm gave 12.4% more AGDBM yield compared to standard check (Table 4).

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The increased in AGDBM yield with the increased in nitrogen rates at closest intra row spacing could be due to the fact that an increment in the N level increased its availability in the soil, so that optimize the nutrient requirement of the dense stands. On other side, Plant grown on close spacing efficiently utilize available nutrients that resulted increase in height of each individual plant, increase their leaf area index and capture more light that enable the plant to utilize photosynthates more efficiently that ultimately leading to accumulation of high amount dry matter. Our results are in line with that of Moraditochaee et al. [27], Imran et al. [24], who obtained maximum biological yield under maximum plant density with application of maximum N- rate and the minimum biological yield under lower plant density with no N- application.

Correlation analysis among growth parameters, grain yield and above ground dry biomass of maize

The correlation study indicate that grain yield was highly and positively correlated with PH (r=0.73), LAI (r=0.41) and AGDBM (r=0.81) (Table 5). It was also positively and significantly correlated with SD (0.32). Similarly above ground dry biomass was highly and positively correlated with PH (r=0.69), LAI (r=0.79) and GY (r=0.81). However, AGDBM was not significantly correlated with stem diameter (Table 5). In general all growth parameters and above ground dry biomass were positively and significantly correlated with GY. This indicates that the GY was positively affected by these parameters as it is the end result of many complex morphological and physiological processes.

This correlation indicates that maize production highly influenced by the growth parameters. These parameters can be enhanced by optimizing nitrogen fertilizer rate and plant spacing which ultimately increased GY of maize.

Economical analysis

From the budget summary of economic analysis, the highest net return (Birr 46591.9 ha-1) was obtained from 115 kg N ha-1 with intra row spacing of 20 cm followed by 92 kg N ha-1 with the same intra row spacing (Birr 45407.5 ha-1) while the lowest net economic return (29072) was recorded from 0 kg N ha-1 with intra row spacing of 40 cm (Table 6). The currently used practice (30 cm intra row spacing with 92 kg N ha-1), gave an economic return of Birr 42493.7 ha-1. Thus, application of 115 kg N ha-1 with 20 cm intra row spacing resulted in 9.64 % increment to the maize income from that of the currently used practice by the farmers. Similar results were obtained by Tana and Moges [28], which indicated higher yield and higher net benefit from higher planting density with higher N rate.

Maize shows high positive responses to plant density and nitrogen. So, modification of these parameters significantly influence grain yield of maize. Based on the results obtained in this experiment, maize hybrid BH 546 produced the highest grain yield when the hybrid sown at 20 cm intra-row spacing with application of either 115 kg N ha-1 or 92 kg N ha-1. Furthermore the experiment was indicated a multiplicative trend of grain yield with increasing N rate and decreasing intra

Table 3: Effect of different nitrogen rates and intra row spacing on grain yield of maize during 2017/2018 cropping season.

IRS (cm)	NR (kg ha^{-1})					
	0	23	46	69	92	115
20	6358.80^{h}	6392.00^{h}	7585.90^{ef}	8709.90^{d}	9886.90^{ab}	10207.80^{a}
30	6619.40^{h}	6711.00^{h}	7525.50^{fg}	8794.00^{cd}	9373.80^{bc}	9544.2^{b}
40	6519.80^{h}	6591.10^{h}	6906.50^{gh}	7711.90^{ef}	8234.20^{de}	8202.7^{de}
LSD (0.05) N x IRS = 648.3		CV (%) = 4.271	b** significant at 1% level			

Means followed by the same letter within column are not significantly different (P<0.05).

Table 4: Effect of different nitrogen levels and intra row spacing on above ground dry biomass of maize during 2017/2018 cropping season.

Intra row spacing (cm)	N rate (kg ha-1)					
	0	23	46	69	92	115
20	21773.1^{ef}	21842.6^{ef}	23250.0^{cd}	23842.6^{c}	25833.3^{b}	26805.6^{a}
30	19597.2^{h}	19972.2^{gh}	21194.4^{f}	22421.3^{de}	23842.6^{c}	23972.2^{c}
40	18138.9^{j}	18250.0^{hj}	19106.5^{hi}	19750.0^{h}	20888.9^{fg}	21064.8^{f}
LSD (0.05) N x IRS = 956.87			CV (%) = 2.474			

Means followed by the same letter within column are not significantly different (P<0.05).

Table 5: Correlation coefficient among growth and yield parameters of Maize during 017/2018 cropping season.

	PH	SD	LAI	GY	AGDBM
PH	1	0.31*	0.44**	0.73**	0.69**
SD		1	-0.43**	0.32*	-0.14^{ns}
LAI			1	0.41**	0.79**
GY				1	0.81**
AGDBM					1

**= highly significance, * =significance and ns= non significance.

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Table 6: Partial budget analysis of nitrogen fertilizer rates and plant densities on maize during 2017/2018 cropping season.

Treatment combination Nr*Irs	GY (kg ha-1)	AGY (kg)	SY (kg ha-1)	ASY (kg)	GYR (Birr)	SYR (Birr)	TR (Birr)	TVC (Birr)	NR (Birr)
0*20	6358.8	5722.9	15414.3	13872.9	31476.1	4161.9	35637.9	6388.2	29249.8
23*20	6392.0	5752.8	15450.6	13905.5	31640.4	4171.7	35812.1	6388.2	29423.9
46*20	7585.9	6827.3	15664.1	14097.7	37550.2	4229.3	41779.5	6678.2	35101.4
69*20	8709.9	7838.9	15132.7	13619.4	43114.0	4085.8	47199.8	7258.2	39941.7
92*20	9886.9	8898.2	15946.4	14351.8	48940.2	4305.5	53245.7	7838.2	45407.5
115*20	10207.8	9187.0	16597.8	14938.0	50528.6	4481.4	55010.0	8418.2	46591.9
0*30	6619.4	5957.5	12977.8	11680.0	32766.0	3504.0	36270.0	6363.2	29906.9
23*30	6711.0	6039.9	13261.2	11935.1	33219.5	3580.5	36800.0	6363.2	30436.8
46*30	7525.5	6773.0	13668.9	12302.0	37251.2	3690.6	40941.8	6653.2	34288.7
69*30	8794.0	7914.6	13627.3	12264.6	43530.3	3679.4	47209.7	7233.2	39976.5
92*30	9373.8	8436.4	14468.8	13021.9	46400.3	3906.6	50306.9	7813.2	42493.7
115*30	9544.2	8589.8	14428.0	12985.2	47243.8	3895.6	51139.4	8393.2	42746.2
0*40	6519.8	5867.8	11619.1	10457.2	32273.0	3137.2	35410.2	6338.2	29072.0
23*40	6591.1	5932.0	11658.9	10493.0	32625.9	3147.9	35773.8	6338.2	29435.7
46*40	6906.5	6215.9	12200.0	10980.0	34187.2	3294.0	37481.2	6628.2	30853.0
69*40	7711.9	6940.7	12038.1	10834.3	38173.9	3250.3	41424.2	7208.2	34216.0
92*40	8234.2	7410.8	12654.7	11389.2	40759.3	3416.8	44176.1	7788.2	36387.9
115*40	8202.7	7382.4	12862.1	11575.9	40603.4	3472.8	44076.1	8368.2	35708.0

Where, AGY= Adjusted Grain Yield, ASY= Adjusted Stalk Yield, GYR=Grain Yield Revenue, SYR=Stalk Yield Revenue, TR= Total Revenue and TVC=Total Variable Cost.

row spacing. So further modification of N rates up ward and intra row spacing down ward might be further increased the grain yield. More importantly, the grain yield was significantly and positively correlated with plant height, leaf area index, stem diameter and aboveground dry biomass.

The recommended intra row spacing (30 cm) with 92 kg N ha-1 is insufficient for hybrid BH 546 maize cultivation. So closer intra row spacing (20 cm) with 115 kg N ha-1 is suitable for the higher yield and high economic return of hybrid maize BH 546 during main seasons at Bako. However, these results were based on single growing season, so their confirmation should be done by further similar experiments across locations and across years.

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