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Effect of nitrogen rate and intra-row spacing on yield and yield components of maize at Bako, Western Ethiopia

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Maize is highly responsive to nitrogen fertilizer rates and plant spacing. Continuous efforts have been carried out to improve the yield potential of maize by modifying their architecture through breeding methods with aim of increasing maize yield through increasing number of plants ha^{-1}. Hybrid BH-546 is the recently released variety for this purpose 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*., 75 cm × 40 cm, 75 cm × 30 cm and 75 cm × 20 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 kg ha^{-1}, were assigned to the experimental plot by factorial combinations. Based on the results, the maximum grain yield (10,208 kgha^{-1}) was obtained when the hybrid was sown at the closest intra-row spacing (20 cm) with application of the highest rate of nitrogen (115 kg ha^{-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 kg N ha^{-1} in the same intra-spacing (20 cm). Moreover, since this experiment was conducted for one season and in one location, the comprehensive recommendation could be drawn by investigating more locations over years for this maize hybrid.

Key words: BH 546, plant density, yield, yield components.

INTRODUCTION

Though maize adapts in wide ranges of agro-climate condition and plays critical role in food security (CSA, 2017), the production and productivity of maize is highly influenced, among several factors, by nitrogen rate and plant density (Gözübenli, 2010; Shrestha, 2013). 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. The yield potential of maize is highly influenced by the amount of intercepted solar radiation, water, and nitrogen supply (Birch et al., 2003). The photosynthetic efficiency of leaves depends on nitrogen concentration in leaves

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(Birch and Vos, 2000; Paponov et al*.,* 2005). N-fertilization provides sufficient nutritional requirements of maize plants and hence promotes its grain production (Khan et al*.,* 2012).

Besides 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 (Farnia et al*.,* 2015). 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 (Tollenaar, 1992; Gözübenli, 2010; Sharifai et al*.,* 2012).

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 (Tollenaar and Wu, 1999; Sangoi et al., 2001). 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 (Tollenaar, 1991). 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 yet determined at study area. Thus, to achieve potential economic yield of BH-546 variety modification of plant spacing with appropriate N-fertilizer rate could be determined. Keeping this in mind this study was designed with the objective of determining the optimum intra-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 site represents a mid-altitude sub-humid agro ecological zone. The total annual rainfall during 2017 season was 1598.0 mm. In this season, there was a rain throughout the year except January and December, but sufficient amount of rainfall for crop growth was recorded from April to September, with maximum precipitation (291.3 mm) in August and minimum precipitation (146.5 mm) in May, within this interval. The area had also mean minimum, mean maximum and average annual temperatures of 12.8, 29.0 and 20.9°C respectively; and humidity ranged from 46 to 57% in the year of 2017 (Bako Agricultural Research Center, Ethiopia, Metrological Data, 2017). The soils of the area are dominantly nitosol.

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 other hybrids. Nitrogen fertilizer in the form of urea (46% N) and phosphorous fertilizer in the form of Triple Superphosphate (46% P_2O_5) 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 plants ha^{-1}, respectively. The treatment set up that contain 75 × 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 m^2) with row length of 4.8 m, and net plot size 4.8 m × 1.5 m (7.2 m^2) 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 P_2O_5 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 other crop management practices were applied uniformly to all plots as per the common experience of the farm. Finally, maize plants in the central net plot area were harvested at harvest maturity stage (December 06/2017) for the analysis.

Crop data collection and measurement

Data were collected from ten randomly selected samples per plot for parameters of number of ears per plant, ear length (cm), number of kernel rows ear^{-1} and number of kernels ear^{-1}. Thousand grain weights (g) were determined from 1000 randomly taken kernels from each plot and weighed using sensitive balance. 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

Table 1. The results of soil physical and chemical properties before planting at Bako Research Center during 2017.

Characteristic of soil	Chemical characteristic of soil						Texture		
	pH (1:2.5H_2O) suspension	OC (%)	OM (%)	TN (%)	AP (ppm)	CEC (cmol 100 g^{-1} 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		

OC: Organic carbon, OM: organic matter, TN: total nitrogen, CEC: cation exchange capacity, AP: available phosphorus, pH: the negative logarithm of the hydrogen ion activity, ppm: parts per million.

measured using electronic balance after removing the husk. Grains were shelled 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% (Biru, 1976), 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:

$$\text{Correction factor} = \frac{\text{100-Actual moisture content}}{\text{100-12.5}}$$

Grain Yield kg $plot^{-1}$ = (100-Actual Moisture Content/87.5)×Field weight (kg)×Shelling percentage

Grain Yield kg ha^{-1} = Yield (kg/plot)×10000/Plot size (m^2)

Harvest index was then calculated as

$$\text{Harvest Index} = \frac{\text{Grain yield}}{\text{Above Ground Dry Biomass}} \times 100$$

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 yield and yield related parameters.

RESULTS AND DISCUSSION

Yield and yield components of maize

The analysis of variance showed that the main effect of nitrogen fertilizer application rate and intra-row spacing highly significantly ($P<0.01$) influenced the ear length, number of kernel rows per ear, number of kernels per ear, thousand grains weight and harvest index, but the interaction effect of the two factors was not significant. Likewise, number of ears per plant was highly significantly ($P<0.01$) influenced by intra-row spacing. However, the interaction effect of N rate and intra-row spacing were not significantly influenced by these parameters. Similarly, the main effect of N rates was not significantly influenced by number of ears per plant. The statistical analysis also revealed that both the main effects (rate of nitrogen and intra-row spacing) and their interaction highly significantly ($P<0.01$) influenced grain yield of maize. Similarly, above ground dry biomass was highly significantly ($P<0.01$) influenced by the main effects of nitrogen fertilizer rates and intra-row spacing, and the interaction of the two factors was also significantly ($P < 0.05$) influenced this parameter (Tables 2, 3 and 4).

Number of ears per plant

Increase in plant spacing resulted to significant increment in number of ears per plant (NEPP) and the highest NEPP (1.50) was produced in the widest intra-row spacing (40 cm), while the lowest NEPP (1.08) was recorded at the narrowest intra-row spacing (20 cm) (Table 2). The reduction of ear number from each plant in response to narrow plant spacing can be attributed to more intra-specific competition for growth limiting factors such as nutrients, water, light and aeration. In such conditions plants may utilize most of such limiting growth factors for vertical growth instead of horizontal growth and consequently plants can be able to develop only one or few functional ears (ear with grain), even though some plants initially emerge more than one ear shoots. The present results are in line with the findings of Muniswamy et al. (2007), Karasu (2012) and Abuzar et al. (2011).

Ear length

The ear length was increased with increase in

Table 2. Effect of different nitrogen rates (NR) and intra-row spacing (IRS) on yield components and harvest index of maize during 2017/2018 cropping season.

Treatment	No. of ear plant^{-1}	Ear length (cm)	No. of kernel rows ear^{-1}	No. of kernels ear^{-1}	Thousand grain weight (g)	Harvest index (%)
NR (kg ha^{-1})						
0	1.23^{c}	15.50^{d}	14.67^{c}	535.87^{d}	303.56^{c}	32.98^{c}
23	1.27^{bc}	15.80^{d}	14.81^{bc}	548.73^{d}	311.56^{c}	33.03^{c}
46	1.33^{ab}	16.80^{c}	15.00^{abc}	564.02^{c}	317.00^{bc}	34.75^{b}
69	1.31^{abc}	17.37^{b}	15.21^{ab}	595.13^{b}	322.22^{bc}	38.26^{a}
92	1.34^{ab}	18.26^{a}	15.32^{a}	608.78^{ab}	340.89^{ab}	39.02^{a}
115	1.38^{a}	18.62^{a}	15.44^{a}	621.63^{a}	353.56^{a}	38.94^{a}
Significance	ns	**	**	**	**	**
LSD (0.05)	0.10	0.37	0.45	13.94	25.63	1.63
IRS (cm)						
20	1.08^{c}	16.50^{c}	14.76^{b}	563.69^{c}	303.28^{b}	33.99^{b}
30	1.36^{b}	16.95^{b}	15.13^{a}	581.77^{b}	329.00^{a}	36.88^{a}
40	1.50^{a}	17.72^{a}	15.34^{a}	591.63^{a}	342.11^{a}	37.62^{a}
Significance	**	**	**	**	**	**
LSD (0.05)	0.07	0.26	0.32	9.86	18.12	1.15
CV	8.27	2.26	3.10	2.51	8.24	4.69

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

nitrogen rates. The longest ear 18.62 cm was recorded from treatments of 115 kg N ha^{-1} application, but it was statistically at par to ear length (18.26) which was obtained under 92 kg N ha^{-1} application. The shortest ear length (15.5 cm) was obtained at control (treatment without N application). However application of 23 kg N ha^{-1} had not brought any significant different compared to the control (Table 2). The increase in ear length in response nitrogen rates might be due to better availability of nutrients in the soil system so that the maize plant expressed fully its yield potential and produce longest ear under high rate of N. These results are in agreement with those of Sharifi and Taghizadeh (2009) and Sharifi and Namvar (2016).

The results also revealed that different intra-row spacing significantly affected the ear length of maize crop. The highest ear length (17.72 cm) was produced at wider intra-row spacing of 40 cm, while the lowest ear length (16.50 cm) was obtained at the narrowest intra-row spacing (20 cm) (Table 2). The reduction of ear length in the narrow plant spacing might be due to crowded stress and series competition among plants and among different organs within a plant for growth limiting factors (water, nutrients, air and light). These results are in line with the previous findings (Azam et al., 2017; Zamir et al., 2011).

Number of kernel rows per ear (NKRPE)

The maximum NKRPE (15.44) was recorded at an application of N in rate of 115 kg N ha^{-1}, but statistically similar row numbers per ear (15.32, 15.21 and 15.00) were also obtained under application of 92, 69 and 46 kg N ha^{-1}, respectively. The lowest NKRPE (14.67) was recorded from the control treatment, but it was statistically similar to 14.81 and 15.00 which was obtained at application of 23 and 46 kg N ha^{-1} (Table 2). This increment in NKRPE in response to nitrogen rates might be attributed to better availability of nutrient in the soil so that plants are enabled to grow vigorously and produce fully viable big ear which can carry several number of kernel rows on it. These results are in agreement with those of Aghdam et al. (2014) who reported that the use of urea fertilizer increased corn growth stages and development, which has increased the number of grain rows per ear of corn.

Main effect of intra-row spacing has also significant effect on the NKRPE. The maximum NKRPE (15.34) was noted when maize hybrid was sown at 40 cm plant spacing, but it was statistically at par with 15.13 which was obtained under 30 cm intra-row spacing. The lowest NKRPE (14.76) was recorded from narrowest intra-row spacing (20 cm) (Table 2). This could be probably crowded stress and intense competition for growth resources under narrow spacing. These results coincide with the finding of Azam et al. (2017) and Abuzar et al. (2011) who stated that number of grain rows per ear decreased as the plant population increased.

Number of kernels per ear (NKPE)

The mean comparison of the result indicated that the maximum mean NKPE (621.63) was recorded from the application of the maximum rate of N fertilizer (115 kg N ha^{-1}); however, this was statistically at par with NKPE of 608.78 produced under the rate of 92 kg N ha^{-1} application. The minimum NKPE (535.87) was produced under no N application, which was statistically similar with 548.75 produced under application of 23 kg N ha^{-1} (Table 2). This increment in NKPE in response to N application rates might be attributed to increased N availability in the soil which is required by plant in large quantity directly for growth purpose and indirectly to make available other nutrients essential for seed setting and seed development such as phosphorus and potassium (Brady, 1984). These results are in agreement with those of many other workers (Sharifi and Taghizadeh, 2009; Khan et al., 2012; Moosavi, 2012).

The main effect of intra-row spacing was also significant (P<0.01) and the highest NKPE (591.63) was recorded in the widest intra-row spacing (40 cm) followed by 30 cm (581.77). The lowest NKPE (563.69) was harvested from the narrowest intra-row spacing (20 cm) (Table 2). The decrease in the number of kernels per ear at narrow intra-row spacing could be attributed to plant competition at crowded plant stands leading to less availability of nutrients for grain formation and development. The result was in agreement to Maddonni and Otegui (2006), Azam et al. (2017), and Gozubenli et al. (2004) who reported that the grain yield of a single maize plant is reduced by proximity to its neighbors.

Thousand grain weight (TGW)

Nitrogen rates significantly increased TGW. The maximum TGW (353.56 g) was recorded in plots that were supplied 115 kg N ha^{-1} which is statistically similar with grain weight of 340.89 g produced under application of 92 kg N ha^{-1}. The minimum TGW (303.56 g) was recorded from control. The plots of those that received 23, 46 and 69 kg N ha^{-1} had not shown any significance difference in TGW compared to control (Table 2). However, numerically there was increasing trend in TGW with increasing N rate. The possible reason for increase in TGW with increased in N application rate could be due to positive effect of N on the growth of maize, increasing leaf area index and duration extending grain-filling period that allowed accumulating more photosynthetic assimilates in the grains. These results coincide with the finding of most researchers (Moosavi, 2012; Hafez and Abdelaal, 2015; Anwar et al., 2017).

The intra-row spacing also had significant (P<0.01) effect on TGW. The maximum TGW (342.11 g) was recorded in a treatment where maize seed was sown in plant spacing of 40 cm, but it was statistically at par with 329.00 g which was obtained at 30 cm intra-row spacing. The lowest TGW (303.28 g) was produced at the narrowest plant spacing (20 cm) (Table 2). Reduction in TGW in response proximity of stands could be due to competition for essential nutrients and other growth limiting resources, whereas increasing intra-row spacing provides better opportunity for crop to utilize and assimilate available resources with less competition; so this might be the reason for producing higher TGW under widest plant spacing. These results agree with finding of Zamir et al. (2011), Khan et al. (2017) and Azam et al. (2017).

Harvest index

The harvest index was increased with increase in N rates and attained the maximum value (39.02%) at rate of 92 kg N ha^{-1} application, but it was statistically similar to harvest indices of (38.26 and 38.94%) obtained under application of 69 and 115 kg N ha^{-1}, respectively. The lowest HI (32.98%) was recorded at a plot with no N application; however, this was statistically similar with HI (33.03%) which was obtained under application of 23 kg N ha^{-1} (Table 2). In these results, we observed that application of insufficient N rate (23 kg N ha^{-1}) and or further increasing N rates beyond the optimum (more than 92 kg N ha^{-1}) did not bring any significant change in harvest index. The increase in HI due to increase in N application rate may be associated with a pivotal role of N in many physiological and biochemical processes during growth and development period that enable the crop to allocate much dry mater into grain which has direct relationship to HI. On the other hand, further increase in N application rates might have enhanced more vegetative growth that resulted to reduction in the ratio of grain to total biological yield (HI). These results coincide with the finding of Aghdam et al. (2014), Sharifi and Namvar (2016) and Anwar et al. (2017).

Likewise, HI was increased with increase in intra-row spacing and the maximum HI (37.62%) was recorded at the widest intra-row spacing (40 cm). But it was not significantly different from HI (36.88%) obtained under 30 cm intra-row spacing. The lowest HI (33.99%) was obtained at 20 cm intra-row spacing (Table 2). This reduction in HI in response to closeness among plant stands might be attributed due to high competition for light so that plant rapidly increase in plant height and allocate much of the dry mater into stalk that resulted to reduction in the ratio of grain to total dry matter. These results are in agreement with Arif et al. (2010), Nik et al. (2011) and Akhtar et al. (2015).

Grain yield

The ultimate goal of crop production is increasing economic yield. Maximum grain yield (10208 kg ha^{-1}) was achieved at the intra-row spacing of 20 cm with the application of 115 kg N ha^{-1}, but it was statistically similar

Table 3. Effect of different nitrogen rates and intra-row spacing on grain yield of maize (kg ha^{-1}) during 2017/2018 cropping season.

IRS (cm)	**NR (kg ha^{-1})**					
	0	**23**	**46**	**69**	**92**	**115**
20	6359	6392^{h}	7586^{ef}	8710^{d}	9887^{ab}	10208^{a}
30	6619^{h}	6711^{h}	7525^{fg}	8794^{cd}	9374^{bc}	9544^{b}
40	6520	6591^{h}	6906^{gh}	7712^{ef}	8234de	8203de
LSD (0.05) N × IRS			648			
CV (%)			4.27			

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 (kg ha^{-1}) during 2017/2018 cropping season.

Intra-row spacing (cm)	**N rate (kg ha^{-1})**					
	0	**23**	**46**	**69**	**92**	**115**
20	21773^{ef}	21843^{ef}	23250^{cd}	23843^{c}	25833^{b}	26806^{a}
30	19597^{h}	19972^{gh}	21194^{f}	22421de	23843^{c}	23972^{c}
40	18139^{j}	18250^{hj}	19106^{hi}	19750^{h}	20889^{fg}	21065^{f}
LSD (0.05) N × IRS			957			
CV (%)			2.47			

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

with (9887 kg ha^{-1}) that was produced under the rate of 92 kg N ha^{-1} application for the same intra-row spacing (20 cm). The minimum grain yield (6359 kg ha^{-1}) 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 plants ha^{-1}) with the application of 92 kg N.ha^{-1}, the mean grain yield was increased by 8.90% when the maize hybrid was sown at intra-row spacing of 20 cm with application 115 kg N ha^{-1}.

The increase 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 increased solar radiation use efficiency that ultimately increases in grain yield. These results are in line with that of Gözübenli (2010) and Shrestha (2013).

Above ground dry biomass (AGDBM)

Application of 115 kg N ha^{-1} to maize hybrid planted at intra-row spacing of 20 cm gave the highest AGDBM yield (26806 kg ha^{-1}) followed by (25833 kg ha^{-1}) which was obtained under application of 92 kg N ha^{-1} in the same intra-row spacing. The lowest AGDBM yield (18139 kg ha^{-1}) was obtained at the widest intra-row spacing (40 cm) without N fertilizer application, but this was statistically similar with 18250 kg ha^{-1} which was 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).

The increase in AGDBM yield with the increase 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 the nutrient requirement of the dense stands can be optimized. On the other hand, plant grown on close spacing efficiently utilize available nutrients that resulted to increased height of each individual plant, increased leaf area index and helping to capture more light that will enable the plant utilize photosynthate more efficiently, ultimately leading to accumulation of high amount dry matter. The present results are in line with that of Moraditochaee et al. (2012) and Imran et al. (2015) 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 AGDBM, yield and yield components of maize

The correlation study indicate that above ground dry

Table 5. Correlation coefficient among growth and yield parameters of maize during 2017/2018 cropping season.

Correlation	NEPP	EL	NKRPE	NKPE	TGW	GY	AGDBM	HI
NEPP	1	0.52**	0.40**	0.43**	0.60**	-0.001^{ns}	-0.46**	0.54**
EL		1	0.54**	0.89**	0.64**	0.71**	0.31*	0.83**
NKRPE			1	0.55**	0.39**	0.33*	0.01^{ns}	0.54**
NKPE				1	0.57**	0.71**	0.35**	0.78**
TGW					1	0.40**	0.004^{ns}	0.66**
GY						1	0.81**	0.72**
AGDBM							1	0.18^{ns}
HI								1

**Highly significant, *Significant, ns: non-significant.

biomass was highly and positively correlated with NKPE (r=0.35) and GY (r=0.81). It was also correlated significantly (r=0.31) with EL. But NEPP was highly and negatively correlated (r=-0.46) with this parameter (Table 5). This indicated the effect of intra-row spacing (that is, when the intra-row spacing increased the AGDBM decreased, while the NEPP increased). AGDBM was not significantly correlated with other parameters. Similarly, grain yield was highly and positively correlated with EL (r=0.71), NKPE (r=0.71), TGW (r=0.40) AGDBM (r=0.81) and HI (r=0.72). It was also positively and significantly correlated with NKRPE (Table 5). In general, HI and all of the yield components were positively and significantly correlated with GY except that of NEPP. This indicates that the GY was positively affected by most of the parameters as it is the end result of many complex morphological and physiological processes. The main case of negative correlation between GY and NEPP is similar to the case mentioned for AGDBM.

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

Conclusion

Maize shows high positive responses to plant density and nitrogen. So, modification of these parameters significantly influence yield and yield components of maize. Based on the results obtained in this experiment, maize hybrid BH-546 produced the highest grain yield when the hybrid was 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 indicated an additive trend of grain yield with increasing N rate and decreasing intra-row spacing. So further modification of N rates upward and intra-row spacing downward might further increase the grain yield.

More importantly, the grain yield was highly significant and positively correlated with ear length, number of kernels per ear, thousand grain weight, above ground dry biomass and harvest index.

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 92 or 115 kg N ha^{-1} is suitable for the higher yield of hybrid maize BH-546 during main seasons at Bako. However, these results were based on single growing season; thus their confirmation should be done by further similar experiments across locations and across years.

CONFLICT OF INTERESTS

The authors have not declared any conflict of interests.

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