Advances in Crop Science and Technology

Zeleke et al., Adv Crop Sci Tech 2018, 6:2
DOI: 10.4172/2329-8863.1000352

Research Article Open Access

Effects of Planting Density and Nitrogen Fertilizer Rate on Yield and Yield Related Traits of Maize (*Zea mays* L.) in Northwestern, Ethiopia

Zeleke A[1*], Alemayehu G[2] and Yihenew GS[2]

[1]*Department of Plant Sciences, Faculty of Agriculture and Environmental Sciences, Debre Tabor University, Ethiopia*

[2]*Department of Plant Sciences, College of Agriculture and Environmental Sciences, Bahir Dar University, Ethiopia*

[*]**Corresponding author:** Zeleke A, Department of Plant Sciences, Faculty of Agriculture and Environmental Sciences, Debre Tabor University, Ethiopia, Tel: +251924240472; E-mail: az.abebe49@gmail.com

Received date: March 23, 2018; **Accepted date:** April 04, 2018; **Published date:** April 10, 2018

Abstract

In Ethiopia, different N-levels and planting densities were recommended based on the environmental conditions for maize production. However, the optimum nitrogen (N) requirements and planting density have not been yet well determined in the study area. A field experiment was conducted to determine N rate and planting density on maize yield in South Achefer district during 2014 cropping season at 3 locations. Three planting densities and four N levels were tested in randomized complete block design in the factorial arrangement with three replications. There were significant differences ($P<0.05$) among panting densities. Plant height, ear height, and leaf area index were significantly increased with increasing planting density from 44444 to 88888 plants ha^{-1}. However, the cob diameters, cob length, numbers of kernels per cob were decreased with increasing plating density. The grain yield was increased by 65.16% on 88888 plants ha^{-1} with 161 kg N ha^{-1} as compared to 44444 plants ha^{-1} with 92 kg N ha^{-1} and it was the best economically (39746.9 birrrs) profitable treatment combination. Thus, it can be concluded that application of 88888 plants ha^{-1} with 161 kg N ha^{-1} was found to be superior both agronomical and economically for maize production in the study area.

Keywords: Maize; Planting density; Nitrogen fertilizer rate; Grain yield; District

Introduction

Maize (*Zea mays*) is one of the most important cereal grain crops used as the human diet, livestock feed and raw material for various industries in large parts of the world [1]. Maize has been selected as one of the high priority crop to feed the increasing population of Ethiopia. It is thus being an important crop for overall food security of the country. World average productivity of maize is about 4.5 t ha^{-1}, while that of developed countries is 6.2 t ha^{-1}. The average productivity of maize in developing countries is 2.5 t ha^{-1}. In Ethiopia, the national average productivity of maize in 2011/12 was reported about 2.95 t ha^{-1} [2]. This indicates that maize productivity of Ethiopian farmers is incredibly far below the world's average due to a number of biotic and abiotic factors. Among many factors, like declining of soil fertility, poor agronomic practice, limited use of agricultural input, insufficient technology generation, and poor seed quality, particularly affect Ethiopian maize productivity considerably [3].

There is a great possibility to enhance maize productivity through increasing its planting density with increasing N fertilizer rate [4]. Nowadays, Ethiopian maize producers require more information about what combination of N-fertilizer level and plant density precisely increases maize yield, while the Government is promoting intensive crops production including maize so as to enhance grains production in the country in general. However, optimum maize yield and planting density and N fertilizer are not yet well determined in the study area. Hence, this experiment was conducted with the objectives of assessing the effect of N rates and plant densities on maize yield and yield-related traits; and to determine economically appropriate nitrogen rate and plant density that maximize the yield of maize in the study area.

Materials and Methods

Description of site

The study was conducted in the main cropping season of 2014 at three sites of South Achefer District of West Gojjam Zone, Northwestern Ethiopia. The area is largely receiving a mono-modal rainfall between June and September with an average annual rainfall of 1499 mm. The mean annual temperature of the area is with minimum and maximum temperatures of 12.1°C and 27°C, in the months of December and April, respectively. The soil is categorized under, clay soil textural class, moderate level of OM and low N fertility class and the moderate class [5]. Maize (*Zea mays* L.), teff (*Eragrostis teff Zucc.* Trotter) and finger millet (*Eleusine coracana* L. (Gaertn)) are among the major cereal crops widely grown in the study area together with the pulses of faba bean (*Vicia faba*), field pea (*Pisum sativum)* and chickpea (*Cicer arietinum)*, and with the oil crops of niger seed (*Guizotia abyssinica*), line seed (*Linumusit atissimum*) and rapeseed (*Brassica capmestris*).

Experimental treatment and procedures

Combinations of four N doses (92, 115, 138 and 161 kg ha^{-1}) and three planting densities (44444, 66666 and 88888 plants ha-1 corresponding to a spacing of 75 × 30, 75 × 20 and 75 × 15 cm) totally twelve treatments were laid out in a randomized complete block in the factorial arrangement with three replications. Blocks were separated from each other by 1 m wide-open space, while experimental plots within replications were separated by 0.5 m apart from each other. The

Citation: Zeleke A, Alemayehu G, Yihenew GS (2018) Effects of Planting Density and Nitrogen Fertilizer Rate on Yield and Yield Related Traits of Maize (*Zea mays* L.) in Northwestern, Ethiopia. Adv Crop Sci Tech 6: 352. doi:10.4172/2329-8863.1000352

gross size of each plot was 3.75 m length by 2.4 m width (9 m2) accommodating 5 rows at 0.75 m inter-row spacing. The net plot size of each plot was 3 m length × 2.4 m width (7.2 m2).

The experimental field was prepared following the conventional tillage practice before planting at all experimental locations. The land was leveled using manual power. Ditches and bunds were constructed for the whole experimental field and each replication. Two maize seeds were planted per hill and then thinning was done after the good establishment of seedlings so as to maintain a single healthy plant per hill. During planting, DAP as the main source of phosphorus at the rate of 200 kg ha^{-1} was applied commonly to all experimental plots. Indeed, the 18% of nitrogen available in DAP fertilizer (totally 36 kg N ha^{-1}) was reduced from each nitrogen rate that has been applied as urea. Nitrogen fertilizer rates were applied in a split in such a way that half during planting and half at the knee height growth stage. All other agronomic practices were applied uniformly to all experimental plots as per their respective recommendations for maize in the study area (Figure 1).

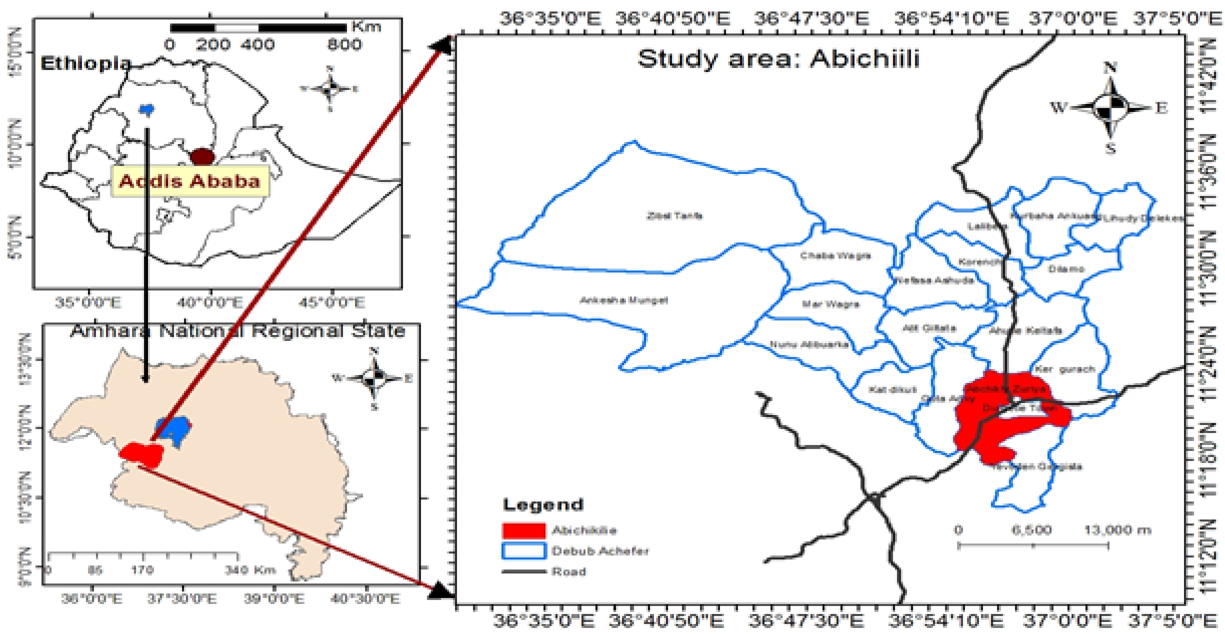

Figure 1: Map of the study area (BOA, 2010).

Data collection

Five plants in each plot were randomly selected and tagged from 3 central rows to collect data including plant height, ear height, leaf area, cob diameter, and cob length. The number of kernels per cob, biomass and grain yield and economic data were taken at harvest. The harvested grain yield from plot (gm/plot) was converted into ton/ha.

Data analysis

Analysis of variance (ANOVA) for all collected data was computed using SAS version 9.1.3 statistical software [6]. Whenever the ANOVA results showed the significant differences between sources of variation, the means were separated using Fisher's least significant difference (LSD). Partial budget analysis for mean grain yield of the treatments over combined locations was also computed [7]. The net benefit of each treatment was calculated by subtracting the total variable costs from the gross benefit.

Results and Discussion

Analysis of variance (ANOVA) for the effects of nitrogen, planting density and their interactions for all maize parameters measured during the course of the investigation (Tables 1-3). Nitrogen fertilizer level and planting density did not showed significant interaction ($P<0.05$) for the parameters of plant height (PH), ear height (EH), leaf area index (LAI), cob diameter (CD), cob length (CL), and number of kernels per cob (KPC). However, maize biomass and grain yield were significantly ($P<0.01$) influenced by the interaction of nitrogen fertilizer and planting density. Hence they are presented and discussed as interaction effect in Table 3.

Effects of planting density and N fertilizer rate on maize growth

Leaf area index: Leaf area index (LAI) was significantly ($P<0.01$) influenced by the main effect of planting density and N fertilizer rate ($P<0.05$) (Table 1). The result of LAI was increased linearly with the increasing of planting density and N fertilizer rates. The highest LAI was obtained in the highest planting density and N fertilizer rate; while the lowest LAI was recorded in the lowest planting density and N fertilizer rate (Table 1). This study revealed that the increased LAI with the increasing of planting density due to more leaf area occupied per unit ground area for maximum light interception and photosynthesis. Similar result was reported by Valadabadi and Farahani [8] stated that leaf area is influenced by genotype, plant population, and climate and soil fertility. Previous research findings also indicated that increasing of leaf area index, total dry weight, and crop growth rate in higher maize density than in lower maize density throughout crop growth season [9]. The increased in LAI with the increasing of N fertilizer rate was possibly due to the marked improvement of plant growth and leaf expansion fostered by the optimum nitrogen nutrition.

Plant height: The plant height was significantly (P<0.01) influenced by the main effects of planting densities (Table 1). Plant height is ranged from 245.25 to 233.04 cm (Table 1). Plant height increased significantly with the increasing of plant planting density. The tallest plant height of maize (245.25 cm) was measured in the highest planting density (88888 plants ha^{-1}), whereas, the shortest plant height of 233.04 cm was recorded in the lowest planting density of 44444 plants ha^{-1} (Table 1). These results agree with Rafiq [10] reported that plant density significantly increased the plant height in hybrid maize. These result confirmed that the findings of Sherifi et al. [11] in maize hybrid.

Ear height at maturity: Ear height was significantly (P<0.05) affected by the main effect of planting density. However, neither the main effect of N fertilizer levels nor the interaction effect of the two factors influenced maize ear height (Table 1). The main effect of planting density showed that ear height was relatively responsive to the change in planting density than N levels. The tallest ear height (136.59 cm) was recorded from 88888 plant ha^{-1} whereas; the shortest ear height (122.81 cm) was measured from 44444 plants ha^{-1} (Table 1). The result generally showed an increase in ear height when planting density increasing from the lowest to the highest density due to crowding effect of the plant and higher intra-specific competition for resources [12].

Treatments	PH(cm)	EH(cm)	LAI
Planting density (plants ha^{-1})			
P1:44444=75 × 30	233.04^{b}	122.81^{c}	3.65^{c}
P2:66666=75 × 20	240.92^{a}	131.88^{b}	5.28^{b}
P3:88888=75 × 15	245.25^{a}	136.59 ^{a}	6.81^{a}
LSD (0.05)	*	**	**
CV	5.13	6.7	9.08
Nitrogen level (kg ha^{-1})			
N1:92	238.98	129.98	5.06^{b}
N2:115	241.5	131.26	5.19^{ab}
N3:138	239.13	131.71	5.33^{a}
N4:161	239.33	128.74	5.40 ^{a}
LSD (0.05)	NS	NS	*
CV (%)	5.13	6.7	9.08

Table 1: Vegetative growth traits of maize as affected by the main effects of planting density and N level on 2014 main cropping season at three field trial locations. Means followed by the same letter within a column are not significantly difference among treatments. CV=coefficient of variation; PH=plant height; EH=ear height; LAI=leaf area index; NS=non- significant difference.

Effects of planting density and N fertilizer rate on maize yield and related traits

Cob diameter: Cob diameter was significantly affected by the main effects planting density. The highest maize cob diameter (16.89 cm) was obtained from planting density of 44444 plants ha^{-1}; whereas lowest maize cob diameters were measured from 88888 plants ha^{-1}(Table 1). These showed that maize cob diameter decreased with the increment of the planting density from 44444 to 88888 plants ha^{-1}. The thickest cobs from the lowest planting density might be due to more nutrients are available for plants and cob grains become larger. This result is in agreement with the work of Sherifi et al. [11] reported that cob diameter increased with decrease in plant density.

Cob length: The main effects of planting densities did significantly (P<0.05) influence on cob length across all experimental locations (Table 2). The longest cob length (21.90 cm) was measured from 44444 plants ha^{-1}; whereas the shortest cob length (20.67 cm) was recorded from the 88888 plants ha^{-1}. The advancement of longest cob length with less planting density might be due to less completion for nutrients, water, and sunlight. The similar trend was also reported by Sherifi et al. [11] and Zhang [13] that the ear diameter decreased with the increasing of plant density.

Number of kernels per cob: The number of kernels per cob was significantly (P<0.05) influenced by the main effect of planting density. The maximum number of grains per cob (482.14) was counted from 44444 plants ha^{-1} and while the minimum number of grains per cob (413.46) was produced in the highest plant population of 88888 plants (Table 2). This is a tendency that lowers planting density enhanced the presence of more number of grains per cob (cob^{-1}). The reason might be due to the availability of more resources to plants on account of low planting density. These results are in accordance with Abuzar et al. [12] who observed that an increase in plant density resulting in decreases the number of kernels per cob.

Treatments population	CD	CL	KPC	BY	GY
Population(plans.ha^{-1})					
P1:44444=75 × 30	16.89^{a}	20.67^{a}	473.60^{a}	1836.59^{c}	7.55^{c}
P2:66666=75 × 20	16.69^{a}	19.69^{b}	455.55^{b}	2421.20^{b}	9.57^{b}
P3:88888=75 × 15	16.32^{b}	19.33^{b}	451.23^{b}	2918.16^{a}	11.70^{a}
LSD (0.05)	*	*	*	**	**
CV (%)	3.38	5.27	6.99	16.15	16.92
Nitrogen (kg.ha^{-1})					
N1:92	16.89^{a}	20.67^{a}	473.60^{a}	2368.1	9.48^{ab}
N2:115	16.69 ^{a}	19.69^{b}	455.55^{b}	2301.1	9.16^{b}
N3:138	16.32^{b}	19.33^{b}	451.26^{b}	2437.3	10.05^{a}
N4:161	16.89^{a}	20.67^{a}	473.60^{a}	2461.4	9.74^{ab}
LSD (0.05)	*	*	*	NS	*
CV (%)	3.38	5.27	6.99	16.15	16.92

Table 2: Yield and its related traits of maize as affected by the main effects of planting density and N level on 2014 main cropping season at three field trial locations. Means in the same letter within a column are

not significant difference, CL=Cob length; CD=Cob Diameter; KPC=Kernel per cob; BY=Biomass yield; GY=Grain yield; NS=Non-significant difference.

Biomass yield: Biomass yields were significantly influenced (P<0.01) by the interaction effect of plating density and N fertilizer rate (Table 3). The maximum biomass yield (3170.80 t ha^{-1}) was obtained from the highest nitrogen level (161 kg ha^{-1}) and planting density (88888 plants ha^{-1}). These results implied that there is a possibility of maximizing biomass yields per unit area by increasing planting density with adequate plant nutrients and favorable environmental conditions. There was an increment of biomass yield parallel with an increase in planting density rate since there is the presence of more number of stands per unit area, improved translocation of dry matter accumulation, efficient N uptake and presence of increased competition for light. Several studies have shown that biomass yield increases progressively as the number of plants increases in a given area at a certain level [14]. However, the lowest biomass yield (1748.30 t ha^{-1}) was recorded from the highest nitrogen level (161 N kg ha^{-1}) and lowest planting density (44444 plants ha^{-1}) (Table 3) due to the application of maximum fertilizer dose on lowest planting density resulted in burning effect of the plant.

Treatment Combination	Plants ha^{-1}	Nitrogen (kg ha^{-1})	Spacing (cm)	BY (t ha^{-1})	GY (t ha^{-1})
P1N1	44444	92	75 cm × 30 cm	1856.90^{e}	7.43^{de}
P1N2	44444	115	75 cm × 30 cm	1830.00^{e}	7.36^{e}
P1N3	44444	138	75 cm × 30 cm	1911.10^{de}	8.46^{cde}
P1N4	44444	161	75 cm × 30 cm	1748.30^{e}	6.96^{e}
P2N1	66666	92	75 cm × 20 cm	2467.50^{bc}	9.77^{bc}
P2N2	66666	115	75 cm × 20 cm	2335.70^{cd}	8.88^{cd}
P2N3	66666	138	75 cm × 20 cm	2416.40^{bc}	9.78^{bc}
P2N4	66666	161	75 cm × 20 cm	2465.20^{bc}	9.83^{bc}
P3N1	88888	92	75 cm × 15 cm	2779.80^{ab}	11.24^{ab}
P3N2	88888	115	75 cm × 15 cm	2737.60^{abc}	11.24^{ab}
P3N3	88888	138	75 cm × 15 cm	2984.40^{a}	11.90^{a}
P3N4	88888	161	75 cm × 15 cm	3170.80^{a}	12.42^{a}
LSD (0.01)				**	**
CV %				19.35	16.74

Table 3: Combined interaction effects of plant population and nitrogen fertilizer rates on grain yield and related traits of maize in 2014 main cropping season at three trial locations. BY=biomass yield, GY=grain yield, Means in the same letter within a column are not significant difference.

Grain yield: Maize grain yield was significantly (P<0.01) affected by the interaction effect of planting density and N fertilizer rate (Table 3). The results of ANOVA showed that the highest grain yield (12.42 t ha^{-1}) was achieved from the combination of the highest planting density (88888 plants ha^{-1}) with the highest nitrogen fertilizer rate (161 kg N ha^{-1}). On the contrary, the lowest grain yield of 6.96 t ha^{-1} was obtained from the minimum planting density (44444 plants ha^{-1}) with maximum N rate (161 kg N ha^{-1}) (Table 3). This result demonstrates that high planting density and N fertilizer were beneficial for optimum yield when all other conditions are favorable to attain the highest grain yield in maize. These results are in conformity with Bozorgi et al. [15] also reported that maximum maize grain yield obtained from the combination of highest planting density with highest in N fertilizer levels. However, the lowest yield was obtained from the combination of lower planting density with higher fertilizer rate; this might be due to toxic and burning effect of higher dose of fertilizer on lower planting density.

Economic analysis of maize grain yield as influenced by plant population density and N fertilizer rates

The superior combinations of plant population and N fertilizer rates that gave the highest yield were identified (Table 4). The computation of total variable cost (TVC), net benefit analysis (NB), dominance analysis and marginal rate of return (MRR) reveals that the best economical treatment combination was the plant population (88888 plants ha^{-1}) and N fertilizer rates (161 kg N ha^{-1}) that gave the maximum grain yield of 12.93 t ha^{-1} with the net benefit value of 39746.87 birr ha^{-1}. The probable reason for grain yield increased due to the increase of ear number but it is essential that in terms of other factors, there is no limitation such as water, light and nitrogen availability.

Conclusion

In this study, plant population had better response in all maize agronomic traits rather than N-fertilize rate. The main effect of plant population density was greatly affected cob length, biomass yield, and grain yield. However, most of maize agronomic traits were not affected by N rate. This study revealed that the highest grain yield was produced from the combination of the highest plant population density and N fertilizer rate. Therefore, it can be concluded that combined application of 88888 plants ha^{-1} and fertilizer rate of 161 kg N ha^{-1} produced the higher grain yield and was found to be most economically profitable.

Treatment No.	PP	N	Total variable Cost	Net Benefit (Birr ha^{-1})	MRR (%)	Rank
1	44444	92	4545.13	21950.9	-	5th
5	66666	92	4848.13	30611.9	2858.416	4th
9	88888	92	5151.13	34736.9	1361.386	3rd
10	88888	115	5701.13	37210.9	449.8182	2nd
12	88888	161	6801.13	39746.9	230.5455	1st

Table 4: Analysis of marginal rate of return and ranking of economical profitable treatments based on their net benefit value combined over locations. pp=plant population ha^{-1}, N=nitrogen kg ha^{-1}, TVC=total variable cost, NB=net benefit value and MRR=marginal rate of return.

References

1. Khan HZ, Malik MA, Saleem MF (2008) Effect of rate and source of organic material on the production potential of spring maize (Zea mays L.). Pak J Agric Sci 45: 40-43.
2. CSA (Central Statistical Agency) (2012) Agricultural Sample survey: report on area and production of major crops (private peasant holdings, Meher season). Statistical Bulletin, Addis Abeba.
3. CIMMYT (International Maize and Wheat Improvement Center) (2004) Second semi-annual progress report for the quality protein maize development project for the horn and east Africa.
4. Vega CRC, Andrade FH, Sadras VO (2001) Reproductive portioning and seed set efficiency in soybean, sunflower and maize. Field Crop Res 72: 165-173.
5. Tekakign M, Haque I, Aduayi EA (1991) Soil, plant, water, fertilizer, animal manure and compost analysis manual. Plant science division working document, Ethiopia.
6. SAS Institute (2003) SAS/STAT guide for personal computers, SAS Institute Inc., North Carolina, USA.
7. CIMMYT (International Maize and Wheat Improvement Center) (1988) Partial budget analysis for mean grain yield.
8. Valadabadi SA, Farahani HA (2010) Effects of planting density and pattern on physiological growth indices in maize (Zea mays L.) under nitrogenous fertilizer application. Journal of Agricultural Extension and Rural Development 2: 40-47.
9. Saberali SF, Sadatnoori SA, Hejazi A (2007) Influence of plant density and planting pattern of corn on its growth and yield under competition with common Lambesquarters (Chenopodium album L.). Pajouhesh and Sazandegi 74: 143-152.
10. Rafiq MA, Ali A, Malik MA, Hussain M (2010) Effect of fertilizer levels and plant densities on yield and protein contents of autumn planted maize. Pak Jagri Sci 47: 201-208.
11. Sherifi RS, Sedghi M, Gholipouri A (2009) Effect of population density on yield and yield attributes of maize hybrids. Res J Boil Sci 4: 375-379.
12. Abuzar MR, Sadozai GU, Baloch AA, Shah IH, Javaid T, et al. (2011) Effect of plant population densities on yield of maize. The Journal of Animal and Plant Sciences 21: 692-695.
13. Zhang J, Dong S, Wang K, Hu C, Liu P (2006) Effect of shading on the growth, development and grain yield of summer. The Journal of Applied Ecology 17: 657-662.
14. Hamidi A, Khodabandeh N, Mohammady-nasab AD (2010) Plant density and nitrogen effects on some traits of maize (Zea mays L.). Plant Ecophysiol 2: 47-52.
15. Bozorgi HR, Dousta HZ, Sadeghi SM, Keshavarz A, Faraji A, et al. (2011) Study effect of pant density and nitrogen fertilizer on yield and yield componentes of maize. World Applied Siense Journal 13: 147-151.