Journal of Natural Sciences Research www.iiste.org
ISSN 2224-3186 (Paper) ISSN 2225-0921 (Online)
Vol.13, No.3, 2022

Effect of Population Density and Fertilizer Rates on Yield and Yield Components of High Land Maize

Sakatu Hunduma and Mebrate Tamirat
Ethiopian Institute of Agricultural Research, Holeta Agricultural Research Center,
P.O. Box 2003, Addis Ababa, Ethiopia
* Correspondence should be addressed to Sakatu Hunduma:sakatuhunduma@gmail.com

Abstract
A field experiment was conducted for two years (2019 and 2020) during the main cropping seasons at Holeta, Welmera wereda, West Shoa, in the central highlands of Ethiopia to determine optimum planting density and fertilizer rates for maize production. The treatments consists of factorial combination of four population densities (44,444, 53,333, 62,500 and 66,666 plants/hectare) and four fertilizer rates (150:200,150:250, 200:200 and 250:200 NPS:Urea kg/ha) laid down in a randomized complete block design (RCBD) with three replications. The main effect of population density significantly ($P \leq 0.05$) affected plant height, ear height, cob diameter and grain yield but not significantly affected cob length, number of cob per plant and thousand seed weight. Even if the main effect of population density did not significantly affect thousand seed weight, the lowest thousand seed weight was recorded at the highest population density. The main effect of fertilizer rates significantly ($P \leq 0.05$) affected only plant height and grain yield. As population density increases maize grain yield was also increasing, and the highest grain yield (8894.2kg/ha) was attained by the highest population density (66,666plants/ha). This means that population density more than 66,666plants /ha may be needed because the grain yield was still in increasing manner. On the other hand, the interaction effect of population density and fertilizer rates was not significant to affect all the tasted growth and yield parameters. Based on statistical and economic analysis results, out of the tasted treatments the highest grain yield was recorded at the highest population density (66,666plants/ha) and using fertilizer rate of 250NPS:200Urea.
Keywords: highland maize, population density, fertilizer rate, yield
DOI: 10.7176/JNSR/13-3-03
Publication date: February 28th 2022

1. 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 (Khan *et al*., 2008). Maize is the second most widely cultivated crop in Ethiopia and is grown under diverse agro-ecologies and socioeconomic conditions typically under rain-fed condition (Abate *et al.*, 2015). 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. It is used for household diet in different forms such as bread, muffin, boiled grain, enjera, local beer (tela), green cob and porridge are the most common prepared forms for direct use (Golla , 2018).

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 (CIMMYT, 2004). There is a great possibility to enhance maize productivity through increasing its planting density with increasing N fertilizer rate Vega *et al*., (2001). 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. Maize is commonly planted in rows of varying spaces, less effort has been made to plant at optimum densities to maximize its productivity in different agro-ecologies of Ethiopia. Summaries of earlier results confirmed that at 5-7 plants/m^2 medium to late maize maturity groups gave maximum yields in humid regions, while early maturity groups produced maximum yields at higher densities in both humid and moisture stress areas (Tenaw *et al.,* 2002). Plant population density has a significant impact on growth and yield of crops, including maize, a popular C4 cereal crop (Cox,1996). Therefore, understanding how plants regulate their growth in response to plant population densities has problems, such as determination of optimal sowing density (Cox, 1996). Increased plant populations could lead to increased yields under optimal climatic and management conditions due to the greater number of smaller cobs per unit area Bavec and Bavec, (2002). Plant population is the prime factor for getting maximum yield which is decided by inter and intra row spacing of crops. Decreasing the distance between neighbor rows at any particular plant population has several potential advantages. First, it reduces competition among plants within rows for light, water and nutrients due to a more equidistant plant arrangement Olson and Sander, (1988). The more favorable planting pattern provided by closer rows enhances maize growth rate early in the season (Bullock *et al.,* 1988), leading to a better interception of sunlight, a higher radiation use efficiency and a greater grain yield Westgate *et al*., (1997). Currently fertilizer rate of 200kg Urea/ha

and 100kg NPS/ha and population density of 53,333 plants/ha is used for maize production at the study area. The current research was designed with the objectives of determining the appropriate population density and fertilizer rate to attain optimum yield for high land maize and to study interaction effect of population density and fertilizer rates on yield and yield components of high land maize.

2. Materials and method

2.1 Site description, Treatments and Experimental procedures

The experiment was conducted for two years (2019 and 2020 main cropping seasons) at Holeta Welmera wereda, West Shoa, in the central highlands of Ethiopia. The environment is seasonally humid and the soil type was reddish brown Eutric Nitisol (IUSS Working Group WRB, 2006). Holeta is located between 09° 03 ′ N latitude and 38° 3 0 ′ E longitude, 30 km west of Addis Ababa, at an altitude of about 2400 m above sea level. The long- term average annual rainfall is 1100 mm, about 85% of which is received from June to September with the remainder from January to May. The average minimum and maximum air temperatures are 6.2°C and 22.1°C respectively. Highland Maize variety 'Jibat' was used as a taste crop for this experiment to study effect of population density and fertilizer rate on yield and yield components of maize production. Four different population levels (44,444, 53,333, 62,500 and 66,666 plants/hectare) and four fertilizer rates (150:200,150:250, 200:200 and 250:200 NPS : Urea kg/ha) were involved in this study. The treatments were the combination of four population density and four fertilizer rates. There was 16 treatments tasted in this trial. The design used was RCBD with factorial arrangement having three replication.

2.1. Statistical analysis

The effect of treatments on crop parameters were statistically analyzed using two-way analysis of variance (ANOVA) with Statistical Analysis System (SAS) software (SAS Institute, 2004). When the ANOVA result showed significant difference among treatments for each parameter, least significant difference (LSD) test at 5% probability level was applied for means separation.

2.2.Partial economic analysis

Partial economic analysis was conducted based on the procedure provided by CIMMYT (1988). Total variable costs were estimated by considering the current prices of urea which was 1606.16Birr per 100 kg and the price of 100 kg NPS was 1610.22Birr and the maize seed cost was 57birr/kg, while grain price was 12.5Birr/kg. The prices of the fertilizers, grain and seed was calculated by taking an average of the two cropping year prices.

3. Results and Discussion

According to the analysis result of the two year data, year was not significantly affect all the parameters tasted except ear height and number of cobs per plant (Table 1). The main effect of population density significantly affect plant height, ear height, cob diameter and grain yield. Even if the main effect of population density did not significantly affect thousand seed weight, at highest population density the lowest thousand seed weight was recorded. In other case the interaction effect of population density and fertilizer rates was not significantly affect the tasted growth and yield parameters in this trial.

3.1 Effects of planting density and fertilizer rates on maize growth parameters

3.1.1 Plant Height: Plant height was significantly ($P<0.01$) influenced by the main effects of planting densities and fertilizer rates (Table 1). The mean average plant height was ranged from 222.42 to 236.76 cm. (Table 1). Maize plant height increased significantly with the increasing of planting density as well as fertilizer rates. The tallest plant height (236.76cm and 235cm) was recorded from the highest plant density (66,666 plants/ha) and highest fertilizer rate (250kgNPS/ha:200kgUrea/ha), respectively whereas, the shortest plant height was recorded in the lowest planting density and lowest fertilizer rate (Table 1). These results agree with Rafiq *et al*., (2010) which reported that plant density significantly increased the plant height in hybrid maize. Interaction effect of population density and fertilizer rate did not significantly affect plant height.

3.1.2 Ear height: Ear height was significantly ($P<0.01$) affected by the main effects of planting densities (Table 1). Ear height increased significantly with the increasing of planting density. The mean average ear height was ranged from 114.33 to 122.16cm. (Table 1). However, neither the main effect of fertilizer rates 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 fertilizer rates. The tallest ear height (125.45cm) was recorded from the highest plant density (66, 666 plants/ha), whereas, the shortest ear height was recorded in the lowest planting density and lowest fertilizer rate (Table 1). The current result was in agreement with Zeleke *et al*., (2018) which showed that ear height was relatively responsive to the change in planting density than N levels.

3.1.3 Cob length and Cob diameter:

Based on two year statistical data analysis of this research work, cob length was not significantly affected by the main effects of planting densities and fertilizer rates (Table 1). But cob diameter was significantly affected by the main effect of population density but not significantly affected by the main effect of fertilizer rates. Both cob length and cob diameter did not significantly affected by the interaction effect of population density and fertilizer rates.

Table 1. Main effects of population density and fertilizer rates on maize yield and yield components at Holeta during the main cropping seasons of 2019 and 2020.

Treatments	Plant height (cm)	Ear height (cm)	Cob Length(cm)	Cob diameter(cm)	Number of cob/plant	TSW (gm)	Grain yield (kg/ha)
Year							
2019	231.3a	126.46a	16.45a	13.94a	1.85a	347.213a	7669.4a
2020	228.3a	113.16b	16.37a	13.01b	1.21b	332.75a	7633.7a
Population density(No. plants/ha)							
44,444	224.90c	114.33c	16.22	13.63a	1.6	343.16	6617.3d
53,333	227.39bc	119.97b	16.8	13.7a	1.56	343.73	7034.0c
62,666	230.29b	119.97b	16.31	13.3b	1.46	347.71	8060.6b
66,666	236.76a	125.45a	16.3	13.29b	1.5	325.33	8894.2a
$LSD_{(0.05)}$	**	**	**ns**	*	**ns**	**ns**	**
CV (%)	**3.92**	**6.87**	**7.69**	**4.33**	**12.34**	**12.33**	**8.58**
Fertilizer Rates (NPS : Urea kg/ha)							
150:200	222.42c	116.35	16.32	13.32	1.47	334.6	6717.1c
150:250	229.51b	119.29	16.61	13.63	1.51	340.88	7913.0ab
200:200	232.41ab	121.45	16.15	13.45	1.57	332.83	7748.9b
250:200	235.0a	122.16	16.56	13.5	1.56	351.62	8227.1a
$LSD_{(0.05)}$	**	**ns**	**ns**	**ns**	**ns**	**ns**	**
CV (%)	**3.92**	**6.87**	**7.69**	**4.33**	**12.34**	**12.33**	**8.58**

3.2 Effects of planting density and fertilizer rates on maize yield and yield related parameters

3.2.1 Number of cob per plant: Based on the statistical analysis of the two year data, number of cob per maize plant was not significantly affected by the main effects of population density and by main effects of fertilizer rate (Table 1). Even if the difference is not significant, the trend of the data showed that number of cob per plant decreases as the population density increases, but number of cob per plan increased as fertilizer rate increases (Table 1). Similarly, interaction effect of population density and fertilizer rate did not significantly affect number of cob per plant.

3.2.2 Thousand seed weight: Based on two year statistical data analysis of this research work neither the main effects of population density and fertilizer rate nor their interaction effect significantly alter maize thousand seed weight (Table 1). But, even if mean thousand seed weight difference was not significant, maize thousand seed weight increased as fertilizer rate increases but it decreases as population density increases and the lowest thousand seed weight was recorded at the highest population density (Table 1). Similar report by Allessi and Power (2004) also revealed that maize cob weight decreased with increased plant population.

3.2.3 Grain yield: Based on the statistical analysis of the two year data, maize grain yield was significantly ($P<0.01$) influenced by the main effects of planting densities and fertilizer rates (Table 1). The mean average grain yield was ranged from 6617.3 to 8894.2 kg/ha. (Table 1). Maize grain yield increased significantly with the increasing of planting density and also increase with increasing of fertilizer rates. The highest grain yield (8894.2 kg/ha and 8227.1kg/ha) was recorded from the highest plant density (66,666 plants/ha) and highest fertilizer rate (250 kg/ha NPS**:**200 kg/ha Urea), respectively. But, the lowest grain yield was recorded by the lowest planting density and lowest fertilizer rate (Table 1). The increase in maize grain yield under high plant density might be due to efficient utilization of available resources like nutrient, water, air and solar radiation. Interaction effect of population density and fertilizer rate did not significantly affect maize grain yield in this research work. In line with this result, Bozorgi*et al*., (2011) also reported that maximum maize grain yield obtained from the combination of highest planting density with the highest in N fertilizer levels. According to Gözübenli (2010), maize hybrids can be grown up to 76500 plant ha-1 with no adverse effect on yield or grain quality. Muhidin (2019) also reported that as maize plant density increase grain yield also increases and the highest grain yield was recorded from the highest population density of 90,909 maize plants/ha.

4. Economic analysis

Partial economic analysis was conducted based on the procedure described by CIMMYT (1988). Total variable costs were estimated by considering the current prices of urea which was 1606.16Birr/100 kg and the price of 100 kg NPS was 1610.22Birr and the maize seed cost was 57birr/kg, while grain price was 12.5Birr/kg. The prices of the fertilizers, grain and seed was calculated by taking an average of the two cropping year prices. Based on the results of statistical data analysis, the interaction effect of the two main factors (population density and fertilizer rates) were not significant and as a result, partial economic analysis were done separately for population density and fertilizer rates as indicated in (Table 2). Accordingly to the partial economic analysis, out of the tasted planting densities population density of 66,666 maize plants/ha records the highest net benefit and also out of the tasted fertilizer rates, 250NPS:200Urea gives the highest net benefit.

Table 2. Dominancy and Marginal rate of return analysis for fertilizer rate and Plant density

No.	Treatments	Adjusted GY(kg/ha)	TVC (Birr/ha)	Gross profit (Birr/ha)	Net benefit (Birr/ha)	MRR (%)
	Population density (No. plants/ha)					
1	44,444	6286.4	8856.14	78580	69723.85	
2	53,333	6682.3	11027.14	83528	72500.85	127.91
4	66,666	8449.4	13282.5	105617.5	92335	879.46
3	62,666	7657.5	15203.84	95718.75	80514.9	**D**
	Fertilizer Rates (NPS : Urea kg/ha)					
1	150:200	6381.2	5627.65	79765	74137.36	
2	150:250	7517.35	6430.73	93966.87	87536.14	1668.4
3	200:200	7361.45	6432.76	92018.12	85585.35	**D**
4	250:200	7815.74	7237.86	97696.75	90458.8	363.01

5. Conclusion and Recommendation

This research trial was designed to identify the optimum population density and fertilizer rates to get optimum maize grain yield in the study area. In this study, the statistical analysis of the two year data showed that the interaction effect of population density and the fertilizer rates were not significant to alter any of the parameters tasted. As population density increases maize grain yield was also increasing, and the highest grain yield (8894.2kg/ha) was attained by the highest population density (66,666plants/ha). This means that population density more than 66,666plants /ha may be needed because the grain yield was still in increasing manner. Out of the tasted combined fertilizer rates, 250NPS:200Ureakg/ha recorded the highest grain yield of 8227.1kg/ha followed by fertilizer combination of 150NPS:250Urea kg/ha which recorded a grain yield of 7913kg/ha. As a conclusion, based on the statistical analysis result and partial economic analysis of the two year data, plant population density of 66,666plants/ha and fertilizer rate of 250NPS:200Urea kg/ha could be recommended for the study area. But future research is required by considering higher seed rates than 66666plants/ha.

6. References

Abate, T., B. Shiferaw, A. Menkir, D. Wegary, Y. Kebede, K. Tesfaye, M. Kassie, G. Bogale, B. Tadesse and T. Keno, 2015. Factors that transformed maize productivity in Ethiopia. Food Security, 7(5): 965-981.Available at: https://doi.org/10.1007/s12571-015-0488-z.

Allessi, J. and Power, J. F. (2004). Effect of plant population, row spacing and relative maturity on dry land corn in the Northern plans. Agronomy Journal 66(2): 316-319.

Bavec F,Bavec M (2002).Effect of plant population on leaf area index ,cob characteristics and grain yield of early maturing maize cultivars (FAO 100-400).EUr.J.Agron.16:151-159. Cox WJ (1996). Whole plant physiology and yield response of maize to plant density. Agro. J.88:489-496

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 components of maize. World Applied Science Journal 13: 147-151.

Bullock, D., R. Nielsen, and J.W. Nyquist. 1988. A growth analysis comparison of corn grown in conventional and equidistant plant spacing. Crop Sci. 28:254–259.

CIMMYT (1988) Farm Agronomic to farmer's recommendation. An Economic Training Manaual. Completely revised edition, D.F. Mexico, p. 51.

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.

Cox WJ (1996). Whole plant physiology and yield response of maize to plant density. Agro. J.88:489-496

Golla Mekonen B (2018) Effect of Nitrogen Rate and Intra-Row Spacing on Yield and Yield Components of Maize (*Zea mays* L.) at Bako, Western Ethiopia.

Gözübenli H (2010) Nitrogen dose and plant density effects on popcorn grain yield. African Journal of Biotechnology 9(25): 3828-3832.

IUSS Working Group WRB. 2006. World reference base for soil resources A framework for international classification, correlation and communication (World Soil Resources Reports No. 103). FAO; Rome, Italy.

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.

Muhidin Biya, "Effect of Inter-and Intra-Row Spacing on Yield and Yield Components of Maize QPM Hybrid, BHQPY545 in Southwestern Ethiopia", International Journal of Research Studies in Science, Engineering and Technology, vol. 6, no.10, pp. 19-26, 2019.

Olson RA, Sander DJ (1988). Corn production .In: Sprague, G.F.; Dudley, J. W.(Ed.).Corn and corn improvement .Madison :American society Agronomy/Crop science Society of America /Soil science Society of America,p.639-686.

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.

SAS Institute (2004). SAS/STAT guide for personnel computers, version 9, edition. Cary, NC: SAS Institute Inc.

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.

Tenaw. Workayahu, Tolessa D., T. Bogale, and W. Negassa, M. Liben, T. Mesfin, B. Mekonen and W. Mazengia. 2002. A Review of fertilizer management on maize in Ethiopia. pp46-55. In: Mandefro Nigussie, D. Tanner and S.Twumasi-Afriya (eds.). Enhancing the contribution of maize to food security in Ethiopia: Proceedings of the second national maize workshop of Ethiopia. 12-16 November 2001, Addis Ababa, Ethiopia. EARO/CIMMYT.

Vega CRC, Andrade FH, Sadras VO (2001) Reproductive portioning and seed set efficiency in soybean, sunflower and maize. Field Crop Res 72: 165-173.

Westgate M.E., Forcella F., D.D. Eicosky, Somsen J. (1997). Rapid canopy closure for maize production in the northern US cornbelt: radiation-use efficiency and grain yield. Field Crops Res. Amsterdam 49(2):249-258

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:10.4172/2329-8863.1000352Core Team (2013). R: A language and environment for statistical computing. R Foundation for Statistical Computing, Vienna, Austria. URL http://www.R-project.org/