E-ISSN: 2618-0618
P-ISSN: 2618-060X

www.agronomyjournals.com
2021; 4(1): 70-74
Received: 20-12-2020
Accepted: 18-01-2021

Muhidin Biya
Jimma Agricultural Research Center, P. O. Box 192, Jimma, Ethiopia

Corresponding Author:
Muhidin Biya
Jimma Agricultural Research Center, P. O. Box 192, Jimma, Ethiopia

Increased application of nitrogen fertilizer rates and plant densities effect on maize (*Zea mays* L.) at Nada Sadacha, Southwestern Ethiopia

Muhidin Biya

Abstract
The field experiments were carried at Nada sadacha waredas, Jimma Zone, for 2017-18 main consecutive cropping seasons. The treatments consisted of factorial combinations of four plant densities (75*20 (66666), 75*25 (53333), 75*30 (44444) and 80*40 (62500 plants h^{-1}) and five Nitrogen and Phosphorous fertilizer rates (69, 92, 115, 138 and 161 N kg ha^{-1}) laid down in an RCBD factorial design with three replications using BH546 variety. All spacings accommodates a single plant per hill except the 80*40 two plants per hill. All grain yield and yield related parameters were significantly affected by N fertilizer rates and plant densities and no interaction. The highest grain (8.66 and 8.73 t/ha) and above ground biomass yield (16.93 and 17.46 t/ha) respectively were obtained from 138 kg ha^{-1} N fertilizer rate and 75*25 cm (53333 plants h^{-1}). The grain yield was significantly increased by 18.47 and 11.31% over the lowest 69 N kg and 92Nkg ha^{-1}(control) respectively also by 30.88% over lower density 80*40 (62500 plants h^{-1}). In conclusion, a medium maturing variety with the application of 138 N kg ha^{-1} and 75*25(53333 plants h^{-1}) gave the highest net benefit (29430.30 and 30110.40 EtB ha^{-1}) with acceptable MMR (172.21 and 346.56%) respectively. Therefore, based on input availability and economic feasibility, a medium maturing variety with the application of 138 N kg ha^{-1} and spacing of 75*25 (53333 plants h^{-1}) taken as optimal and recommended for maize (BH546) variety production under rainfed condition of the study area.

Keywords: Maize, BH546, plant population density, nitrogen fertilizer rates

1. Introduction

Maize (*Zea mays* L.) is one of the most important cereal crops on which millions of people depend for their livelihood. It is one of the most versatile emerging crops having wider adaptability under varied agro-climatic conditions and successful cultivation in diverse seasons and ecologies for various purposes. Globally, maize is known as “Queen” of cereals because it has the highest genetic yield potential among the cereals. In Ethiopia, maize stands first of all other cereal crops in annual production and productivity, although it is second in area coverage next to tef (CSA, 2018). Currently in Ethiopia maize is cultivated by 10.6 million households on 2.1 million hectares and produced 8.4 million tones as compared to 5.2 million tons of teff (CSA, 2018). Its contribution was 28 % over the total national grain production. The popularity of maize in Ethiopia is partly because of its high value as a food crop as well as the growing demand for the Stover as animal fodder and source of fuel for rural families. (Abdirazak and Bereket, 2018) [2].

Among the plant nutrients, primary nutrients such as nitrogen and phosphorus play a crucial role in determining the growth and yield Srikanth *et al*., (2009). Some soil types in Ethiopia contain enough amounts of essential nutrients for the plant's development. The majority of soils in the country contains low to medium total N and found inherently low in available P. This could be due to long term cultivation practice that depletes plant nutrients and soil resource degradation as a result of soil erosion and run-off and this becomes a threat to agricultural productivity in Ethiopia. Besides these the southern part of Ethiopia including Jimma zone the soil was acidic due to high rainfall area causes unavailability nutrients to plant. These soils suffered multi-nutrient deficiencies so that, application of mineral fertilizers has become mandatory to increase crop yields in such soils Adeniyan and Ojeniyi, (2005) [3].

Plant population density has a significant impact on growth and yield of crops, including maize, a popular C4 cereal crop Cox, (1996) [8]. Decreasing the distance between neighbour 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 Porter *et al*., (1997). The more favourable planting pattern provided by closer rows enhances maize growth rate early in the season Bullock *et al*., (1988) [6], leading to a better interception of sunlight, a higher radiation use efficiency and a greater grain yield Westgate *et al*., (1997).

Maize is commonly planted in rows of varying spaces; less effort has been made to study the optimum densities to maximize its productivity in different agro-ecologies of Ethiopia. Some studies on maize plant population densities indicate that better yields were obtained at planting density in a range of 4-7 plants m^{-2} (40,000-70,000 plants ha^{-1}) Tenaw *et al*., (1993). Later studies 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).

Most Studies shows that under the low plant density and low nitrogen rate the utilization and conversion of available resources like solar radiation, nutrient and water in to dry matter production decrease Shrestha, (2013); Farnia *et al*., (2015). Also under high plant density and high nitrogen rate the height of plant increase vertically with decreasing stalk strength resulting in high lodging Qian *et al*., (2010). Keeping this fact in view this study was initiated to prove the recently released HB546 hybrids maize under application of increased N fertilizer rate and plant population study under main season conditions.

2. Materials and Methods

2.1 Description of the Study Area

The current field experiments were conducted in at two sites for three consecutive main cropping seasons of Nada sadacha waredas, Jimma Zone Southwestern Ethiopia at farmers' fields. The sites were located at latitude 7º37' N and longitude 37º 14'E and lay at an altitude of 1753 M.A.S.L. The average minimum and maximum temperature are 6 ºC and 25ºC respectively and reliably receive good rains 1446 mm per annum cropping season. The farming system of the study site is cereal crops dominated with maize, tef, and sorghum. Also, it has a convenient topography which is very suitable for all agricultural practices.

2.2 Experimental treatment and procedures

Medium maturing maize (BH546) variety which was adapted to low-mid altitude (1000-1800 masl) areas and released recently were used for the field experiment. They were white-coloured and have yield potential. The combination of five Nitrogen fertilizer rates (69, 92, 115, 138 and 161 N kg ha^{-1} with recommended 69 P kg ha^{-1} uniformly applied) and four plant population densities (75*20 (66666), 75*25 (53333), 75*30 (44444) and 80*40 (62500 plants h^{-1}) twenty treatments were laid out as a randomized complete block design (RCBD) in factorial arrangement with three replications. Blocks were separated from each other by 1.5 m wide-open space, while experimental plots within replications were separated by 1 m apart from each other. The gross size of each plot was 4.0 m length by 5.25m width (21 m^2) accommodating 8 rows. The inner 6 rows used for data collection. Nitrogen applied per stand or hill base. To increase the nitrogen use efficiency, it was split into two equal rates and applied at planting time and knee height stages.

The experimental field was prepared following the conventional tillage practice and furrow opened by using oxen. Two maize seeds were planted per hill and thinned after establishment to maintain a single healthy plant per hill except 80*40 (62500 plants h^{-1}) two plants per hill. All other agronomic practices like three times hand weeding were applied uniformly to both experimental plots as per their respective recommendations for maize in the study area.

2.3 Soil Sampling and Analysis

A composite surface soil (0-30 cm depth) sample was collected from both sites with a gauge auger before planting; the experimental field was blocked into three parts depending upon land uniformity. Plant residues on the sampling soil surface were removed.

The soil samples were then analyzed at Jimma Agricultural Research Center soil laboratory for chemical properties (Soil pH, Total N, CEC, Available potassium and Available phosphorus).

Table 1: Selected Physico-chemical properties of the soil of the experimental sites before planting

Soil characters	2017	2018	Source
pH(1:2.5) (H_2O)	4.700	4.19	Batjes NH (1995) [4]
Av P(ppm)	3.915	4.23	Tekalign and Haque (1991) [23]
TN (%)	0.203	0.217	Berhanu D (1980) [5]
Ex. K (cmolc kg-1)	0.957	0.675	DEFRA (2007) [9]
CEC (cmolc kg-1)	18.96	21.08	Landon (1991) [5]

Where pH= hydrogen power, TN=Total Nitrogen, Av. P=Available phosphorous, CEC=cation exchange capacity, Kv. K=Available potassium. Values are the means of duplicated samples.

Source: Jimma agricultural research center soil laboratory.

2.3 Data collection

The data collected were growth, yield, yield related and other agronomic data were collected.

2.4 Economic analysis

To assess the costs and benefits associated with different treatments (N and Plant population density), the partial budget technique as described by CIMMYT (1988) [7] was applied. Economic analysis was done using the prevailing market prices for inputs at planting and outputs, at the time the crop was harvested. All costs and benefits were calculated on ha-1basis of Ethiopian Birr (EtB). The inputs and/or concepts used in the partial budget analysis were the mean grain yield of each treatment in the three years, the field price of BH546 Hybrid maize grain (sale price grain yield minus the costs of fertilizer, planting, seed), the gross field benefit (GFB) ha-1(the product of field price of the mean yield for each treatment), the field price of Seed rate kg ha-1, fertilizer and wage rate, the total costs that varied (TCV) which included the sum of field cost of seed, fertilizer and its wage for planting and application. The net benefit (NB) was calculated as the difference between the GFB and the TCV. Actual yield was adjusted downward by 10% to reflect the difference between the experimental yield and the yield farmers could expect from the same treatment. There were optimum plant population density, timely labour availability and better management (e.g. weed control, rainfall) under the experimental conditions CIMMYT, (1988) [7].

2.5 Data analysis
Analysis of variance (ANOVA) for all collected data was computed using R software version 3.5.3 statistical software R Core Team (2019-03-11). Whenever the ANOVA results showed the significant differences between sources of variation, the significant differences among means were determined by the least significant difference (LSD) test at 5% probability.

3. Results and Discussion
3.1 Some of the Soil Chemical and Physical Properties of the Study Area
Results of soil chemical properties of farm field's soil have been indicated in (Table 1). The soil pH in H_2O was ranged from 4.19 to 4.70 found in very strongly acidic Batjes NH (1995) [4]. Total N was ranged from 0.203 to 0.217% which was in a medium range for crop growth and development according to Berhanu, (1980) [5] and Av P 3.915 to4.23 ppm (Table 1). The available phosphorus concentration was found in low range Tekalign M, Haque I (1991) [23]. The different farm fields were needs different rates of nitrogen and phosphorous fertilizer management for maize. The exchangeable potassium concentration was ranged from 0.675 to 0.975 which is found high range DEFRA (2007) [9]. The CEC concentration was ranged from 18.96 to 21.08 cmol+kg^{-1} was found in medium to high range Landon (1991) [5].

3.2 Plant Height
The analysis of variance (Table 1) showed significant ($P \leq 0.01$) difference in maize plant height yield due to the effect of N application. The effect of N showed a significant increase in plant height from 261.46 to 274.77cm with an increase in the level of N from the lowest 69/69 to 138/69 N rate kg ha^{-1} but significantly decreased with a further increase of applied N rate to 138/69 kg N ha^{-1} (Table 2). The current result was in agreement with Muhidin *et al*., (2019b) [19] there was an increase in plant highest with an increase in N rate and also increase in plant height in response to higher rates of nitrogen has been confirmed by the previous findings of Wajid *et al*., (2007) [25]. The highest plant height (274.77cm) obtained with the application of 138/69 kg N ha^{-1} was 5.08% higher over the lowest. In the case of plant population density the highest plant height 271.23 cm recorded from the highest density 75*20 (66666) while the lowest was from the lower density 75*30 (44444) 260.02cm (Table 2). Plant height shows that a linear increase with plant population increase and the inverse is true. The result was in agreement with the report of Muhidin *et al*., (2019) [19] plant height increased significantly with the increasing of plant planting density because of plants computes for light and nutrients when densely populated and it shows the same trend across the location.

3.3 Logging percentage
Logging percentage had significant differences (P<0.001) effect only due to plant population density (Table 2). The highest Logging percentage of 4.50 was recorded from the application of the higher 138 kg ha^{-1} N rate and it had 8.43% increment over the lowest 69 kg ha^{-1} N rate. While the lowest 3.89 was recorded from the highest 161 kg ha^{-1} N rate because of further increase. In case of plant population density, the logging percentage ranges from 3.65 to 5.75 from the highest density 75*20 (66666 plants h^{-1}) to 80*40 (62500 plants h^{-1}). The highest 5.75 logging percentage obtained from the lower 80*40 (62500 plants h^{-1}) with 57.53 % increase over highest density 75*20 (66666 plants h^{-1}) or control. The current results were inconsistent and showed the trend of logging increasing with plant population density due to as plan height increase and stem diameter decrease or became thinner. The result was in agreement with the obtained results indicating that as the plant population density increased the lodging percent also increased and vice versa as Sisay *et al*., (2020) [21] reported. Gou *et al*., (2010) [26], who reported more observed lodging at high plant population density as compared with lower densities; As the plant density increases the internodes become thinner, making the plant more prone to stalk lodging Song *et al*., (2016) [22]. The stored carbohydrates in the maize stalks were transported to grains and weakened the basal internodes, thus reducing the bending quality and providing an ease of lodging (Xue *et al*., 2016) [26];

Table 2: Plant height and logging percentage of BH546 as affected by N fertilize rate and plant population density at Nada Sadacha

Nitrogen fertilizer rate (Kg ha^{-1})	Plant height (cm)	Logging Percentage (%)
69/69	261.46	4.15
92/69	266.67	4.47
115/69	264.09	3.88
138/69	274.73	4.50
161/69	262.50	3.89
LSD (0.05)	11.47	Ns
Plant Population Density (ha^{-1})		
75*20 (66666)	271.23	3.65
75*25 (53333)	269.61	3.57
75*30 (44444)	260.02	3.73
80*40 (62500)	262.70	5.75
Mean	265.89	4.41
LSD (0.05)	10.23	2.15
CV (%)	24.48	7.54

3.4 Above ground biomass yield
The above ground biomass yield was significant differences (P<0.001) effect due to N fertilizer rates and plant population density (Table 3). The highest above ground biomass yield 16.97 t ha^{-1} was recorded from the application of the highest 138 and 161 kg ha^{-1} N rate was 10.34 and 14.9% higher over the lowest 69 kg ha^{-1} N rate and control respectively. While the lowest 14.77 t ha^{-1} was recorded from the lowest 69 kg ha^{-1} N rate. It implies that increased application of N rate significantly increase in above ground biomass yield due to nitrogen promotes growth and development of plants like plant height that leads in an increase in biomass up to the maximum response. This is due to an excess application is affected the growth and height of the plant by delaying germination, drying the leaf and damaging the plant Uhart and Andrane, (1995) [24]. The increase in plant height with concerning increased N application rate indicates maximum vegetative growth of the plants under higher N availability due to the increase in cell elongation as nitrogen is essential for plant growth process including chlorophyll which is responsible for the dark green colour of stem and leaves which enhance vigorous vegetative growth Karasu, (2012) [11]; Adeniyan, (2014) [3] and Moges, (2015) [16].

In the case of the effect of plant population density, the highest above ground biomass yield 17.54 and lowest 13.50 t ha^{-1} was recorded from the 75*20 (66666 plants h^{-1}) and 80*40 (62500 plants h^{-1}**)**. It shows that above ground biomass yield increase with plant population per unit area increase directly due to like a number of cobs harvested and plant height had similar tend which results increase in biomass yield directly These result in agreement with the increase in grain and stover yields consistently with increasing plant density is due to the number of plants or cobs per unit area Abebe *et al*., (2020) [1]. These results were in agreement with Bullock *et al*. (1998) [6] who reported that narrow row spacing made more efficient use of available light and shaded the surface soil more completely during the early part of the growing season while the soil is still moist and therefore, narrow row spacing is more effective in producing biomass.

Table 3: Grain yields, biomass yields and harvest index of BH546 as affected by N fertilizer rate and plant population density at Nada Sadacha

Nitrogen fertilizer rate (Kg ha^{-1})	Grain yield (ton ha^{-1})	Above Ground Biomass yield (t ha^{-1})	Harvest index
69/69	7.31	14.77	0.492
92/69	7.78	15.38	0.500
115/69	8.44	16.93	0.495
138/69	8.66	16.97	0.506
161/69	8.55	16.97	0.498
LSD (0.05)	1.14	1.61	Ns
Plant Population Density (ha^{-1})			
75*20 (66666)	8.72	17.54	0.49
75*25 (53333)	8.73	17.46	0.50
75*30 (44444)	8.47	16.30	0.52
80*40 (62500)	6.67	13.51	0.48
Mean	8.15	16.20	0.50
LSD (0.05)	0.95	1.25	Ns
CV (%)	12.72	23.35	17.42

3.5 Grain yield
The grain yield was significantly ($P<0.001$) affected by both the main effects of N fertilizer rates and plant population density (Table 3). The effect of N showed a significant increase in grain yield from 8.66 to 7.31 t ha^{-1} with an increase in the level of N from the lowest 69 to 138 kg ha^{-1} and significantly decreased with a further increase of applied N rate to 138 kg N ha^{-1} (Table 3). The result indicated that the grain yield was significantly highest and increase in 18.47 and 11.31% over-application of 69 and 92 kg ha^{-1} N rate (control). Higher grains yield at higher nitrogen levels might be due to the lower competition for nutrient and positive effect of N on plant growth, leaf area expansion and thus increase solar radiation use efficiency which indirectly increases dry matter production for grain filling that ultimately increases in grain yield (Golla *et al*., 2018) [10]. Also, the highest mean grain yield 8.73 and 8.72 t ha^{-1} were recorded from the 75*25 (53333) and 75*20 (66666 plants h^{-1}) respectively which were statistically not varied. The effect of plant population density showed a significant increase in grain yield from 6.67 to 8.72 t ha^{-1} with an increase in plant population from the control 80*40 (62500 plants h^{-1}) to 75*25 (53333 plants h^{-1}) and significantly decreased with a further increase of plant population density to 75*25 (53333 plants h^{-1}) (Table 3). The highest grain yield (8.73 t ha^{-1}) obtained with the 75*25 (53333 plants h^{-1}) was 30.88 % higher over the lower density. Thus, balanced growth and development of plants need optimum plant population density because optimum density enables plants efficient utilization of available nutrients, soil water and better light interception coupled with other growth influencing factors Sisay *et al*, (2020) [21]. Similarly, results were obtained by Makinde and Ayoola (2010) [15] who reported that conjunctive application of organic and inorganic fertilizers is effective for the growth of maize and improving the yields.

3.6 Harvest index
The effect of harvest index was significantly ($P<0.05$) not influenced by both plant population density and N fertilizer rates. All the harvest index result was in the acceptable range of 0.4 - 0.6 for maize (Hue, 1995). The highest harvest index of 0.506 was obtained from the higher 138 kg ha^{-1} N rate and while the lowest was 0.492 from the lowest rate of 69 kg ha^{-1} (Table 3). The current result showed a trend of increase with N rate increase and the inverse is true for plant population density. Similalry, Lawrence (2008) [12] reported that the harvest index in maize increased when nitrogen rates increased. Also in case of plant population density, the highest harvest index of 0.52 was obtained from the 75*20 (66666 plants h^{-1}) and the lowest was 0.48 from 80*40 (62500 plants h^{-1}). The result showed that harvest index increase with plant population decrease and the current results were in agreement with the findings of Zamir *et al*., (2011) [27] and Moraditochaee *et al*.,(2012) who claimed that with increasing the plant population, the harvest index was decreased.

Table 3: Partial budget analysis for N fertilizer rates and plant population density at current prices.

N fertilizer rates (kg ha^{-1})	Grain yield t ha^{-1}	Adjusted Grain Yield t ha^{-1}	Gross Field Benefit	TCV (EtB ha^{-1})	Net Benefit (EtB ha^{-1}	Dominance	MRR (%)
69	7.31	6.58	26316	872.85	25443.15	UD	------
92	7.78	7.00	28008	1163.8	26844.20	UD	481.54
115	8.44	7.60	30384	1454.75	28929.25	UD	716.64
138	8.66	7.79	31176	1745.7	29430.30	UD	172.21
161	8.55	7.70	30780	2036.65	28743.35	DO	-----
Plan Population Density (ha^{-1})							
75*30 (44444)	8.47	7.62	30492	1108	29384.00	UD	-----
75*25 (53333)	8.73	7.86	31428	1318	30110.40	UD	346.56
80*40 (62500)	6.67	6.00	24012	1562	22450.00	DO	-----
75*20 (66666)	8.72	7.85	31392	1662	29730.00	DO	-----

TCV= total cost that varied, Retail price of grain =Birr 4.00 per kg; EtB = Ethiopian Birr; Fertilizers urea = Cost of Birr 12.65, per kg; NPs =Cost Birr 15.90 per kg; MMR= Marginal Rate of Return; NB = Net benefit;

4. Conclusion and Recommendation
The result indicated that the grain yield was significant. Most important parameters of maize BH546 variety responded strongly to increased application of N fertilizer rates and plant population density. Accordingly, grain yield was increased with applied N fertilizer rates and plant population density. Application of 138 kg N ha-^{1} and 75*25(53333) gave significantly higher grain yield response. The grain yield was significantly increased by the highest and increase in 18.47 and 11.31% over application of 69 and 92 kg ha^{-1} N rate (control). The partial budget analysis based on the field prices of inputs and maize grain yield showed that under prevailing market conditions and based on partial budget analysis the application 138 N kg ha^{-1} and 75*25(53333 plants h^{-1}) gave the highest net

benefit (29430.30 and 30110.40 EtB ha^{-1}) with acceptable MMR (172.21 and 346.56%) respectively, Therefore, input availability and economic feasibility, a medium maturing variety with the application of 138 N kg ha^{-1} and spacing of 75*25 (53333 plants h^{-1}) taken as optimal and recommended for maize (BH546) variety production under rain fed condition of the study area.

5. Acknowledgements
The gratefully acknowledge Mr Kemerudin Aba Mecha who helped in overall trial management and support for collecting data from the field. Our thanks are also extended to Jimma agricultural research centers soil laboratory for allowing us to use lab facilities and assisting us in lab analysis as well.

6. References
1. Abebe Worku, Bitwoded Derebe, Yayeh Bitew, Gobezie Chakelie, Meqanint Andualem. | Response of maize (*Zea mays* L.) to nitrogen and planting density in Jabitahinan district, Western Amhara region, Cogent Food & Agriculture 2020;6(1):1770405.
2. Abdirazak A, Bereket T. Pre-Scaling up of Improved Maize Varieties in Essera and Boloso Sore Woreda of Southern Nation Nationalities and Peoples Regional State, Ethiopia. Agri Res & Tech: Open Access J 2018;17(2):556019. DOI: 10.19080/ARTOAJ.2018.17.556019.
3. Adeniyan ON. Effect of different population densities and fertilizer rates on the performance of different maize varieties in two rain forest agro ecosystems of South West Nigeria. Journal of Plant Science 2014;8(8):410-415.
4. Batjes NH. Aglobal data set of soil pH properties. Technical Paper 27, International Soil Reference and Information Centre, Wageningen 1995.
5. Berhanu D. A survey of studies conducted about soil resources appraisal and evaluation for rural development in Ethiopia, Addis Ababa. Landon JR. Booker tropical soil manual: A hand book for soil survey and agricultural land evaluation in the tropical and sub tropics. Long man Scientific and Technical, Essex, New York 1980-91, 70.
6. Bullock DG, Nielsen RL, Nyquist WE. A growth analysis comparison of corn grown in conventional and equidistant plant spacing. Crop Science 1988;28:254-258.
7. CIMMYT. From Agronomic Data to Farmer Recommendations: An Economic Traning Manual. International Maize and Wheat Improvement Centre, Mexico, D.F 1988, 79.
8. Cox WJ. Whole plant physiology and yield response of maize to plant density. Agronomy Journal 1996;88:489-496.
9. DEFRA (Department for Environment, Food and Rural Affairs). Fertilizer recommendations for gricultural and horticultural crops (RB209), 6th ed., London, TSO 2007. Engineering and Technology 2007-19;6(10):19-26.
10. Golla B, Tadesse B, Chalsisa D, Bayisa E. Effect of sowing time and environmental variation on yield of different Maize varieties. J Plant Sci 2018;3(1):041-045. DOI: http://dx.doi.org/10.17352/ojps.000014
11. Karasu A. Effect of nitrogen levels on grain yield and some attributes of some hybrid maize cultivars grown for silage as second crop. Bulgarian Journal of Agricultural Science, 2012, 18.
12. Lawrence JR, Ketterings QM, Cherney JH. Effect of nitrogen application on yield and quality of corn. Agronomy Journal 2008;100:73-79.
13. Khalid *et al*. Reported that, Effect of nitrogen and phosphorus on the fodder yield and quality of two Sorghum cultivars (*Sorghum bicolor* L.). Int. J Agri. Biol 2003;5(1):61-63.
14. Landon JR. Booker tropical soil manual: A handbook for soil survey and agricultural land evaluation in the tropics and sub-tropics. Longman Inc, New York, U.S.A 1984, 450.
15. Makinde EA, Ayoola OT. Growth, yield and NPK uptake by maize with complementary organic and inorganic fertilizers. African Journal of Food, Agriculture, Nutrition and Development 2010;10(3):2203-2217.
16. Moges AW. Effect of Nitrogen Fertilizer Rates and Plant Densities on Yield And Yield Related Traits of Maize (*Zea maize* L.) Under Irrigation in Southern Tigray, Ethiopia 2015.
17. Moraditochaee M, Motamed MK, Azarpour E, Khosravi Danesh R. Effects of nitrogen fertilizer and plant density management in corn farming. Asian Research Publishing Network Journal of Agricultural and Biological Science 2012;7:133-137.
18. 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 2019;6(10):19-26.
19. Muhidin Biya, Sisay Gurmu, Eshetu Yadete. "Determination of NP Fertilizer Requirement for Newly Released Medium Maturing Maize Varieties at Jimma Zone, Southwestern Ethiopia", International Journal of Research Studies in Science, Engineering and Technology, 2019;6(12):13-19.
20. R Core Team. R: A language and environment for statistical computing. R Foundation for Statistical Computing, Vienna, Austria 2019-03-11. URL http://www.R-project.org/.
21. Sisay Gurmu, Muhidin Biya, Eshetu Yadete. Effect of NP Fertilizer Rates and Plant Population Density on Late Maturing Maize Variety at Jimma and Buno-Bedele Zone, Southwestern Ethiopia. Journal of Environment and Earth Science www.iiste.org. ISSN 2224-3216 (Paper) ISSN 2225-0948 (Online) 2020;10:6.
22. Song YH, Yukui R, Guta B, Jincai L. Morphological characteristics of maize canopy development as affected by increased plant density. PLoS One 2016;11:e0154084.
23. Tekalign M, Haque I. Phosphorus status of some Ethiopian soils, II. Forms and distribution of inorganic phosphates and their relation to available phosphorus. Tropical Agriculture 1991;68(1):2-8.
24. Uhart SA, Andrade FH. Nitrogen deficiency in maize: I. Effects on crop growth, development, dry matter partitioning, and kernel set. Crop Science 1995;35:1376–1383.
25. Wajid A, Ghaffar A, Maqsood M, Hussain K, Nasim W. Yield response of maize hybrids to varying nitrogen rates. Pakistan Journal of Agricultural Sciences 2007;44:217-220. Link: https://tinyurl.com/yd4xwm3h
26. Xue J, Gou L, Zhao Y, Yao M, Yao H, Tian J *et al*. Effects of light intensity within the canopy on maize lodging. Field Crop Research 12016;88:133-114.
27. Zamir MSI, Ahmad AH, Javeed HMR, Latif T. Growth and yield behaviour of two maize hybrids *Zea mays* L. towards different plant spacing. Cercetări Agronomice în Moldova 2011;14:33-40.