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Effect of Blended (NPSB) Fertilizer Rates and Plant Population on Yield and Yield Components of Maize (Zea mays L.) at Bako, Oromia National Regional State, Ethiopia

Fufa Anbessa[1*] Thomas Abraham[2] Habtamu Ashagre[2]
1.Oromia Agricultural Research Institute, Bako Agricultural Research Center, P.O.Box 03, Bako Ethiopia
2. College of Agriculture and Veterinary Medicine, Ambo University, P.O.Box 19 Ambo Ethiopia

Abstract
Maize (Zea mays L.) is the major cereal crop in Ethiopia and plays a crucial role in ensuring food security. However, its productivity is constrained by a number of problems, among which use of high or low plant population and poor soil fertility management are the most critical once. Therefore, a field experiment was undertaken to determine the optimal NPSB fertilizer rate and plant population for maize at Bako. The experiment was laid out in split plot design distributing three levels of plant population [53,333 plants ha^{-1} (25 x75 cm), 66,666 plants ha^{-1} (60x25cm) and 76923 plants ha^{-1} (65x20cm)] in the main plots and five levels of NPSB fertilizer rates (0,100,150,200 and 250 kg NPSB ha^{-1}) and recommended NP rates as sub-plots. The interaction of plant population and NPSB rates influenced significantly (P<5 %) leaf area index, number of cobs $plot^{-1}$, number of kernel cob^{-1}, dry biomass and thousand kernel weight. The highest leaf area index 6.661 was recorded on the combination of 66,666 plants ha^{-1} with 200 kg NPSB fertilizer rate. The highest number of cob $plot^{-1}$ (115.3) and dry biomass yield 28,299 kg ha^{-1} were recorded from 66,666 plant ha^{-1} with 150 kg NPSB ha^{-1}, and 53,333 plant ha^{-1} with standard check 92/69 kg NP ha^{-1}, respectively. The highest grain yield 9954 kg ha^{-1} with net profit of 76,038 Birr with marginal rate of return 598% was obtained from 150 kg NPSB ha^{-1} with 66666 plants ha^{-1} (60 cmx25 cm). Therefore, application of 150 kg NPSB ha^{-1} with 66666 plants ha^{-1} for farmers in the study area and with similar agro-ecology can use and can improve maize productivity. However, the experiment need to be further verified in multi-locations for better usage at different agro-ecologies.
Keywords: plant population, blended fertilizer, maize, yield
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1. INTRODUCTION

Maize (*Zea mays* L.) is a multipurpose crop that provides food, feed and industrial row material (Zamir *et al.*, 2010). It is an important cereal crop in the world and cultivated in wide agro ecology (Bassu *et al*, 2014) and ranks third next to wheat in total production over the world (Aziz *et al.*, 2007). It is also known as queen of cereals due to its high potential of production in diverse agro-climatic conditions. It contributes at least 36% of global crop production (Rao *et al.*, 2013).

Majority of Africans are depended on maize directly or indirectly as a human food, animal feed and cash crop for lively hood income sources, amidst soil nutrient deficiencies (Sigunga and Musandu, 2008). It is the main staple food for millions of people in developing countries especially in Sub-Saharan Africa. It is an important source of protein and energy for human as well as animals and a source of raw material for the industry. It is a C_4 crop with a great photosynthetic efficiency (Lukombo *et al*., 2013**)**.

Maize is also the major cereal crop in Ethiopia in terms of its production (CSA, 2017; Abate *et al*., 2015). It is the most widely cultivated cereal crop in terms of area coverage of 2,128,948ha and production with about 8,395,687 tones per anum in Ethiopia (CSA, 2018). It is also the major staple food crop and source of cash in the country. Although maize is one of the most productive crops in Ethiopia, it was not able to play a significant role in ensuring food security because of various factors.

The estimated average yields of maize for smallholder farmers in Ethiopia are about 3.9 tons ha^{-1}, which is much lower than the yield recorded under demonstration plots which was 5 to 6 tons ha^{1} (CSA, 2018). Thus, the potential maize productivity in the country has not yet been exploited. To alleviate this situation, different research activities have been undertaken using various fertilizer sources in different parts of the country (Tolassa D. *et al.*, 2001). But still the site-specific optimum fertilizer rates for the crop in the country was not recommended and the farmers are not using optimum inorganic fertilizer due to its cost punishment and knowledge gap Tadesse (2016).

The yield of maize is highly increasing with the punishment of chemical fertilizer costs for the farmers and environmental pollution. Bio-fertilizer that Azotobacter used in many cereal crops also changes the yielding capacity of the maize if it is used in proper ways (Mansour *et al*., 2012). Chemical fertilizer application and modern nutrient management is the crucial one (CIMMYT, 1996). In Ethiopia it was seen that there is a deficiency of some other nutrients and a newly blended fertilizer is started to be imported to the country Ethio SIS (2013). Blended fertilizer is an important input in maize production, however appropriate rate has to be determined to achieve economically viable yield.

Lack of Optimum plant population per hectare is also another factor for yield reduction in maize. Over population, under population and inadequate seed rate based on variety and other factors is an important problem for less productivity. Some varieties have expanded canopy and the other erected type of canopy and the plant density should be different based on variety Farland, (2013). Increasing plant population with the presence of optimum moisture and soil fertility, the maize grain yield increased highly up to 15 tones ha^{-1} (Douglas *et al., 2017).* In developed and some developing nations plant density was based on variety and rate of fertilizers, which reported higher yield (Qian *et al.*, 2016). The low plant density reduces maize production due to higher weed infestation in vacant spaces. As maize is not a tillering crop, low density plant population will result in substantial yield reduction. Even though there is no single recommendation of plant density per hectare, plant population is the important factor to the maize yield (Raouf *et al.,* 2009).

In west region of Ethiopia Bako, there was no optimum recommendation of plant population and fertilizer rates for individual location and verity (Zelleke *et al.*, 2010; Belay, 2015), (Begizew and Adunga, 2017), (CSA, 2017). Therefore, this study based on improving food security by determining optimum inorganic fertilizer rates and plant population that economically feasible for the farmers of the area.

2. MATERIALS AND METHODS

2.1. Description of the Study Site

The experiment was conducted at Bako Agricultural Research Center in east Wollega Zone, Oromia National Regional State in 2018/19 main cropping season under rain fed conditions. Bako Agricultural Research Center is geographically located at 9° 06' N and 37° 09'E latitude and longitude respectively. The study area is far away about 260km in the west direction of Addis Ababa. It is in mid-altitudes about 1650m.a.s.l. Rain fed agriculture is most popular in the area as it receives an inconsistent rainfall (1220 mm/annum) throughout the crop growing season (Mekonnen, 2018). The rain fall starts at the mid of April and ceases by the end of September and sometimes extends up to mid-October or early November. Maximum rainfall is usually received in June to October (Appendix 3). The average temperature is 21.7^{0}C. The dominant soil texture of the research area was clay soil (Table 4).

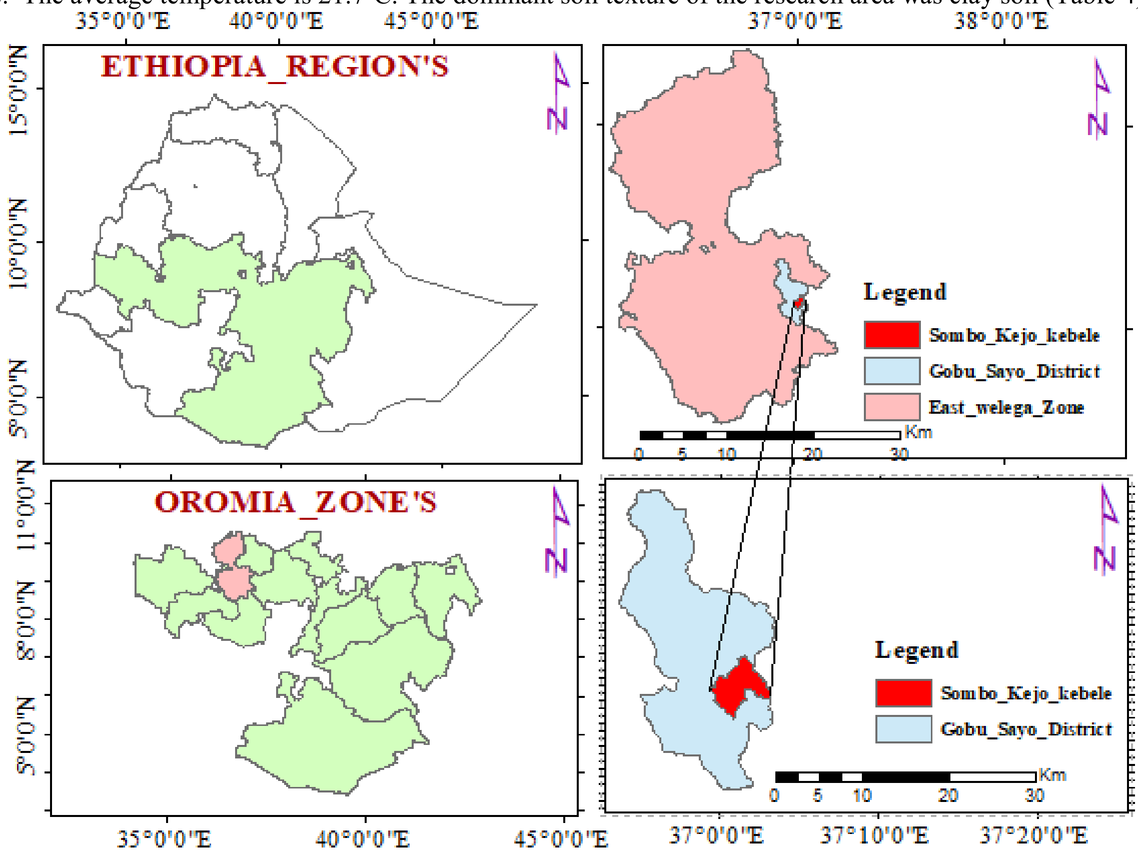

Figure 1 Location map of the study area

2.2. Description of Experimental Materials

High yielding maize hybrid BH-546 that is released to the agro-ecology of the area was used for this study. BH-546 is one of the most successful hybrid variety released in 2013 by National Maize Research Program based at

Bako Agricultural Research Centre, Oromia National Regional State, Ethiopia. The variety has a wider adaptability and grows well at altitudes ranging from 1000 to 2000 meters above sea level with annul precipitation of 1000 to 1200 mm. Blended fertilizer NPSB, was used as the source of nutrients. The blended NPSB fertilizer contains 18.9% nitrogen, 37.75% P_2O_5, 6.95% sulfur and 0.1% B. urea was used for the supplement of nitrogen to fill the nitrogen recommendation 92 kg N ha^{-1} of the crop in the study area. Nitrogen was constant for all plots with calculating nitrogen which was found in the blended fertilizer and the rest amount was supplied from the urea.

2.3. Experimental Design and Treatments

2.3.1. Experimental design

A split plot design was used for the study and three Plant population treatments 53,333 (25x 75cm), 66,666 plants ha^{-1} (60 x 25 cm) and 76,923 plants ha^{-1} (65x 20 cm) were distributed over the main plot, whereas the fertilizer treatments control, 92/69 kg NP ha^{-1}, 100, 150, 200 and 250 kg NPSB ha-1 were distributed over sub-plots, and every treatment was replicated three times. The Plot size used for each treatment in every replication was equal and 5.1 X 4.5m.

2.3.2. Treatments

The treatments include three plant populations [53,333 (75x25cm), 66,666 (60x25cm) and 76923 (65x20cm)] and six fertilizer rates (control, recommended NP (92N with 69 P_2O_5 kg ha^{-1}), 100, 150, 200 and 250 kg NPSB ha^{-1}) with the supplement of nitrogen fertilizer urea used for the study. Nitrogen was applied uniformly as per the recommendation of the area. The calculation of N in the blended NPSB fertilizer and split application was carried out in the case of nitrogen. Half nitrogen was applied on planting date and the rest was top dressed at knee height stage (40 days after planting) after removal of weed from all plots. All required agronomic practices such as, land preparation, weed management, inter cultivation and other activities were carried out for all plots uniformly.

2.3.3. Arrangement of treatments

The treatments were arranged as listed in the Table 1 below, and the combination of plant population and NPSB rates are shown on Appendix 1.

Table 1. Description of plant population and fertilizer rates treatments

Main factors	Factors level	Description
	53,333	75x25cm
Plant density	66,666	60 x25cm
(plants ha^{-1})	76,923	65x20cm
Fertilzer		NPSB+N ha^{1}
	Control	0kg ha^{-1}
NPSB fertilizer rates	Recommended	92N + 69 P_2O_5
(kg ha^{-1})	100	a100 +73.1
	150	150+63.65
	200	200+54.2
	250	250+44.75

2.4. Data collection

2.4.1 Phonological and growth parameters

Days to 50% emergence: The number of days on which 50% of the plant emerged was recorded with personal observation of the emerged plants on the plots.
Days to 50% tasseling: The number of days on which 50% of the plants produce tassel was estimated in personal observation.
Days to 50% silking: The number of days on which 50% of the plats silk was counted and recorded from days to plant to days to silking.
Days to physiological maturity: It was recorded as the number of days after sowing to the formation of a black layer at the point of attachment of the kernel with the cob.
Leaf area index: was measured on the basis of L*W*0.75 (correction factor) multiplied with the number of leave and total plants grown on the harvestable plot area and divided by the area grown on it
Plant height: was measured as the height from the soil surface to the base of the tassel of five randomly taken plants from the harvestable area at 90% physiological maturity.
Plant Girth: The thickness of the plant was measured using centimeter

2.4.2. Yield and yield components

Cob length: was measured from the point where the ear attaches to the stem to the tip of the ear.
Number of kernels per ear: It was computed as the average number of kernels of five randomly selected ears from the central net plot areas or harvestable area.
Number of cobplot^{-1}: It was counted the total cobs collected from the plot on harvestable area. **Number of rows per cob**: It was counted the average total rows found on the five cobs on the five randomly selected cobs from

harvestable plot.

Thousand kernels weight: Thousand kernels weight was determined from 1000 randomly selected from each plot and weighed using sensitive balance.

Grain yield: was measured using electronic balance and then adjusted to 12.5% moisture and converted to hectare basis using the formula as described by Biru, (1979)

$$C.V=\frac{100-Y}{100-X}, Ad.\ Yield = C.V * \text{Plot Yield}$$

Above ground biomass: Plants from the net plot area were harvested at physiological maturity and weighed after sun drying for 15 days using spring balance on the research field.

Harvest index: was calculated as the ratio of grain yield to total aboveground biomass yield and multiplied by hundred. $\text{HI\%} = (\text{GY} \div \text{AGBM})(100)$

2.5. Soil Sampling and Analysis

The composite initial sample of pre-planting and post-harvest samples (plot based) on the surface of 0-20 cm were taken from the experimental site following the procedure of taking surface soil sampling. After harvest at each plot five samples were collected in X pattern and composited for analysis. The samples were taken to BARC laboratory and Ethiopian water design works for soil nutrient analysis. The pre-planting soil physical properties were determined Using Hydrometer method (Bouyoucos 1962) include soil moisture content, soil texture, bulk density using core method (Grassman and Reinch 2002) and particle density also determined by pycnometeric method (Bouyoucos 1962).

The soil chemical properties studied include soil pH, exchangeable bases (Ca, Mg,K), organic carbon, organic matter, total nitrogen, available phosphorus, and sulfur. Soil pH was determined using a pH meter with combined glass electrode in water (H_2O) at 1:2.5soil: water ratio as described by Carter (1993). Organic carbon was determined by oxidizing carbon with potassium dichromate in sulfuric acid solution following the Walkley and Black method (1934). Finally, the organic matter content of the soil was calculated by multiplying the organic carbon percentage by 1.724 (Broadbent, 1958). The total nitrogen content in soil was determined using the Kjeldahl procedure by oxidizing the organic matter with sulfuric acid and converting the nitrogen into NH_4^+ as ammonium sulphate (Sahlemedhin and Taye, 2000). Exchangeable acidity was determined by saturating the soil samples with potassium chloride solution and titrated with sodium hydroxide as described by Mclean (1965). Exchangeable bases (Ca, Mg, K and Na) in the soil were estimated by the ammonium acetate (1M NH_4OAc at pH 7) extraction method. In this procedure, the soil samples were extracted with excess of NH_4OAc solution, and Ca and Mg in the extracts were determined by atomic absorption of spectrophotometer (Anderson and Ingram, 1996).

2.6 Statistical Analysis

The collected agronomic data, soil data and leaf nutrient content were subjected to Analyses of variances using computer software Genstat-15 (Laes Agriculture Trust, 2012) software. Least Significant Difference (LSD) test at 5% probability was used for mean separation when the analysis of variance (ANOVA) indicates the presence of significant differences of the mean of the treatments.

2.7 Economic Analysis

Economic analysis was performed to investigate the economic feasibility of the treatments (fertilizer rates) and plant population that concern to the cost of seeds. A partial budget was used for economic analysis as described by CIMMYT, (1988).The average open market price for maize grain, blended fertilizer and urea were 8 birr kg^{-1}, 12.80 birr kg^{-1}, and 11.00 birr kg^{-1}, respectively, while the price of improved seed was 65birr kg^{-1}. The minimum rate of return acceptable to farmers (MRR) and the highest net benefit of the treatment were used to recommend to the farmers.

3. RESULTS AND DISCUSSION

3.1. Physicochemical properties of the soil

3.1.1. Before planting soil analysis

The physicochemical properties of the soil of the study area at the pre-planting are shown in Table 4. The soil contains 59% clay, 6% silt and 35% sand, which is categorized in to clay soils according to soil textural classification (Tadesse, 1991). The soil reaction of the experimental site was moderately acidic with a pH of 5.74 as described by Murphy (1968) and (Tadese, 1991). Similar results were obtained by Fassil and Charles (2009) who reported that in western part of Ethiopia the soils tends to acidic soil.

The organic matter content of the experimental site soil was recorded as 5.21% which was considered as medium and stable (Musinguzi *et al.*, 2013). According to them soils in Sub-Saharan Africa can nourish crops if the soil organic matter content is more than 3.4% based on the soil textural class that can hold the nutrients for plant growth and development. The optimum SOM also improve the buffering capacity of the agricultural soils based on the soil textural class and decomposed organic materials (Murphy *et al*., 2014). However, the amount of organic carbon content recorded was categorized as low 3.06 %, (Landon, 1991).

Therefore, the experimental soils qualify for medium in total N and low in organic carbon. The very low organic carbon and medium in total nitrogen content of the study area indicate low fertility status of the soil. This result is similar with Bekele *et al*. (2016) who reported that very low OC and very low to medium N content indicated low fertility status of the soil. This is also in line with the reports of Woldeamlak and Leo (2003) and Achalu *et al*. (2012).

The available phosphorus was found to be 11.8 (ppm) that was considered as medium,(Taddesse, 1991) hence addition of phosphorus fertilizer to the soil of study site expected to increase grain yield. These results are in agreement with findings of EthioSIS, (2015) and Endalkachew *et al*., (2018) who reported that cultivated land in Ethiopia regularly shows low available phosphorus to the crop. The available sulfur concentration of the study site was found to be 68.76 mg kg^{-1} soil. According to NFDC, (1992) it falls in the range of adequate.

The status of Ca in tested soils (16 Cmol (+) kg^{-1}) has been ranges with in high ranges (London 1991). The percent of exchangeable potassium in studied soils had 0.39 Cmol (+) kg-^{1}found in low according to Landon, (1991) rating. The soils in the study area had low K, indicating that these soils have no adequate levels of K for crop production. The result disagrees with the common idea that Ethiopian soils are reach in K. But it agrees with Belay (1996) and Wakene (2001) who reported K deficiency in Eutric Vertisols of Melbe (Tigray) and Dystric Nitisols of Bako area, respectively

Table 2. Physicochemical properties of soil of research site

Soil property	Mean value
BD (g/m3)	1.54
Moisture content	25.2
Sand (%)	35
Clay (%)	59
Silt (%)	6
Textural class	clay
pH	5.74
OC (%)	3.02
OM (%)	5.21
TN (%)	0.26
Av.P (ppm)	11.8
EMg (meq/100gsoil)	7
ECa (meq/100g soil)	16
K (%)	0.39
Av.S (mg/kg)	68.76

Mg=milligram, BD=bulk density, OC=Organic carbon, OM=organic matter, TN=total nitrogen, AvP=available phosphorus, EMg=exchangeable magnesium, ECa=exchangeable calcium, Av.S=available sulfur

3.1.2. After harvest soil analysis

There was significant difference ($P<0.05$) on available phosphorus and soil pH of the soil after harvest among treatments (Table 3). Nevertheless, available nitrogen, organic carbon, organic matter, exchangeable magnesium and exchangeable calcium nutrient content were not significantly affected by NPSB fertilizer treatments. The post-harvest soil analysis indicated that the highest available phosphorus 14.057 ppm was recorded from the plot treated with standard check 69/92 kg NP ha^{-1} that exceeded the pre-plant soil result 11.8 ppm and it was followed by 11.643 ppm available phosphorus from the plot with 250kg NPSB ha^{-1} fertilizer rate. The least available P 5.380ppm was recorded from control. Similarly, available phosphorus 7.52, 8.22 and 6.49 ppm were recorded from treatment 100, 150, and 250 kg NPSB ha^{-1} respectively, which was statistically at par with the pre-plant soil available Phosphorus (Table 3). This result was similar with the finding of Fekadu *et al*. (2018) who reported that increase inorganic fertilizer rate reduces soil pH value or acidifies the soil.

Application of NPSB fertilizer reduced soil pH after harvest. In the plots that were with control and 100 kg NPSB ha^{-1} fertilizer rate, pH of the soil was higher than the other treatments (pH recorded were 5.486 and 5.477 respectively). The rest treatments increased the acidity of the soils as compared with the control and 100 kg NPSB ha^{-1} which could be due to the increases in acidification of the soil (Table 3). High application of inorganic fertilizers such as phosphorus, Nitrogen and sulfur acidifies the soil based on the form of nutrient in fertilizer and rain fall of the study site (Fikadu *et al.,* 2018).

Table 3. Effect of NPSB fertilizer rates on nutrient content of post-harvest soil

(NPSB kg ha[1])	pH	TN (%)	AP (ppm)	OC (%)	OM (%)	Ex.Mg (meq/100gsoil)	Ex.Ca (meq/100gsoil)
Control	5.486a	0.2144	5.380e	2.490	4.292	8.56	16.33
69/92(NP)	5.233b	0.2044	14.057a	2.372	4.091	12.78	16.44
100	5.477a	0.2200	7.519cd	2.536	4.371	9.78	21.11
150	5.364ab	0.2100	8.217c	2.424	4.180	10.56	16.67
200	5.288b	0.2044	6.491de	2.382	4.109	10.17	19.94
250	5.303b	0.2378	11.643b	2.751	4.739	9.89	16.78
LSD (5%)	0.1368	Ns	1.62	Ns	Ns	Ns	Ns
CV (%)	2.7	23.1	18.9	22.8	22.9	66.3	25.2

Means with the same letters shoed there was no significant difference among treatments, TN= total nitrogen, AP=available phosphorus, OM=organic matter, OC=organic carbon, Ex.Ca=exchangeable calcium, Ex.Mg=exchangeable magnesium,

There was significant difference (P< 0.05) among treatments of plant population on available P of the soil after harvesting (Table 4). However, plant population didn't affect significantly (P<0.05) parameters like percentage of total nitrogen, percent of organic carbon, organic matter, exchangeable magnesium, exchangeable calcium and soil pH (Table 4).The highest available P 12.234 ppm in the soil after harvest was recorded from the plot with plant population of 53,333 plants ha^{-1} followed by 8.645 ppm of available P from the plot with 76,923 plants ha^{-1}. The lowest mean of available P of 5.775 ppm was recorded from the plot with 66,666 plants ha^{-1} (Table 4). This result might be due to the competition of plants for nutrients and the plot with the optimum fertilizer plants extracted the P in the soil and the mean of available P was low. The low available phosphorous of the studied area might be due the low soil pH, while block the available P of the experimental area

Table 4. Effect of plant population on nutrient content of the soil after harvest

Plant population ha^{-1}	pH	TN (%)	P (%)	OC (%)	OM (%)	Ex.Mg(meq/100gsoil)	Ex.Ca (meq/100gsoil)
53,333	5.184	0.2178	12.234a	2.502	4.314	9.06	16.50
66,666	5.512	0.2200	5.775c	2.555	4.404	11.61	18.11
76923	5.379	0.2078	8.645b	2.421	4.172	10.19	19.03
LSD(0.05)	Ns	Ns	1.63	Ns	Ns	Ns	Ns
CV (%)	2.7	23.1	18.9	22.8	22.9	66.3	25.2

Means with the same letters showed there was no significant difference among treatments, TN= total nitrogen, AP=available phosphorus, OM=organic matter, OC=organic carbon, ECa=exchangeable calcium, EMg=exchangeable magnesium, ns=non-significant

3.3.1. Days to 50% emergence

Data on days to emergence was presented on Table 8. The main factors of plant population, NPSB fertilizer rates and their interaction have no significant (P< 0.05), effect on days to emergence (Table 8). The reason might be the seeds to germinate, it uses the food in the endosperm stored earlier and it does not need any food from the other and has no capacity to prepare its own food and no any competition for food and resources (Kawsar *et al*., 2012). This result in line with the research report of (Shahzad *et al*., 2015).

3.3.2. Days to 50% tasseling

The levels of NPSB fertilizers had a significant effect (P<0.05) on days to tasselling, while plant population and the interaction of the plant population and level of fertilizer had no statistically significant effect on days to tasselling (Table 8 and Ap.T 3).The highest number of days to tassel (81.6) was recorded on the control treatment and early tasselling (77.4 days) was recorded on the treatment of 150 kg NPSB ha^{-1}. Similarly 78 - 79.67 days were registered for 50% tasseling on the treatments 92/69NP, 100, 200 and 250 kg NPSB ha^{-1} which were statistically at par (P<0.05). These results are in line with Sikandar *et al.* (2007) plant population does not changed days to tassel or it takes similar days to tassel for wide and narrow planted maize hybrids. The result also agrees with Shahzad *et al.* (2015) who reported that optimum fertilizer rate facilitates growth and development of maize and that optimum fertilizer level fasten the maize to tassel. Chakravarthy and Jagannathan (2017) also described as fertilizer rate influenced tasseling days by hastening physiological activities of maize.

3.3.3. Days to 50% silking

Data regarding days to silking 50% in (Table 8 and Ap.T 2) presented were revealed that (P<0.05) there was no significant difference among treatments of plant population of maize and interaction of plant population and fertilizer rates. The plant population did not change the days to silking in the research area. The analysis of variance showed that days to silking was affected by different NPSB fertilizer rates (P<0.05). The longest number of days to silking (89 days) was recorded on the treatment of control. All treatments that with different level of fertilizer made fast the silking of maize and all were statistically par that about 85-86 days. These results are in agreement with the Sikandar *et al.* (2007); Shahzad *et al.* (2015) who claim the days to silk 50% not significantly affected by plant population of maize but fertilizer level significantly influence the duration of tasselling of maize. Even though there was a lot of reasons to facilitating of the fertilizer for shortening of duration of tasselling, the nutrient which provided to the plant hastens the growth and development of the plant and the duration of every life stage of the plant is shortened (Shahzad *et al.*,2015).

Table 8. Effect of fertilizer rate and plant population on phenological parameters

Treatment	DE (50%)	DT (50%)	DS (50%)	DM (90%)	PG (cm)
NPSB rates					
0	7	81.60a	89a	146a	7.0b
92/69 NP	8	78.70b	85b	143ab	7.5ab
100	8	79.70b	86b	142b	7.5ab
150	8	77.44b	85b	143ab	8.0a
200	8	79.11ab	86b	143ab	7.5ab
250	8	78ab	85b	143ab	7.8ab
LSD (5%)	Ns	3.3	2.9	3.3	0.6
CV (%)	5.1	4.3	3.4	4.3	8.1
Plant population					
53,333 (25*75cm)	7.8	78.44	85.6	141.2	8.14a
66,666 (60*25cm)	7.2	79.6	86.3	145.0	7.1b
76,923 (65*20cm)	7.6	79.2	86.0	143.3	7.7ab
LSD (5%)	Ns	Ns	Ns	Ns	0.42
CV (%)	5.1	4.3	3.4	1.9	8.1

Mean with the same latter in the column showed no significant difference. ns = non-significant, DE=days to emergence, DT=days to tassel, DS=days to silking, DM=days to mature, PG=plant girth

3.3.4. Days to 90% maturity

The days to 90% maturity was not influenced by plant population (P<0.05) that there was no statistically significant difference among treatments of plant population and interaction of plant population in 90% maturity days among treatments level of plant population but only the magnitude was different. The longest maturity days of 144.9 days was recorded from the plot with 66,666plants/ha followed by 143.4 days to maturity from the plot with 76,923 plants/ha. The shortest maturity days of 141.2 was recorded from the plot with 53,333plants/ha. The analysis of variance revealed that (P<0.05) statistically significant difference among treatments was created by NPSB rates or duration of maturity was influenced by fertilizer rates. The longest duration 146 90% maturity days was recorded on the treatment that received no fertilizer (control) and all other treatments were with similar duration or the days it took to them 90% maturity days was statistically at par that 142-143 days (Table 8 Ap. T. 2). The result coincides with Shahzad *et al.* (2015) that fertilizer affected maturity days when the interaction of fertilizer and plant population not affected maturity days. This might be due to the power of fertilizer to hasten growth and development of the plant and maturity days can be shortened (Kawsar *et al.,* 2012)

3.3.5. Plant girth

Plant girth is the thickness of the stem which is important for the growth and development, resource transformation and lodging tolerance of maize plant. The main factors plant population and NPSB fertilizer rate significantly (P<0.05) affected plant girth (Table 8 and Ap. T. 2), however their interaction did not affect the girth of the maize plant. The highest plant girth 8.1cm and 7.7cm was recorded from the treatment with 53,333 and 76,923 plants ha^{-1} respectively, while the lowest plant girth (7cm) was recorded from the plot with 66,666 plants ha^{-1}. The thickness of the stem of the maize in plot with the lower plant density can be due to the low competition for resources among plants or may be another complex phenomenon. The result was in line with Azeem *et al.* (2018) wider space in inter and intera-row spacing increased plant girth.

There was a statistical significant (P<0.05) difference among treatments of NPSB fertilizer rates. The highest (8cm) and the lowest (7cm) plant girth were recorded from plots which received 150 kg NPSB ha^{-1} fertilizer rate and control treatments, respectively. The plant girth that was recorded from the rest of the treatments was statistically at par (Table 8). This result agreed with Onasanya *et al.* (2009) who reported that the levels of fertilizer applied affected stem girth and plant treated with optimum fertilizer rate resulted in a well-developed stem girth. A well-developed plant girth helps the plant to resist lodgings because of winds and other factors (Adamu *et al.*, 2015). The report of Afe *et al.,* (2015) also supported this result that the application of integrated inorganic and organic fertilizer at optimum level strength the stem of the maize crop.

3.3.6. Plant height

Plant height was significantly (P<0.05) affected by NPSB fertilizer rate and the interaction effect of main factors, however was not affected by plant population (Table 9 and Ap. T. 3). The highest plant height (326cm) was recorded from the plot with 66,666 plants ha^{-1} and 100 kg NPSB ha^{-1} fertilizer rate followed by the plot with 76,923 plants ha^{-1} and 200 kg NPSB ha^{-1} fertilizer rate which gave about 323.7cm of plant height. The lowest plant height of 269.3cm was recorded from the plot with 53,333 plants ha^{-1} and control (Table 9 and Ap. T. 3). This parameter is very important parameter in maize production, because it relates with grain yield and lodging of the crop Abdul Saboor *et al*. (2018) found that optimum fertilizer 100-150 kg ha^{-1} and plant population of 66,666-76,923 plant ha^{-1} the plant height 323.7-326cm.The reason for this highest plant height may be the amount of fertilizer provided to the plant that optimum was hastens the plant height and other plant part development. This finding was in line with Robertson *et al*. (2012); Achieng *et al*. (2010) who reported that the amount of fertilizer applied influences the plant height of maize. Similarly, Farshad and Mojtaba (2014) reported that the application of sufficient amount of fertilizer influenced plant height. This result was also supported by Dange (2016) application of new blended fertilizer to maize crop increased plant height than the earlier used NP fertilizer.

Table 9. Interaction effects of plant population and fertilizer rates on plant height in cm.

Fertilizer Rates (NPSB) $kgha^{-1}$	Plant population ha^{-1}			
	53,333plats/ha	66,666plant/ha	76,923plants/ha	Mean
0	269.3d	286.3bcd	285cd	280.2
92/69 NP	315abc	324.7a	321.7ab	320.4
100	324.3a	326a	309.3abc	319.9
150	318abc	313abc	314.7abc	315.2
200	310.3abc	309.7abc	323.7a	314.6
250	318abc	318.7abc	317.3abc	319.2
Mean	309.8	313.1	311.9	311.6
LSD (5%)		18.64		
CV (%)		3.6		

Means with the same letters are statistically the same

3.3.7. Leaf area index

There was significant ($P<0.05$) difference in leaf area index of maize among treatments of plant population, blended fertilizer rates and interaction of the main factors in maize (Table 10 and Ap. T. 4). The highest LAI (6.66) was recorded from the treatment of 66,666 plants ha^{-1} with 200 kg NPSB ha^{-1} fertilizer rate, followed by 76,923 plants ha^{-1} with 250 kg NPSB ha^{-1} fertilizer rate which resulted in 6.49. The lowest Leaf Area Index (3.48) was recorded from 53,333 plants/ha with control treatment. The highest LAI was recorded in the range of 66,666-76,923 plant ha^{-1} with application of 100-250 kg NPSB ha^{-1} fertilizer and the LAI also recorded higher in this range. Dense plant population with sufficient nutrient increased leaf area index (Lukombo *et al*., 2013). In line with the result Robertson *et al*. (2012) reported that dense plant population with optimum nutrient changed LAI positively. The reason for these phenomena may be the applications of optimum nutrients to the plant facilitate leave development which increases leave LAI.

Table 10. Interaction effects of plant population and fertilizer rates on leaf area index

Fertilizer Rates (NPSB)kg^{1}	Plant population with intera and inter spacing			
	53,333plants ha^{-1}	66,666plants ha^{-1}	76,923plants ha^{-1}	Mean
0	3.488b	4.575ab	4.656ab	4.2
92/69 NP	4.445ab	5.64ab	5.286ab	5.1
100	4.422ab	5.271ab	5.555ab	5.0
150	4.533ab	5.737ab	6.326a	5.5
200	4.599ab	6.661a	6.17ab	5.8
250	4.856ab	5.63ab	6.494a	5.7
Mean	4.4	5.6	5.7	5.23
LSD (0.05)		1.426		
CV (%)		16.4		

NPSB=fertilizer containing nitrogen, phosphorus, sulfur and boron

3.3.8. Cob length

There was no statistically significant ($P<0.05$) difference in the main and interaction effects among treatments of plant population and NPSB fertilizer levels (Table 11 and Ap. T. 4). Cob length magnitude changed from 19.4 cm to 19cm when the plant population increased from 53,333 to 66,666 and 76923 plants ha^{-1}. Similary, Fanadzo *et al*. (2010) reported as plant population increased cob length was slightly influenced in negative direction. Only numerical change (18.6 to 19.6 cm) was observed among treatments as the amount of fertilizer level increased from control. The result was in agreement with Raouf and Ali (2016) who reported that the amount fertilizer increased the length of the cob also increased than the control.

3.3.9. Number of rows per cob

There was no significant ($P<0.05$) difference among treatment due the level of plant population except that of magnitude. When the plant population increased from 53,333 to 66,666 and 76,923 plants ha^{-1}, the rows per cob reduced from 15.8 to 14.9 but the change was not statistically significant difference (Table 11 and Ap. T. 2). Similarly Fanadzo *et al*. (2010) reported that additional plant population did not changed Number of rows per cob significantly, however it showed a positive magnitude. Application of different levels of NPSB fertilizers did not changed the number of rows per cob. The interaction of the plant population and NPSB fertilizer rate also not changed the number of rows per cob. This result was similar with Raouf and Ali (2016) who reported that application of additional fertilizer not changed significantly but only the magnitude was changed positively. This may be the rows per cob in maize designed at the early growth stage of maize when there is no competition among plants for growth and development. Therefore, at that time the number of rows per cobs was developed in similar manner but the size and other part of the grain can be developed by the further incurred crop management.

3.3.10. Harvest index (%)

There was no statistically significant P< (0.05) difference among treatments of NPSB fertilizer levels and plant population on harvest index (Table 11 and Ap. T. 4). But only numerical change was observed from both level of factors plant population and fertilizer levels.

Table 11. Main effect of fertilizer rate and plant population on maize cob length, number of rows cob-1, harvest index

Treatment	CL (cm)	NR	HI (%)
NPSB rates			
0	18.6	14.7	41.7
92/69 NP	18.6	15.5	37.92
100	19.44	15.04	39.9
150	19.6	15.09	37.7
200	18.9	14.82	37.6
250	19.4	15.16	38.64
LSD (5%)	Ns	Ns	Ns
CV (%)	6.6	4.5	8.3
Plant population			
53,333 (25*75cm)	19.4	15.82	39.37
66,666 (60*25cm)	18.9	14.96	39.27
76,923 (65*20cm)	19	14.91	38.08
LSD (0.05)	Ns	Ns	Ns
CV (%)	6.6	4.5	8.3

CL=cob length, NR=number of row per cob, HI=harvest index; Ns= statistically non-significant

3.3.11. Number of cobs per plot

There was significant (P<0.05) difference among treatments concerning the number of cobs per plot by the level of plant population and level of NPSB rates (Table 12 and Ap. T. 4). The interaction of plant population and level of NPSB fertilizers also influenced cobs per plot and the highest cob numbers (118, 115 and 113 cobs per plot) were recorded from the interaction of 66,666 plants ha^{-1} with 250 kg NPSB ha^{-1}, 66,666 plants ha^{-1} with 150 kg NPSB ha^{-1}, and 66666 plants ha^{-1} with 100 kg NPSB ha^{-1} fertilizer rate respectively. The lowest cob number 81 cobs per plot were harvested from the interaction of 53,333 plants ha^{-1} and control (Table 12 and Ap. T. 4). This result agreed with Besufikad and Tesfaye (2018) who reported as interaction of optimum plant population and fertilizer rate increase the number of cobs harvested per plot. The optimum plant population may facilitate to the plants to use the resources and the optimum fertilizer rate helps the plant to be nourished through its growth seasons (Onasanya *et al*., 2009; Dagne, 2016).

Table 12.Interaction effects of plant population and fertilizer rate on number of cob plot-1

Fertilizer Rates (NPSB) kgha-1	Plant population ha^{-1}			
	53,333	66,666	76,923	Mean
0	81de	106.0abcd	85.0cde	88.1
92/69 NP	73.33e	99.3abcde	110.0abc	96.8
100	82.67de	113.0ab	102.7abcd	99.4
150	81.33de	115.3a	107.3abcd	101.3
200	87.0bcde	106.0abcd	104.0abcd	99.0
250	87.67bcde	118.0a	106.3abcd	104.0
mean	82.2	109.6	102.6	98.1
LSD (0.05)		13.51		
CV (%)		8.2		

3.3.12. Number of kernels per cob

Kernel number per cob is the very prominent factor influencing yield in the maize research. There was no significant ($P<0.05$) difference among treatments of plant population and levels of NPSB fertilizer rates on number of kernels per cob. However, there was a significant ($P<0.05$) difference among treatments of interaction of plant population and NPSB fertilizer rates on number of kernels per cob. The highest kernel number per cob 666 was registered at the treatment that received 76,923 plants ha^{-1} with 150kg NPSB ha^{-1} fertilizer rate, which was statistically par to all treatments except the control treatment with 76,923 plants per hectare. Plants that received with sufficient NPSB fertilizer rate are capable to use that nutrient and facilitate to use other nutrients in the soil and can form a bigger cobs that can hold more number of grain per cobs (Fahad *et al.,* 2014).While the reason for low kernels per cob under unfertilized plots with higher population could be due to the high competition for growth resources, that leads to the smallest cobs with few grains. This finding agreed with Dagne (2016) ; Fanadzo *et al.* (2010).

Table 13. Interaction effects of plant population and fertilizer rates on number of kernels cob^{-1}

Fertilizer Rates (NPSB) $kgha^{-1}$	Plant population ha^{-1}			
	53,333	66,666	76,923	Mean
0	642.8a	620.2ab	478.2b	580.4
92/69 NP	637.8ab	656.5a	629.9ab	641.4
100	611.7ab	593.1ab	595.5ab	600.1
150	634.2ab	574.3ab	666.4a	625
200	614.9ab	629.3ab	595.6ab	615.3
250	622.8ab	614.7ab	653.7a	630.4
Mean	627.4	614.7	603.2	
LSD (5%)		82.48		
CV (%)		8.1		

Means with similar letters are statistically the same

3.3.13. Dry biomass

Dry biomass is a major contributor to total output of maize and dependent upon management and other factors that influence maize production. Dry biomass was varied significantly ($P<0.05$) by main factors plant population and level of NPSB fertilizer rates as well as interaction of plant population and fertilizer rates (Table 13 and Ap. T. 4). The highest biological yield (28,299 kg/ha) was recorded from the plot that received 53,333 plants ha^{-1} with 92/69 kg N and P_2O_5 ha^{-1} followed by the plot with 66,666 plants ha^{-1} with 150 kg NPSB ha^{-1} fertilizer rate which has produced 26361kg ha^{-1} dry biomass yield (Table 14). The lowest biological yield of 12051 kg ha^{-1} was harvested from the control with 53,333 plants per hectare (Table 14). The finding was agreed with Dagne (2016);Tajul *et al.* *(*2013**).** Biological yield of maize increase as the rate of fertilizer and plant population increased. The reason for increasing biomass may be due to the increased fertilizer which hastens plant vegetative growth (Getachew and Jens, 2014), and moreover dense plant population per unit area increases the biological yield of the plants (Abuzar, 2011).

Table 14. Interaction effects of plant population and fertilizer rate on dry biomass yield

Fertilizer Rates (NPSB+N) kgha-1	Plant population ha^{-1}			
	53,333	66,666	76,923	Mean
0	12051g	19325f	14747g	15374
92/69 NP	28299a	20499ef	25658abc.	24819
100	23975.bcd	22272def	25018bcd	23755
150	23442bcde	26361ab	22130def	23978
200	23946.bcd	23117cde	23779bcd	23614
250	24601bcd	24740bcd	24982bcd	24774
Mean	22174	22580	23403	**22719**
LSD (5%)		1567.3		
CV (%)		4.1		

Means with the same letter are statistically the same

3.3.14. Thousand kernel-weight

There was significant ($P<0.05$) difference among the main factors plant population and NPSB fertilizer rate, and their interaction for thousand seed weight ($P<0.01$) (Table 15 and Ap. T. 3). The highest thousand kernel weight 285.8g was recorded from the plot that received 66,666 plants ha^{-1} and control, which was par with all treatment combination, except 100 kg NPBS ha^{-1} with 53333 and 66,666 plants/ha, 92/69 NP and 200 kg NPSB ha^{-1} with 76923 plants ha^{-1} (Table 15). The lowest thousand seed weight (192.1g) was recorded on 92/69 NP with 53,333 plants ha^{-1}. The reason behind the result may be complexes and need further study. Similarly, Shahar *et al*. (2002) reported that interaction of plant population and fertilizer rate change the thousand kernel weight of maize that they had observed that increasing fertilizer rate with similar plant density increased1000-grain weight. This may because of the optimum plant population and fertilizer rates improve the size of grain and appearance of it. As a result, the bigger grain size may increase its weight (Amjed *et al*., 2011).

Table 15. Interaction effects of plant population and fertilizer rates on thousand kernel weight (g)

Fertilizer Rates (NPSB) kgha-^{1}	Plant population ha^{-1}			
	53,333	66,666	76,923	Mean
0	257.4abc	285.8a	240.4abcd	261.2
92/69 NP	192.1d	206.9abc	214bcd	204.3
100	202.5bcd	218.7bcd	260.3abc	227.2
150	238.8abcd	242.4abcd	236.9abcd	239.4
200	253.1abcd	258.3abcd	220.8bcd	244.1
250	226.5abcd	254abcd	269.4ab	250.0
Mean	228.4	244.4	241.2	238
LSD (0.05)		32.5		
CV (%)		8.2		

Means with the same letters are statistically the same

3.3.15. Grain yield

The grain yield of maize was significantly (P<0.05) affected by plant population and application of fertilizer rates as well as the interaction of the main factors (Table 16 and Ap. T. 4). The highest grain yield of 9954 kg ha^{-1} was recorded from the interaction of 66,666 plants ha^{-1} with 150 kg NPSB ha^{-1} fertilizer rate, followed by the interaction of 76,923 plant ha^{-1} with 150 kg NPSB ha^{-1} rate that recorded 9944 kg ha^{-1} grain yield. The plot that received 66,666 plant ha^{-1} and 150kg NPSB ha^{-1} fertilizer rate exceed the standard check by 22.7 % and the control by 32 % in grain yield. The lowest grain yield of 4701 kg ha^{-1} was recorded from the plot with low plant population 53,333 plants ha^{-1} with control (Table 16). The plots received 92/69 kg NP ha^{-1} with 53,333 plants ha^{-1}, 150 kg NPSB ha^{-1} with 53,333 plants ha^{-1}, 200 kg NPSB ha^{-1} with 53,333 plants ha^{-1}, 100 kg NPSB ha^{-1} with 66,666plants ha^{-1}, 250kg NPSB ha^{-1} with 66,666 plants ha^{-1}, 200 kg NPSB ha^{-1} with 76,923 plants ha^{-1} and 250 kg NPSB ha^{-1} with 76,923 plants ha^{-1} were statistically par and gave 9409 kg ha^{-1}, 9167 kg ha^{-1}, 9167 kg ha^{-1}, 9458 kg ha^{-1}, 9454 kg ha^{-1}, 9037 kg ha^{-1} and 9660 kg ha^{-1}, respectively. The plots received 76,923 plant ha^{-1} with 92/69 kg NP ha^{-1}, and 76,923 plant ha^{-1} with 100 kg NPSB ha^{-1} also produced statistically similar grain yields 9803 kg ha^{-1} and 9908 kg ha^{-1}, respectively. This study indicated that maize grain yield depends on the plant population and amount of NPSB fertilizer applied per unit area.

Maize is a heavy feeder crop which is sensitive to plant spacing and fertilizer applied per unit area. An increase in plant population up to certain point with optimal fertilizer application increased grain yield because it reduces the strong competition with weed and using available resources (Fanadzo *et al*., 2010). The balanced nitrogen, phosphorus, sulfur and boron levels might have helped in efficient absorption and utilization of other required plant nutrients which ultimately increased the grain yield. Increase in grain yield up to certain level of NPSB was directly related to the vegetative and reproductive growth phases of the crop and attributes to complex phenomenon of NPSB utilization in plant metabolism. Progressive increase of plant population and amount of fertilizer increase grain yield up to certain level (Tajul *et al*., 2013). Similar results were also reported by Vijaya *et al*. (2018)s;Tolera *et al*. (2009).

Table 16. Effect of plant population and fertilizer rate on grain yield (Kg)

Fertilizer Rates (NPSB) kgha^{-1}	Plant population ha^{-1}			
	53,333	66,666	76,923	Mean
0	4701f	7490de	6241ef	6144
92/69 NP	9409abcd	8115bcde	9803ab	9109
100	7981cde	9454abcd	9508abcd	9114
150	9167abcd	9954a	9944a	9688
200	9167abcd	8866bcd	9303abcd	9112
250	9458abcd	9037bcd	9660abcd	9385
Mean	8313.3	8819.3	9143.2	8759
LSD (0.05)		1158.4		
CV (%)		7.9		

Means with similar letter showed non-significant difference

3.4. Economic analysis

The highest net return of 76,038 ETB with high MRR value of 598% was obtained from plot treated with 150 kg NPSB ha[1] and plant population of 66,666 plants ha^{-1}. This recommendation is also supported by CIMMYT (1988) which stated that farmers should be willing to change from one practice to another if the marginal rate of return of that change is greater than the minimum acceptable rate of return.

Table 18. Economic, partial budget and marginal rate of return analysis

No	PP	FR	FC	SC	TVC	AGY	GB	NB	MRR (%)
1	53333	0	0	400	400	4701	37608	37208	
2	66666	0	0	500	500	7490	59920	59420	21212
3	76929	0	0	577	577	6241	49928	49351D	
4	53333	100	2506	400	2906	7981	63848	60942	63
5	66666	100	2506	500	3006	9454	75632	72626	11684
6	76929	100	2506	577	3083	9508	76064	72981	461
7	53333	150	3094	400	3494	9194	73552	70058D	
8	66,666	150	3094	500	3594	9954	79632	76,038	598
9	76929	150	3094	577	3671	9944	79552	75881D	
10	53333	92/69NP	3560	400	3960	9409	75272	71312D	
11	53333	200	3619	400	4019	9167	73336	69317D	
12	66666	92/69NP	3560	500	4060	8116	64928	60868D	
13	66666	200	3619	500	4119	8866	70928	66809D	
14	76929	92/69NP	3560	577	4137	9803	78424	74287D	
15	76929	200	3619	577	4196	9303	74424	70228D	
16	53333	250	4858	400	5258	9458	75664	70406D	
17	66666	250	4858	577	5435	9037	72296	66861D	
18	76929	250	4858	577	5435	9660	77280	71845D	

PP=plant population, FR=fertilizer rates, FC=fertilizer costs, SC=seed costs, TVC=total variable cost, AGY=adjusted grain yield, GB=growth benefit, NB=net benefit, MRR=marginal rate of return, D=dominance

4. CONCLUSION AND RECOMMENDATIONS

4.1. Conclusion

Maize is one of the most important food security crops in west Oromia. The maize variety BH-546 showed considerable responses to variation in plant population and NPSB fertilizer levels in the study area. Soil of the study area was moderately acid; however, after harvest the pH of the soil decreased from 5.74 to 5.3. Moreover, the initial soil test indicated that the soil has low Organic carbon, medium total nitrogen, medium available phosphorus, sufficient sulfur and low potassium content. However, the soil nutrient content after harvest was not influenced by fertilizer rates and plant population except the available phosphorus which was influenced by fertilizer rates and plant population. Plant tissue nutrient concentration was also influenced by level of fertilizer rates and plant population.

Plant population and NPSB fertilizer influenced the phenology, growth, yield and yield components of maize at Bako. Agronomic parameters like leaf area index, number of rows per cob, plant height, number of cobs per plot, number of kernel per cob, dry biomass yield, thousand kernel weight and grain yield were increased with the increment plant population and fertilizer rates from 53,333 to 66,666 plants ha^{-1} and 100 to 150 kg NPSB ha^{-1}, respectively. The commonly used plant population 53,333 plants ha^{-1} gave lower yield than 66,666 plants ha^{-1} and 76,923 plants ha^{-1} for variety BH- 546. In general, medium plant population 66,666 plants ha^{-1} and 150 NPBS kg/ha gave the maximum grain yield 9,954 kg ha^{-1} with net profit of 76038 birr and marginal rate of return 598%.

4.2. Recommendation

To increase the productivity of maize in western region of Ethiopia determining the optimum NPSB fertilizer rate with optimum plant population have a paramount significance to maize varieties across different agro-ecology. The maximum gain yield (9954kg ha^{-1}) was obtained with 66,666 plants ha^{-1} with 150 kg NPSB fertilizer rate with a net profit of 76,038 birr and MRR 598 %. Therefore, it can be recommended to the farmers of the area and similar agro-ecology. However, further research should be carried out in the future to confirm the findings in the study since the experiment was done for a year on a single location.

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