# Effects of Applying Blended Mineral NPS and Nitrogen Fertilizers on Growth, Yield Components, and Yield of Maize (*Zea mays* L.) in Fedis District, Eastern Ethiopia

**Mekuannet Belay Kebede* and Habtamu Zeleke Utta**

School of Plant Sciences, Haramaya University, P.O. Box 138, Dire Dawa, Ethiopia

## Abstract

**Background:** Maize is the major and most important cereal crop next to sorghum in eastern Ethiopia. However, the yield of the crop is low mainly due to low inherent soil fertility and poor soil fertility management practices.

**Objective**: Field experiments were conducted during the main rainy cropping season in 2018 and 2019 to assess the effect of blended mineral NPS and N fertilizer on growth, yield components, and yield of maize varieties.

**Materials and Methods**: The treatments consisted of two open-pollinated maize varieties (Baate and Melkasa-2), three blended NPS fertilizer rates (50, 100 and 150 kg NPS ha$^{-1}$), and three nitrogen fertilizer rates (43.5, 87 and 130.5 kg N ha$^{-1}$). The experiments were laid out as a randomized complete block design in a factorial arrangement and replicated three times per treatment.

**Results**: The results showed that leaf area index, plant and ear height, ear diameter, number of kernels per ear, and grain yield were significantly affected by the interaction effects of variety, NPS fertilizer, and year. The maximum ear diameter and the number of kernels per ear were produced from the Baate variety in response to the application of 100 and 150 kg NPS ha$^{-1}$in the 2019 cropping season. Besides, the highest aboveground biomass yield (18.5 t ha$^{-1}$) was obtained from the variety Baate treated with 150 kg NPS and 130.5 kg N ha$^{-1}$. The maximum grain yield (8.0 t ha$^{-1}$) was obtained from the Baate variety in response to the application of 150 kg ha$^{-1}$ NPS in the 2019 cropping season. The application of 87 kg N ha$^{-1}$ produced a high grain yield, which was also found to be economically feasible for both varieties. The partial budget analysis also affirmed that the highest net benefit (44850.0 ETB) with the higher marginal rate of return (764%) was obtained from Baate variety supplied with 150 kg NPS ha$^{-1}$, which was economically more feasible than Melkasa-2 variety with the application of 150 kg NPS ha–1(6.7 t ha–1 ).

**Conclusion**: It is concluded that cultivating the Baate maize variety with the application of 150 kg NPS fertilizer ha–1 and 87 kg N ha–1 was found to be economically optimum for smallholder farmers in the study area to enhance productivity of the crop.

**Keywords**: Baate; Economic analysis; Fertilizer rate; Melkasa-2; Yield related traits

## 1. Introduction

Maize plays a significant role in the overall economy and food security and covers nearly 197, 204, 250 million hectares of the world's arable land (FAOSTAT, 2019). It is also the most widely grown staple food crop in eastern Africa occupying more than 15.7 million ha (FAO, 2019). Maize is the second most widely cultivated crop in Ethiopia next to tef and is grown under diverse agro-ecologies and socioeconomic conditions (Tsedeke Abate *et al*., 2017). According to a report of the Central Statistical Agency (2020), around 17.68% of Ethiopian cultivated land is covered by maize and its national average yield is 4.2 t ha$^{-1}$. Similarly, it is the second most important staple food crop next to sorghum in the eastern Hararghe Zone of Ethiopia and its average yield is 3.5 t ha$^{-1}$ (CSA, 2020). However, the average yield of maize in eastern Hararghe, in particular, is 3.5 t ha$^{-1}$ and that in the country is 4.2 t ha$^{-1}$ (CSA, 2020), both of which are lower than the world's average yield of 5.8 t ha$^{-1}$ (FAO, 2019).

The low productivity of maize in Ethiopia is attributed to many factors like biotic, abiotic, and poor agronomic practices. Poor soil fertility is one of the bottlenecks for sustaining maize production and productivity in Ethiopia. Most Ethiopian soils are deficient in nutrients especially nitrogen and phosphorus (Tekalign Mammo *et al*., 2001) due to the removal of crop residue and animal dung by small scale farmers for competing ends such as fuelwood and construction of houses (IFPRI, 2010). In addition, over-cultivation, insufficient inputs of replacement nutrients, accelerated soil erosion caused by inappropriate land uses and poor soil management practices as well as unbalanced fertilization also aggravates soil nutrient depletion which adversely affects crop production and consequently poses a potential threat to global food



*Corresponding Author: belaym2012@gmail.com



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security and agricultural sustainability (Tan *et al*., 2014). Therefore, application of appropriate types and rates of commercial fertilizers have been credited with nearly 50% of crop yield increments (Stewart *et al*., 2005). However, smallholder farmers have been applying di-ammonium phosphate (DAP) and urea at lower rates because of the constantly increasing prices of fertilizers. Besides, smallholder farmers have been also applying blanket recommendations of DAP and urea that do not consider soil fertility status and crop requirements and are often sub-optimal.

A recent soil mapping report by EthioSIS (2014) has shown that sulfur is deficient in most Ethiopian soils including some parts of eastern Ethiopiain addition to phosphorus and nitrogen. Therefore, the Ethiopian Ministry of Agriculture has recently introduced the blended NPS fertilizer for use in the study area and other similar areas particularly in place of DAP fertilizer (MoANR, 2013). However, the recommended rate of blended NPS to open-pollinated maize variety has not described and the combined effect of blended NPS and nitrogen on maize production particularly in the study area has not been well studied so far.

Nevertheless, some field experiments conducted on few maize varieties in some other areas. For instance, a field experiment conducted in Haramaya (Raare) district has confirmed that the highest grain yield of a hybrid maize variety was obtained in response to the combined application of 150 kg NPS and 87 kg N t $ha^{-1}$ (Mekuannet Belay and Kiya Adare, 2020). Dagne Chimdessa (2016) also reported that in western Oromia, the application of blended fertilizers increased maize productivity compared to the previously applied recommended mineral nitrogen (urea) and phosphorus (di-ammonium phosphate). Similarly, the application of NPS and urea significantly increased the grain yield of maize in the West Gojjam Zone of Ethiopia as compared to the blanket recommendation of DAP + Urea (Mesfin *et al*., 2019). Mekuannet Belay (2020) reported that the responses of yield and yield components of maize varieties to blended NPS and urea varied in different seasons. However, in most cases, the small scale farmers have been applying 100 kg NPS with 150 kg urea $ha^{-1}$ for different soils types and maize (open and hybrid) varieties as a blanket recommendation albeit the response of maize plant to application fertilizer rates vary from variety to variety, location to location, and also depends on the availability of the nutrients (Onasanya *et al*., 2009). Therefore, the relevance of this experiment was to determine optimum blended mineral NPS and nitrogen fertilizer rates for Baate and Melksasa 2 maize varieties and recommend to the farmers as well as other stalk holders to improve production in the study area and other similar agro-ecologies.

In the eastern Hararghe Zone particularly in Fedis district, not sufficient research has been done to investigate the effect of blended NPS as well as mineral nitrogen and phosphorus fertilizers (DAP and Urea). As a result, there is no documented information on responses of yield and yield-related traits of maize to combined blended mineral NPS and nitrogen fertilizer rates. Therefore, this study was conducted to assess the effect of applying blended mineral NPS and nitrogen fertilizer rates on growth, yield components, and yield of open-pollinated maize varieties.

## 2. Materials and Methods

### 2.1. Description of the Experiment Site

Experiments were conducted under rain-fed conditions during the main cropping season for two consecutive years (2018/19 and 2019/20) at a research sub-station of Haramaya University in Fedis district of Oromia Regional State of the East Hararghe Zone in Ethiopia at a place called Beko. Geographically, Fedis is located at the latitude of 9°07'51.6"N and longitude of 42°04'24.3"E. The area has an average altitude of about 1702 meters above sea level. The soil texture of the experimental site is sandy. In the 2018 main cropping season, the mean maximum and minimum temperatures of the district during the season of the experiment were 28.0 and 14.0 °C, respectively; the total annual rainfall was 750 mm. In the 2019 main cropping season, the mean maximum and minimum temperatures were 28.3 and 13.4 °C, respectively, and the total annual rainfall was 516.3 mm (Figure 1).

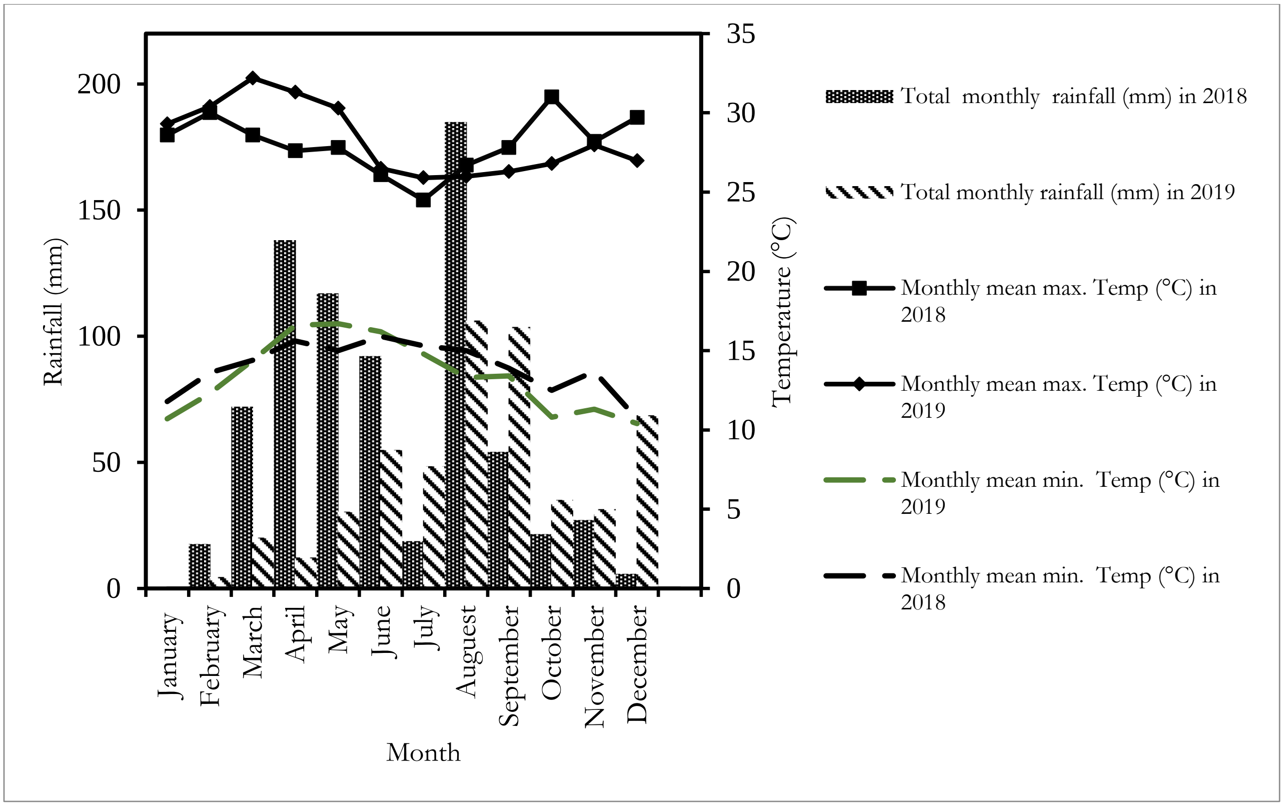


Figure 1. Total monthly rainfall (mm), mean maximum and minimum temperatures (°C) at Fedis in the 2018 and 2019 cropping season (Fedis Agricultural Research Center Meteorological station, 2019).

### 2.2. Description of Experimental Materials

#### 2.2.1. Planting material

Maize varieties named Baate and Melkasa-2 were used as test crops. The plant height and ear height of the Baate variety reach 180 cm and 95 cm, respectively, and the number of days required to reach maturity is 145 days. On the other hand, the plant height and ear height of the Melkasa-2 variety are also 150 cm and 70 cm, respectively, and the number of days required maturity is 130 days.

Baate variety was released by Haramaya University in 2017. Melkasa-2 variety was released by Melkassa Agricultural Research Center in 2004. Baate variety is adaptable to mid and high altitude areas. The elevation at which Baate variety grows best ranges from mid to highland areas, which is 1300 to 2000 meters above sea level`. Baate variety is adaptable to mid and high altitudes. Melkasa-2 variety is adaptable to mid and low altitudes. The elevation at which it grows best ranges from low to midland areas, which is 500 to 1800 meters above sea level. Regarding yield potential, Baate variety can produce grain yield that ranges between 4.5 to 6.0 t ha$^{-1}$ on-station but 3.5 to 4.5 on farmers' field. Melkasa-2 variety has a slightly higher yield potential which ranges between 5.5 to 6.5 t ha$^{-1}$ on-station but 4.5 to 5.5 on farmers' field (MoA, 2019).

#### 2.2.2. Fertilizer material

Urea was used as a source of nitrogen (100 kg urea = 46% N) and blended NPS was also used as a source of phosphorus, nitrogen and sulfur. One hundred kilograms of NPS fertilizer contains 19% N, 38% $P_2O_5$ and 7% S per 100 kg.

### 2.3. Treatments and Experimental Design

The treatments consisted of two open-pollinated maize varieties (Baate, Melkasa-2), three rates of NPS fertilizer (50, 100 and 150 kg ha$^{-1}$), and three rates of nitrogen fertilizer (43.5, 87 and 130.5 kg N ha$^{-1}$). The blanket recommendation rates of urea (150 kg urea or 87 kg Nha$^{-1}$) and blended NPS (100 kg ha$^{-1}$) were used as control treatments. The experiment was laid out as a randomized complete block design (RCBD) with three replications per treatment. Treatments were assigned to each plot randomly. The gross and net plot areas were 12.6 m$^2$ and 6.3 m$^2$, respectively. Each plot had four rows with two central rows used for data collection and analysis and the side row of each plot were left as a border effect. The spacing between rows and plants was 75 and 30 cm, respectively.

### 2.4. Soil Sampling and Analysis

Before sowing, soil samples were taken randomly to the depth of 0–30 cm from 15 spots of the experimental field. The collected soil samples were composited to one sample and air-dried, ground, and sieved using a 2 mm sieve to prepare for laboratory analysis. The samples were analyzed for soil texture, pH, organic carbon (OC), total nitrogen (TN), available phosphorus, and cation exchange capacity (CEC) using the following standard analytical procedures. Soil pH was measured using a glass electrode pH meter in a supernatant of 1:2.5 soils to a solution ratio of $H_2O$. Organic carbon of the soils was determined following the wet digestion method as described by Walkley and Black (1934). Total N of the soil was determined through digestion, distillation and titration procedure of the Kjeldahl method as described by Jackson (1967). Available P content was measured after Bray (1945). The Cation Exchange Capacity was determined according to Jackson (1967) method. Sulfur soil laboratory analysis was not done due to lack of chemicals in Central soil laboratory analysis of Haramaya University, However, some parts of eastern Ethiopia soils are found to be low in sulfur content as reported by EthioSIS (2014) and as a result, blended NPS fertilizer is introduced in place of Di-ammonium phosphate (DAP) (MoANR, 2013).

**Selected soil physical and chemical properties**

The results of the laboratory analysis of the selected physical and chemical properties of soils of Fedis research station are presented in Table 2. The textural class of the soils sandy based on the soil textural triangle of the International Society of Soil Science (ISSS) system (Rowell, 1994). The pH of the experimental soil is 7.48 which are slightly alkaline based on pH limit (7.4 to 7.8) as described by (Jones, 2003). The pH is in the range of 6.0 to 7.5 favourable for maize production.

Table 2. Soil physical and chemical properties of the experimental field before sowing.

| Analysis | Result | Rating | Reference |
|---|---|---|---|
| Sand (%) | 80 | | |
| Silt (%) | 5 | | |
| Clay (%) | 15 | | |
| Texture | Sand | | |
| pH (1:2.5 soil/water) | 7.48 | Slightly alkaline | Jones (2003) |
| Available P (mg kg soil$^{-1}$) | 16.77 | Medium | Cottenie (1980) |
| OC (%) | 2.3 | Medium | Tekalign Tadesse (1991) |
| Total N (%) | 0.11 | Low | Murphy (1968) |
| CEC (cmol$_{(+)}$ kg soil$^{-1}$) | 15.86 | Medium | Hazelton and Murphy (2007) |

### 2.5. Experimental Procedures

The land was ploughed, disked and harrowed by a tractor. Field leveling was done manually before sowing. Then, two seeds were sown per hole on 15 June 2018 and on 20 June 2019 and covered with soil manually. Thinning to a single plant per hill was done when seedlings produced three to four leaves. The full dose of NPS and half (½) of the N fertilizer was applied at sowing while the remaining half (½) was applied at the knee height stage of growth as side-dressing (Tadesse Tilahun *et al*., 2013). Hand weeding and cultivation were done throughout the growing season manually. Spraying the insecticide (Fastac) was also carried out to protect the plants from the fall armyworm (*Spodoptera frugiperda)*. Harvesting of the two central rows of each plot was carried out manually with a sickle at the end of the month of October in both years.

### 2.6. Data Collection

**Growth variables**

The leaf area index was determined as the ratio of leaf area per plant divided by the respective ground area occupied by the plant. Plant height was measured from ten randomly pre-tagged plants from the net plot area and then their height was measured from the soil surface to the point where the tassel started to branch with a meter rod at physiological maturity. Ear height was recorded from ten randomly pre-tagged plants from each net plot area and the ear height was measured from the ground level to the node bearing the top useful ear with a meter rod at physiological maturity (CIMMYT, 1985).

**Yield components and yield**

The number of ears plant$^{-1}$ was taken from ten randomly pre-tagged plants in the net plot area, and then their ears were counted at harvest and the average was recorded. Ear length was recorded from ten randomly taken ears from the net plot area and measured from the point where ears were attached to the stalk to the tip of the ear with a glass ruler after harvest and the average was recorded. Ear diameter was recorded from ten randomly taken ears from the net plot area, and then their diameter was measured at the middle of the ear with a caliber ruler. The number of kernels per ear was recorded by multiplying the total number of rows per ear and the number of kernels per row from five randomly taken ears in the net plot area after harvest and the average was recorded. A thousand kernels were counted from randomly taken ears after shelling by using a kernel counter. Then, the thousand kernel weight was recorded by weighing a thousand kernels using a sensitive balance and adjusting the moisture level to 12.5%. Aboveground dry biomass yield was weighed after the entire plants were harvested from the net plot area, weighed using field balance. Grain yield from the net plot area was weighed using a field balance after adjusting the moisture content to 12.5%. The harvest index was calculated as the ratio of grain yield to the total aboveground dry biomass yield per plot × 100 (CIMMYT, 1985).

### 2.7. Data Analysis

All data were subjected to analysis of variance (GLM procedure) using Genstat software program version 17th (VSN International, 2012). Homogeneity of variances was evaluated using the F-test as described by Fisher (1935). Since the F-test results of most agronomic parameters of the two-seasons data depicted homogeneity of variances, a combined analysis was done. The Fisher's protected least significant difference (LSD) test at 0.05 probability level was used to separate treatment means where significant treatment differences were detected.

### 2.8. Partial Budget Analysis

Partial budgets are useful and appropriate in the economic analysis of experimental data (Byerle, 1980). Partial budgets merely compare the changes in benefits with the changes in costs that are due to changes in treatments. The dominance analysis procedure as detailed in CIMMYT (1988) was used to select potentially profitable treatments from the range that was tested. The selected and discarded treatments using this technique are referred to as Undominated and Dominated' treatments, respectively. The cost-benefit ratio was calculated by considering the sale of prices of grain yield at harvesting time (8.0 ETB/kg) and cost of fertilizers at sowing time (100kg NPS/ 1500.0ETB and 100kg urea/1450.0 ETB) and their application costs per man-days (150.0 ETB. The mean grain yield was adjusted by subtracting 10% to reflect the difference between experimental and farmer yields due to differences in management. Then net benefit (NB) was calculated by subtracting the total variable cost from gross benefit (GB) and marginal rate of return (MRR%) was also calculated by the change in net benefit/change in total variable cost (TVC) x 100. Thus, the treatment which was non-dominated and having a MRR of greater or equal to 50% with the highest net benefit was taken to be economically profitable.

## 3. Results and Discussion

### 3.1. Effect of Blended NPS and N Rates on Growth Parameters of Maize Varieties

#### 3.1.1. Leaf area index

The main effects of NPS fertilizer, year, variety significantly ($P < 0.01$) influenced leaf area index. However, the main effect of nitrogen fertilizer did not influence this variable of the plant. The two-factor interaction of year and variety also significantly ($P < 0.05$) influenced leaf area index. However, the three-factor interactions of variety × NPS fertilizer × year as well as variety × N fertilizer × year also significantly ($P < 0.05$) influenced the leaf area index of the maize varieties (Table 2). Regarding the interaction effect of variety × NPS fertilizer × year, among treatment relatively higher leaf area indices were recorded for Baate variety in response to applying 50, 100, and 150 kg NPS $ha^{-1}$ in 2019.

For example, for the year 2019, the leaf area index recorded for Baate variety at the rate of application 50 kg NPS $ha^{-1}$ exceeded the leaf area index of Melkassa 2 variety in the same year at the same rate of NPS fertilizer application by about 36% (Table 3). Among treatments comparatively, the higher leaf area index of the Baate variety and the lower leaf area indices of the Melkasa-2 variety could be due to the existence of genetic variation between the two varieties. Both varieties produced higher leaf area indices in the 2019 cropping season at all NPS levels as compared to 2018. Thus, in the year 2019, the leaf area index of the Baate variety at the application of 50 kg NPS per hectare exceeded the leaf area index of the same variety at the same rate of NPS fertilizer application by about 88%.

This is possibly due to the presence of optimum monthly rainfall distribution for maize production in the 2019 growing season (June to October) as compared to the 2018 growing season that may have led to favorable vegetative (leaf) growth as a result of improved photosynthesis. However, the higher leaf area index obtained in this study is lower as compared to the maximum optimum leaf area index (5 to 6) of maize described by Tong *et al.* (2009). Nevertheless, the lower the leaf area index could have, the greater the solar utilization efficiency, which is closely related to the grain number and weight during the filling stage. This result is in line with the findings of Mekuannet Belay and Kiya Adare (2020) who reported that leaf area index was significantly affected by variety, NPS and year and produced a higher leaf area index (4.3) from the application of 150 kg NPS $ha^{-1}$ in 2019 as compared to 2018. Similarly, Rao *et al.* (2001) also reported that the application of optimum amounts of plant nutrients are important to promote the formation of chlorophyll which in turn resulted in higher photosynthetic activity, vigorous vegetative growth, and taller plants that produced more leaves per plant. Similarly, Sisay and Adugnaw (2020) reported that the leaf area index of maize increased in response to increasing the rate of blended NPS fertilizer.

Significant variations in leaf area indices were also observed due to the interaction of variety × N fertilizer × year. For instance, as N fertilizer increased from 43.5 to 130.5 kg ha$^{-1}$, the leaf area index of the Baate variety was slightly increased from 3.0 to 3.1 in the 2019 cropping season. The is because optimum application of N rate increases photosynthetic processes, the number of leaves per plant and leaf area as well as net assimilation rate (Ahmad *et al*., 2009). Similarly, Tolera Abera *et al.* (2017) reported that the leaf area index of maize was significantly affected by the interaction of variety by nitrogen but not affected by the application of different rate of N.

Mitiku Woldesenbet and Asnakech Haileyesus (2016) also reported that the number of leaves per plant increased as nitrogen increased from 0 to 92 kg ha$^{-1}$. On the other hand, the leaf area index of the Melkasa-2 variety was increased by nearly 7.7% when the N fertilizer rate increased from 43.5 to 87 kg ha$^{-1}$ in the same season (Table 3). The lower harvest indices were recorded in the 2018 cropping season. This could be due to the availability of ill rainfall distribution in the 2018 cropping season resulted in lower leaf area indices in 2018. Comparatively, the Baate variety produced higher leaf area indices in both seasons. Having small leaf areas and a small number of leaves per plant from the Melkasa-2 variety may have resulted in lower leaf area indices. Even though higher leaf indices (3.1) were found in some treatments, this value is lower as compared to the maximum optimum leaf area index obtained from hybrid varieties (Tong *et al*., 2009). Other findings also confirmed that the leaf area index was highly affected by variety and years (Sun *et al*., 2019). Leaf area index is also influenced by genotypes and environment as reported by Birch *et al.* (1998). Li *et al.* (2011) also reported that modern maize varieties had longer growth periods, higher leaf areas and slower leaf senescence. Similarly, improved maize varieties had a higher leaf area index than local varieties Lukeba (2013). From the aforementioned findings, it can be estimated that the optimum leaf area index for open-pollinated maize variety could be less than 5 or the optimum leaf area index of hybrid maize varieties.

In the 2019 cropping season, higher leaf area indices were obtained at all fertilizer rates compared to in 2018 cropping season. This is possibly due to the presence of ample rainfall with even distribution throughout the growing season of 2019 that may attribute to have good root extension and development to absorb more soil nutrients for producing more leaves per plant. The result has coincided with Mhizha *et al.* (2012) who reported that a significant increase of total seasonal precipitation is not important in rainfed maize production but its distribution is essential for crop phenology development. For instance, the minimum rainfall (18.8 mm) recorded in July may affect plant growth and development unlike that of 2019 which received 48.5 mm in the same month (Figure 1). In addition, shorter plant heights were also recorded in 2018 cropping that may influence the number of leaves produced per plant.

### 3.1.2. Plant height and ear height

Plant height was significantly ($P < 0.05$) influenced by the main effects of NPS fertilizer, year, variety. However, it was not influenced by the main effect of nitrogen. This variable was significantly ($P < 0.05$) influenced also by the two-factor interaction of year and variety. However, it was also influenced by the three-factor interactions of variety × NPS fertilizer × year as well as NPS fertilizer × N fertilizer × year significantly ($P < 0.01$). Ear height was influenced in the same way except that it was not influenced by the main effects of NPS fertilizer (Table 2).

The tallest maize plants were recorded in the 2019 cropping year in response to the application of 50 kg NPS ha$^{-1}$ plus 43.5 kg N ha$^{-1}$ and 50 kg NPS ha$^{-1}$ plus 87 kg N as well as in response to the application of 100 kg NPS ha$^{-1}$ plus 43.5 kg N ha$^{-1}$ and 100 kg NPS ha$^{-1}$ plus 130.5 kg N ha$^{-1}$. In addition, the application of 150 kg NPS ha$^{-1}$ plus 43.5 kg N ha$^{-1}$, 150 kg NPS ha$^{-1}$plus 87 kg N ha$^{-1}$, 150 kg NPS ha$^{-1}$ plus 130.5 kg N ha$^{-1}$ resulted in the tallest maize plants. On the other hand, the shortest maize plants were obtained in the 2018 growing year in response to all rates of the fertilizer application (Table 4). For example, the average height of maize plants in the 2019 growing year obtained in response to the application of a higher rate of the NPS fertilizer (100 kg NPS ha$^{-1}$) plus a higher rate of the nitrogen fertilizer (87 kg N ha$^{-1}$) exceeded the average heights of maize plants in the 2018 growing season in response to the application of the lowest rate of the NPS fertilizer (50 kg NPS ha$^{-1}$) plus the lowest rate of the nitrogen fertilizer (43.5 kg N ha$^{-1}$) by about 59.2% (Table 4).

Table 2. Mean squares of pooled analyses of variances for growth parameters, yield components and yield of Baate and Melkasa-2 maize varieties during the 2018 and 2019 main cropping seasons in Fedis District, Eastern Ethiopia.

| Source of variation | DF | LAI | PH (cm) | EH (cm) | NEPPL | EL(cm) | ED(cm) | NKPE | TKW (g) | BY (t ha$^{-1}$) | GY (t ha$^{-1}$) | HI (%) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Replication (Rep)** | 2 | 0.41 | 190.2 | 29.41 | 0.026 | 0.234 | 0.068 | 6307.0 | 1798.0 | 10.3 | 1.04 | 0.0008 |
| **Year (Y)** | 1 | 33.52* | 54742.5** | 37352.5** | 1.235** | 112.44** | 6.34** | 57998.0** | 147332.0** | 1941.2** | 271.3** | 0.022** |
| **Variety (V)** | 1 | 6.09** | 585.7* | 1017.5** | 0.001$^{NS}$ | 0.36$^{NS}$ | 0.73** | 109696.0** | 47.0$^{NS}$ | 62.7** | 30.7** | 0.0066* |
| **NPS** | 2 | 0.31** | 647.7* | 141.1$^{NS}$ | 0.125** | 0.61$^{NS}$ | 0.04$^{NS}$ | 10416.0** | 714.0$^{NS}$ | 21.1* | 7.4** | 0.003$^{NS}$ |
| **Nitrogen (N)** | 2 | 0.09$^{NS}$ | 144.5$^{NS}$ | 10.6$^{NS}$ | 0.017$^{NS}$ | 0.20$^{NS}$ | 0.04$^{NS}$ | 4109.0$^{NS}$ | 106.0$^{NS}$ | 5.2$^{NS}$ | 2.8* | 0.003$^{NS}$ |
| **V x NPS** | 2 | 0.02$^{NS}$ | 210.3$^{NS}$ | 88.1$^{NS}$ | 0.032$^{NS}$ | 0.68$^{NS}$ | 0.02$^{NS}$ | 7588.0* | 3498.0$^{NS}$ | 10.9$^{NS}$ | 3.3* | 0.002$^{NS}$ |
| **V x N** | 2 | 0.06$^{NS}$ | 123.9$^{NS}$ | 44.5$^{NS}$ | 0.047$^{NS}$ | 0.63$^{NS}$ | 0.07$^{NS}$ | 1105.0$^{NS}$ | 3549.0$^{NS}$ | 7.0$^{NS}$ | 0.01$^{NS}$ | 0.009** |
| **V x Y** | 1 | 0.72** | 682.5* | 223.9* | 0.001$^{NS}$ | 4.98* | 0.03$^{NS}$ | 1175.0$^{NS}$ | 2851.0$^{NS}$ | 16.2$^{NS}$ | 1.5$^{NS}$ | 0.003$^{NS}$ |
| **NPS x N** | 4 | 0.72$^{NS}$ | 272.4$^{NS}$ | 63.7$^{NS}$ | 0.054$^{NS}$ | 1.83$^{NS}$ | 0.03$^{NS}$ | 1233.0$^{NS}$ | 708.0$^{NS}$ | 5.7$^{NS}$ | 3.3* | 0.002$^{NS}$ |
| **NPS x Y** | 2 | 0.01$^{NS}$ | 143.1$^{NS}$ | 22.8$^{NS}$ | 0.003$^{NS}$ | 1.27$^{NS}$ | 0.04$^{NS}$ | 9626.0** | 1383.0$^{NS}$ | 24.7** | 2.4$^{NS}$ | 0.001$^{NS}$ |
| **N x Y** | 2 | 0.06$^{NS}$ | 48.4$^{NS}$ | 7.7$^{NS}$ | 0.006$^{NS}$ | 0.31$^{NS}$ | 0.03$^{NS}$ | 4125.0$^{NS}$ | 695.0$^{NS}$ | 1.9$^{NS}$ | 1.2$^{NS}$ | 0.001$^{NS}$ |
| **V x NPS x N** | 4 | 0.08$^{NS}$ | 448.1$^{NS}$ | 39.6$^{NS}$ | 0.030$^{NS}$ | 0.80$^{NS}$ | 0.05$^{NS}$ | 1331.0$^{NS}$ | 2644.0$^{NS}$ | 17.4* | 0.9$^{NS}$ | 0.002$^{NS}$ |
| **V x NPS x Y** | 2 | 0.19* | 1624.3** | 273.6** | 0.054$^{NS}$ | 5.62** | 0.10* | 9969.0** | 1167.0$^{NS}$ | 48.5** | 10.7** | 0.001$^{NS}$ |
| **V x N x Y** | 2 | 0.2* | 379.6$^{NS}$ | 10.9$^{NS}$ | 0.090* | 0.27$^{NS}$ | 0.02$^{NS}$ | 1160.0$^{NS}$ | 1927.0$^{NS}$ | 17.7* | 1.6$^{NS}$ | 0.0001$^{NS}$ |
| **NPS x N x Y** | 4 | 0.1$^{NS}$ | 1561.7* | 134.6* | 0.054* | 2.22$^{NS}$ | 0.01$^{NS}$ | 2129.0$^{NS}$ | 1359.0$^{NS}$ | 6.2$^{NS}$ | 1.0$^{NS}$ | 0.003$^{NS}$ |
| **V x NPS x N x Y** | 4 | 0.21$^{NS}$ | 650.9$^{NS}$ | 40.8$^{NS}$ | 0.030$^{NS}$ | 0.39$^{NS}$ | 0.05$^{NS}$ | 1813.0$^{NS}$ | 1919.0$^{NS}$ | 5.9$^{NS}$ | 1.1$^{NS}$ | 0.001$^{NS}$ |
| **Error** | 70 | 0.06 | 9499.7 | 46.01 | 0.021 | 1.07 | 0.026 | 1757.0 | 1934.0 | 4.93 | 0.76 | 0.001 |
| **CV (%)** | | 11.2 | 448.1 | 11.2 | 14.0 | 6.6 | 3.6 | 8.7 | 13.3 | 17.2 | 16.5 | 8.7 |

Note: *NS,* and **; Non-significant; Significant at $P < 0.05$ and $P < 0.01$, respectively; DF = Degree of freedom; LAI = Leaf area index; PH = Plant height; EH = Ear height; NEPPL = Number of ears per plant; EL = Ear length; ED = Ear diameter; NKPE = Number of kernels per ear; TKW = Thousand kernels weight; BY= Biomass yield; GY= Grain yield; HI = Harvest index; and CV = Coefficient of variation.*

Table 3. Leaf area index of maize as influenced by the interactions of variety × NPS × year as well as variety × N fertilizer × year during the 2018 and 2019 main cropping seasons in Fedis District, Eastern Ethiopia.

| Treatment | | NPS fertilizer rate (kg ha$^{-1}$) | | |
|---|---|---|---|---|
| Variety | Year | 50 | 100 | 150 |
| Baate | 2018 | 1.6$^{d}$ | 1.9$^{c}$ | 1.9$^{c}$ |
| | 2019 | 3.0$^{a}$ | 3.1$^{a}$ | 3.1$^{a}$ |
| Melkasa-2 | 2018 | 1.4$^{d}$ | 1.5$^{d}$ | 1.5$^{d}$ |
| | 2019 | 2.2$^{c}$ | 2.5$^{b}$ | 2.5$^{b}$ |
| LSD (0.05) | | 0.23 | | |
| | | Nitrogen fertilizer rate (kg ha$^{-1}$) | | |
| Baate | | 43.5 | 87 | 130.5 |
| | 2018 | 1.8$^{ef}$ | 1.9$^{de}$ | 1.6$^{fg}$ |
| | 2019 | 3.0$^{a}$ | 3.1$^{a}$ | 3.1$^{a}$ |
| Melkasa-2 | 2018 | 1.4$^{h}$ | 1.5$^{gh}$ | 1.5$^{gh}$ |
| | 2019 | 2.6$^{b}$ | 2.4$^{bc}$ | 2.3$^{cd}$ |
| LSD (0.05) | | 0.23 | | |
| CV (%) | | 11.2 | | |

Note: *Means in the table following the same letters are not statistically significant at 0.05probability level; LSD = Least significant difference; and CV = Coefficient of variation.*

An adequate application of blended fertilizer to maize plant under adequate rainfall may enable the plant to take up more water and nutrients from the soil. This could be attributed to more photosynthesis and translocation of assimilates to vegetative parts rather than reproductive parts, as a result of which the tallest plants were recorded at the highest fertilizer rate. Similarly, Ullah *et al.* (2015) reported that nitrogen is an essential element that increases plant height because it facilitates active cell division to form building blocks for cell expansion. Nitrogen is also essential for utilization of carbohydrates within plants and stimulation of root development as well as uptake of other nutrients (Khan *et al.*, 2014). The result is in line with the findings of Mitiku Woldesenbet and Asnakech Haileyesus (2016) who reported that plant height was increased as nitrogen rate was increased from 0 to 92 kg N ha$^{-1}$. Similarly, Alias *et al.* (2003) stated that the maximum plant height (195.9 cm) was obtained in response to applying 125 kg P ha$^{-1}$. Berhe Meresa and Marie Belay (2020) also reported that the application of blended fertilizer significantly increased plant height as compared to the control treatment and other treatments that received lower rates of the fertilizer. Application of the blended fertilizer significantly increased plant height as compared to the recommended NP fertilizers and the control treatment (Dagne Chimdessa, 2016). Maqsood *et al.* (2001) and Ayub *et al.* (2002) also reported that a significant effect of NP application was observed on plant height in response to increasing the application of NP fertilizer.

The tallest maize ears were recorded in the 2019 growing year in response to the combined application of 50 kg NPS fertilizer ha$^{-1}$ with 43.5 and 87 kg N fertilizer ha$^{-1}$. Similarly, the combined application of 100 kg NPS ha$^{-1}$ with 87, and 130.5 kg N ha$^{-1}$, as well as 150 kg NPS fertilizer ha$^{-1}$ with all the nitrogen fertilizer rates, as well as 150 kg NPS fertilizer ha$^{-1}$ with all the nitrogen fertilizer rates produced the highest ear heights in the same growing year. The combined application of 100 kg NPS fertilizer with 87 kg N fertilizer in the 2019 cropping year increased the ear height of the maize plant nearly by 56% over the lowest combined fertilizer application of 50 kg NPS plus 43.5 kg N in the 2018 cropping year. The shortest ear height recorded at the lowest combined fertilizer application rate could be due to poor root development, extension and stunted growth of maize plant owing to deficiency of phosphorus and nitrogen fertilizers. This result is harmonized with the findings of Kidist Abera (2013) who reported that the ear height of maize increased from 138.3 cm to 163.3 cm as the N rate increasing from 0 to 174 kg N ha$^{-1}$. Similarly, findings also reported by Geremew Taye (2009).

Table 4. Plant height, ear height and number of ears per plant as influenced by interaction effect of NPS × N × year during the 2018 and 2019 main cropping seasons in Fedis District, Eastern Ethiopia.

| Year | NPS rate (kg ha$^{-1}$) | N rate (kg ha$^{-1}$) | Plant height (cm) | Ear height (cm) | Number of ears per plant |
|---|---|---|---|---|---|
| 2018 | 50 | 43.5 | 113.2$^{g}$ | 37.0$^{f}$ | 0.86$^{h}$ |
| | | 87 | 122.2$^{e–g}$ | 40.0$^{ef}$ | 0.89$^{gh}$ |
| | | 130.5 | 119.0$^{fg}$ | 40.3$^{d–f}$ | 0.91$^{f–h}$ |
| | 100 | 43.5 | 124.3$^{d–g}$ | 44.5$^{de}$ | 0.88$^{gh}$ |
| | | 87 | 118.8$^{fg}$ | 39.2$^{ef}$ | 0.92$^{f–h}$ |
| | | 130.5 | 131.8$^{de}$ | 44.5$^{de}$ | 0.99$^{e–h}$ |
| | 150 | 43.5 | 127.0$^{d–f}$ | 41.7$^{d–f}$ | 0.96$^{e–h}$ |
| | | 87 | 135.8$^{d}$ | 47.3$^{d}$ | 1.03$^{d–g}$ |
| | | 130.5 | 128.8$^{d–f}$ | 43.2$^{d–f}$ | 0.97$^{e–h}$ |
| 2019 | 50 | 43.5 | 173.3$^{ab}$ | 81.6$^{a}$ | 1.062$^{c–f}$ |
| | | 87 | 169.8$^{a–c}$ | 78.4$^{a–c}$ | 1.23$^{ab}$ |
| | | 130.5 | 158.4$^{c}$ | 74.1$^{bc}$ | 0.95$^{e–h}$ |
| | 100 | 43.5 | 161.3$^{bc}$ | 73.7$^{c}$ | 1.063$^{b–f}$ |
| | | 87 | 180.2$^{a}$ | 84.0$^{a}$ | 1.22$^{a–c}$ |
| | | 130.5 | 168.1$^{a–c}$ | 78.8$^{a–c}$ | 1.18$^{a–d}$ |
| | 150 | 43.5 | 169.5$^{a–c}$ | 80.8$^{ab}$ | 1.26$^{a}$ |
| | | 87 | 169.3$^{a–c}$ | 78.8$^{a–c}$ | 1.11$^{a–e}$ |
| | | 130.5 | 176.2$^{ab}$ | 83.2$^{a}$ | 1.27$^{a}$ |
| LSD (0.05) | | | 13.4 | 7.8 | 0.17 |
| CV (%) | | | 7.9 | 11.2 | 14.0 |

Note: *Means in the table following the same letters are not statistically significant at 0.05 probability level; LSD= Least significant difference; and CV = Coefficient of variation.*

### 3.2. Effect of Blended NPS and N Rates on Yield Components and Yield of Maize Varieties

#### 3.2.1. Number of ear per plant

The number of ears per plant was significantly ($P < 0.01$) influenced by the main effects of NPS fertilizer and year. However, it was not significantly affected by the main effects of variety and nitrogen fertilizer. On the other hand, the number of ears per plant was significantly ($P < 0.05$) influenced by the three-factor interactions of variety × N fertilizer × year as well as NPS fertilizer × nitrogen fertilizer and year (Table 2).

The maximum numbers of ears per plant within treatments were recorded from plants supplied with combined application of 100 kg NPS fertilizer ha$^{-1}$ with 87 and 130.5 kg N fertilizer ha$^{-1}$ as well as 150 kg NPS fertilizer ha$^{-1}$ with all rates of the nitrogen fertilizer in 2019 growing year (Table 4). This result indicated that the application of 150 kg NPS fertilizer ha$^{-1}$ plus 130.5 kg N fertilizer ha$^{-1}$ under ample and good monthly rainfall distribution could be an optimum fertilizer rate to produce more photosynthetic activity and synthesized more carbohydrate that stimulated root growth and development of economic parts resulted in a higher number of ears per plant. Similarly, Dagne Chimdessa (2016) reported that the number of ears per plant increased as the blended fertilizer rate increased. On the other hand, Kumar and Kumar (2017) stated that the application of 100 kg P ha$^{-1}$gave the maximum number of ears per plant (1.25). The minimum number of ears per plant of maize was obtained from the lowest combined fertilizer application rate (50 kg NPS ha$^{-1}$ and 43.5 kg N ha$^{-1}$) in the 2018 growing year. The minimum numbers of ears per plant were recorded in the 2018 growing year compared to the 2019 growing year. This is probably because the presence of adequate rainfall with good monthly distribution in the 2019 growing year may help soil nutrients become easily available to plant roots. Similarly, Jifara Gudeta *et al.* (2021) reported that increasing NPSZn level from 0 to 100 kg ha$^{-1}$ and N level from 0 to 35.4 kg ha$^{-1}$ significantly increased the number of cobs per plant from 1.00 to 2.00.

#### 3.2.2. Ear length and diameter

The ear length of maize was significantly ($P < 0.01$) influenced by the main effect of year but other main effects were non-significant. Besides, it was also significantly ($P < 0.05$) affected by the three-factor interaction of variety × NPS fertilizer × year. Ear diameter was affected in the same way except that it was significantly ($P < 0.01$) affected by the main effect of variety (Table 2). The longest ear lengths of maize were produced from the Baate variety fertilized with all NPS fertilizer rates in the 2019 growing year, but these mean values of ear lengths were statistically at par with the

Melkasa-2 variety received the same NPS fertilizer rates in the same growing year (Table 5). This is probably Baate variety could be better to convert growth resources into economic part or provide assimilates to sink. The maximum assimilates supply should be available during maize grain filling (Arif *et al*., 2010). The probable reason could be due to a favorable environment optimum utilization of solar light, higher assimilated production and its conversion to starches resulted in higher ear length as reported by Derbay *et al.* (2004).

Similarly, Jifara Gudeta *et al.* (2021) reported that the highest ear length of maize (18.0 cm) was obtained from the blended application of 100 kg NPSZn and 35.4 kg N $ha^{-1}$. However, shorter ear lengths of maize were recorded for both varieties in the 2018 growing year almost in all NPS fertilizer rates as compared to the 2019 growing year. The mean values of ear lengths obtained from the Baate variety were slightly higher than those obtained from Melkasa -2 variety in the 2019 growing year. The ear length of the Baate variety grown in 2019 growing at 50 kg and 100 kg NPS fertilizer $ha^{-1}$ exceeded the ear length of the same variety grown in the 2018 year at the lowest NPS fertilizer application rate of 50 kg $ha^{-1}$ by 25.7%.

The highest ear diameters of the Baate variety were produced in response to applying 100 kg NPS and 150 kg NPS fertilizer $ha^{-1}$ in the 2019 growing year. The ear diameters of Baate and Melkasa-2 were increased from 4.63 to 4.85 cm and 4.55 to 4.65 cm in the same order in the 2019 growing ear. Similarly, the same trends were also observed in the 2018 growing year albeit thinner ear diameters were recorded compared to the ear diameters recorded in the 2019 growing year. The average ear diameters of Baate variety obtained in response to the application of the highest NPS fertilizer rate (150 kg NPS $ha^{-1}$) in 2019 growing year increased the average ear diameter of Melkasa-2 variety obtained in response to the application of the lowest NPS fertilizer rate (50 kg NPS $ha^{-1}$) in 2018 growing year nearly by 19.5%. This is possibly due to adequate fertilizer application to the maize plants under good rainfall amount and distribution, which may have resulted in vigorous growth that helps to produce more green leaves to produce more photosynthetic assimilates and translocate to the sink (kernels) resulted in large size. Perhaps kernel size may be one of the determinant factors for ear diameter due to varietal difference. Similarly, Onasanya *et al.* (2009) found that the highest ear diameter was obtained at the higher phosphorus fertilizer application.

Table 5. Ear length and ear diameter of maize varieties as influenced by the interaction of variety, NPS and year during the 2018 and 2019 main cropping seasons in Fedis District, Eastern Ethiopia.

| Variety | NPS (kg $ha^{-1}$) | Ear length (cm) | | Ear diameter (cm) | |
|---|---|---|---|---|---|
| | | 2018 | 2019 | 2018 | 2019 |
| Baate | 50 | $13.6^{d}$ | $17.1^{a}$ | $4.21^{de}$ | $4.63^{bc}$ |
| | 100 | $14.4^{cd}$ | $17.1^{a}$ | $4.33^{d}$ | $4.75^{ab}$ |
| | 150 | $15.0^{c}$ | $16.3^{ab}$ | $4.33^{d}$ | $4.85^{a}$ |
| Melkasa-2 | 50 | $15.3^{bc}$ | $16.2^{ab}$ | $4.06^{f}$ | $4.55^{c}$ |
| | 100 | $14.8^{c}$ | $16.8^{a}$ | $4.07^{ef}$ | $4.63^{bc}$ |
| | 150 | $14.5^{cd}$ | $16.5^{a}$ | $4.15^{ef}$ | $4.65^{bc}$ |
| LSD (0.05) | | 0.97 | | 0.15 | |
| CV (%) | | 6.6 | | 3.6 | |

Note: *Means in the table following the same letters are not statistically significant at 0.05 probability level; LSD = Least significant difference; and CV = Coefficient of variation.*

### 3.2.3. Thousand kernels weight and number of kernels per ear

Thousand kernel weight was significantly ($P < 0.01$) influenced by the main effect of year but other main effects were non-significant. The number of kernels per ear was significantly ($P < 0.01$) affected by the main effects of year, variety and NPS fertilizer. However, the main effect of nitrogen did not show a significant effect on this yield component. On the other hand, this yield component was also significantly ($P < 0.05$; $P < 0.01$) affected by the two-factor interactions of variety × NPS fertilizer as well as NPS fertilizer × year, respectively. In addition, it was also significantly ($P < 0.01$) influenced by the three-factor interaction of variety × NPS fertilizer × year (Table 2). The mean thousand kernel weight obtained in the 2019 growing year increased by 25.2% over the mean thousand kernel weight obtained in the 2018 growing year. This could be due to the presence of good monthly rainfall distribution throughout the cropping season that may extend the grain-filling period.

The maximum numbers of kernels per ear of the Baate variety were attained when the plants were fertilized with 50 kg NPS and 100 kg NPS $ha^{-1}$ in the 2019 growing year. For each growing year, the average numbers of kernels per ear obtained from both varieties increased with the increasing NPS fertilizer from 50 to 150 kg NPS ha$^{-1}$except Baate variety in the 2019 growing year (Table 7). For instance, the average number of kernels per ear obtained from Melkasa-2 increasing by 11.8% and 9.0% as the NPS fertilizer rate was increased from 50 to 150 kg ha$^{-1}$ in 2018 and 2019 growing years, respectively. The average number of kernels per ear obtained for Baate variety in response to the application of the higher NPS fertilizer rate (100 kg NPS ha$^{-1}$) in 2019 growing year surpassed the average of the number of kernels per ear obtained for Melkasa-2 variety in response of the application of the lowest NPS fertilizer rate (50 kg NPS ha$^{-1}$) in 2018 growing year closely by 34.8%. This could be because the longest ears and widest ear diameters were found for Baate maize variety in response to applying 100 kg NPS fertilizer rate in 2019 cropping season, which could have a direct contribution to producing the maximum number of kernels per ear. This may be due to maximum photosynthetic activity and carbohydrates use within a plant that stimulated root growth and development as well as the uptake of other nutrients (Khan *et al*., 2014). Similarly, Alias *et al.* (2003) reported that increasing the rate of phosphorus from 0 to 125 kg ha$^{-1}$ increased the number of kernels per ear of maize. Maqsood *et al.* (2001) also found that number of kernels per ear of maize was increased as P and N increased to a certain level. Reported that the number of kernels per was significantly affected by NP and variety (Khan *et al*., 2014).

#### 3.2.4. Aboveground biomass yield

Aboveground biomass yield was significantly ($P < 0.01$; $P < 0.05$) affected by the main effects of variety, year and NPS fertilizer, respectively. This yield was also significantly ($P < 0.01$) affected by the two-factor interaction of NPS fertilizer and year. Moreover, it was significantly ($P < 0.05$) influenced by the three-factor interactions of variety × NPS fertilizer × year as well as variety × N fertilizer × year and significantly ($P < 0.01$) affected by similar interaction of variety × NPS fertilizer × N fertilizer (Table 2).

The highest aboveground biomass yield of the Baate variety was obtained in response to the application of the highest combined fertilizer rate of 150 kg NPS fertilizer ha$^{-1}$ plus 130.5 kg N fertilizer ha$^{-1}$. The aboveground biomass yield of the Baate variety increased as the NPS fertilizer rate was increased from 50 to 150 kg ha$^{-1}$ at each rate of the nitrogen fertilizer. However, the same trends were not observed for Melkasa-2 variety (Table 6). The average aboveground biomass yield obtained from Melkasa-2 variety in response to the application of 50 kg NPS fertilizer ha$^{-1}$ plus 130.5 kg N fertilizer reduced from the average aboveground biomass yield obtained from Baate variety in response to the application of the highest combination fertilizer rate (150 kg NPS ha$^{-1}$ and 130.5 kg N ha$^{-1}$) by 83.2%. Indeed, the Baate variety produced higher aboveground biomass yields at all fertilizer levels as compared to the Melkasa-2 variety. Because higher mean values of growth variables and yield components of Baate variety were recorded in the 2019 growing year, which could be attributed to the higher biomass yield produced in the same year. This is possibly due to the presence of genetic variation along with good monthly rainfall distribution. In this case, the Baate variety had a better response to applied fertilizer rates for producing higher biomass yield. Similarly, Mekuannet Belay and Kiya Adare (2020) reported that the responses of varieties to applied nutrients are governed by soil moisture. Consistent with the results of this studyy, Ahmad *et al.* (2018) also reported that variety and nitrogen had a significant effect on biomass yield of maize Similarly, Geremew Taye *et al.* (2015) and Hussain *et al.* (2015) and reported that biological yield of maize was influenced by the combined application of P and N.

Table 6. Aboveground biomass yield of maize varieties as influenced by the interaction of variety x NPS x N during the 2018 and 2019 main cropping seasons in Fedis District, Eastern Ethiopia.

| Variety | NPS (kg ha$^{-1}$) | N (kg ha$^{-1}$) | | |
|---|---|---|---|---|
| | | 43.5 | 87 | 130.5 |
| Baate | 50 | 13.67$^{b–e}$ | 13.7$^{b–d}$ | 13.3$^{c–f}$ |
| | 100 | 13.8$^{b–d}$ | 14.9$^{bc}$ | 13.7$^{b–d}$ |
| | 150 | 14.0$^{b–d}$ | 15.8$^{b}$ | 18.5$^{a}$ |
| Melkasa-2 | 50 | 11.7$^{d–h}$ | 10.76$^{gh}$ | 10.1$^{h}$ |
| | 100 | 10.4$^{h}$ | 10.8$^{f–h}$ | 13.2$^{c–g}$ |
| | 150 | 12.5$^{c–h}$ | 10.7$^{h}$ | 11.2$^{e–h}$ |
| LSD (0.05) = 2.56 | | | | |
| CV (%) = 16.7 | | | | |

Note: *Means in the table following the same letters are not statistically significant at 0.05 probability level; LSD = Least significant difference; and CV = Coefficient of variation.*

#### 3.2.5. Grain yield

The main effects of all three factors, namely, NPS fertilizer, N fertilizer, year, and variety significantly ($P < 0.05$) influenced the grain yield of maize. In addition, the two-factor interactions of NPS fertilizer and variety as well as that of NPS and N fertilizer significantly ($P < 0.05$) influenced this variable of the plant. However, the higher order interaction, namely, the three-factor interaction of variety × NPS fertilizer × year also significantly ($P < 0.01$) affected the grain yield of the crop (Table 2).

For each growing year, increasing the rate of the NPS fertilizer increased the grain yield of the crop. However, significantly higher grain yields were obtained in the 2019 growing season for both varieties. Thus, the highest grain yields were obtained for the Baate variety in the 2019 growing in response to the application of 100 kg NPS $ha^{-1}$ as well as 150 kg NPS $ha^{-1}$. However, the lowest grain yield for this variety in the same year was obtained in response to the application of 50 kg NPS $ha^{-1}$. However, the yield increments in the year 2019 were only slight, although significant, and amounted to only 13% when comparing the application of 50 kg NPS $ha^{-1}$ and 150 kg NPS $ha^{-1}$. However, the grain yield of the Baate variety obtained in the 2019 cropping year in response to the application of 150 kg NPS $ha^{-1}$ exceeded the grain yield of the same variety obtained in 2018 in response to the application of 50 kg NPS $ha^{-1}$ by about 196%. The response of varieties to applied fertilizer could be due to the low contents of total nitrogen and available phosphorus as indicated in soil analysis in Table 1.

Melkasa-2 maize variety produced the lowest grain yields in the year 2018 in response to the application of all three rates of the NPS fertilizer (Table 7). For each growing year, the average grain yields of both varieties increased as NPS fertilizer was increased from 50 to 150 kg $ha^{-1}$although the extents of increment at all NPS fertilizer rates varied between the two growing years. This probably signifies that the application of adequate amounts of fertilizer to maize plants in the presence of an adequate amount and evenly distributed rainfall like in the 2019 growing season (Figure 1) promotes higher availability of nutrients of the nutrients and their uptake by plants. Similarly, Mugiyo *et al.* (2018) reported that the higher amount of rainfall and even distribution of rainfall produced a higher grain yield of maize. Therefore, the maximum grain yield at the highest level of P may be due to adequate availability of nutrients in the soil and their uptake by the plants especially during the seed filling stage improved production and partitioning of photoassimilates to reproductive part especially during the time of seed formation. Possibly, the existence of a varietal difference between the two varieties may have had its contribution to yield variations. This result is in line with the findings of Tolera Abera *et al.* (2009) who reported that the grain yields of maize varieties were significant across the cropping seasons, and higher grain yields of maize were obtained in the 2001 cropping season as compared to 2003. Similarly, Mekuannet Belay and Kiya Adare (2020) also reported that that the highest grain yield of maize was obtained from the combined application of 150 kg NPS $ha^{-1}$ with 130.5 kg N $ha^{-1}$ in the 2019 cropping season. Kumar and Kumar (2017) also confirmed that the highest grain yield of maize (6.0 t $ha^{-1}$) was found for plots fertilized with 100 kg $ha^{-1}$ P as compared to lower P levels.

Higher grain yields of two maize varieties were recorded in 2019 as compared to the 2018 main cropping season though the Baate maize variety produced much higher grain yields than the other variety at almost all fertilizer rates in both seasons. Almost all yield components namely, number of ears per plant, ear length, ear diameter, number of kernels per, thousand kernel weight, and biomass obtained in the 2018 growing year were lower as compared to 2019. As a result, the average grain yields of both varieties obtained in this season were low. Because these yield components could have a direct contribution to the grain yield. The reduction in yield components in the 2018 growing year could be due to erratic rainfall distribution (Figure1). Mhizha *et al.* (2014) reported that maize requires about 600 mm of rainfall of even distribution to reach physiological maturity. Other findings Ahmad et al. (2018) also confirmed that maize crop can be grown where annual precipitation exceeds 600 mm with well distributed over the growth period. Annual total rainfall received in the 2018 cropping season was higher in that of 2019 cropping season but its distribution was not regular as 2019. Therefore, this confirmed that the rainfall distribution (rain days) is more important than seasonal totals and strongly correlated to district maize average yield as described by Mugiyo *et al.* (2018). Similarly, Zerihun Abebe and Hailu Feyisa (2017) reported that the average grain yield of maize varied due to seasons.

Significantly, a higher average grain yield of maize was obtained from the highest application of N fertilizer rate. Thus, the average grain yield obtained in response to the application of the highest rate of N fertilizer (130.5 kg N ha–1) exceeded the average grain yield obtained from the application of the lowest N fertilizer rate (43.5 kg N ha–1) by about 12.2%. Similarly, Zerihun Abebe and Hailu Feyisa (2017) reported that the highest average grain yield of maize was found from the application of a higher N fertilizer rate (92 kg $ha^{-1}$). The findings of Geremew Taye *et al.* (2015) also confirmed that grain yield of maize increased as the nitrogen application rate was increased from 0 to 184 kg $ha^{-1}$. This apparently signifies that response of maize to the applied N fertilizer may be due to low contents of total nitrogen in the soil (Table 1).

Table 7. Number of kernels per ear and grain yield of maize varieties as affected by the interaction of variety by NPS and year in 2018 and 2019 main cropping seasons in Fedis District, Eastern Ethiopia.

| Variety | | Number of kernels per ear | | Grain yield (t ha$^{-1}$) | |
|---|---|---|---|---|---|
| | NPS (kg ha$^{-1}$) | 2018 | 2019 | 2018 | 2019 |
| Baate | 50 | 430.1$^{fg}$ | 550.8$^{ab}$ | 2.7$^{g}$ | 7.1$^{bc}$ |
| | 100 | 521.5$^{a–c}$ | 555.8$^{a}$ | 4.0$^{e}$ | 7.7$^{ab}$ |
| | 150 | 507.8$^{b–d}$ | 511.6$^{bc}$ | 5.5$^{d}$ | 8.0$^{a}$ |
| Melkasa-2 | 50 | 412.2$^{g}$ | 447.9$^{fg}$ | 3.2$^{e–g}$ | 5.5$^{d}$ |
| | 100 | 414.9$^{g}$ | 471.1$^{b–f}$ | 3.7$^{ef}$ | 6.3$^{cd}$ |
| | 150 | 460.9$^{ef}$ | 488.3$^{c–e}$ | 3.1$^{fg}$ | 6.7$^{c}$ |
| LSD (0.05) | | 39.41 | | 0.82 | |
| CV (%) | | 8.7 | | 16.5 | |

Note: *Means in the table following the same letters are not statistically significant at 0.05 probability level; LSD = Least significant difference; and CV = Coefficient of variation.*

### 3.3. Partial Budget Analysis

This partial budget analysis was done based on the average yield of each treatment across all repetitions (Duncan *et al*., 1990) to assess only significant treatments to select the most economically feasible rates of NPS treatments on two pollinated maize varieties. Partial budget analysis was done for only significant treatments by taking the mean grain yield of two seasons. Based on partial budget analysis, the highest net benefit (44,850.0 ETB) with the highest marginal rate of return (764 %) was obtained from Baate variety at 150 kg NPS ha$^{-1}$application rate in the 2019 cropping season. Similarly, the application of 100 kg NPS ha$^{-1}$produced the highest net benefit (39,120.0ETB) with a higher marginal rate of return (812%) in the same season. This is probably due to the presence of a regular monthly distribution of rainfall throughout the growing season in 2019. The application of 87 kg N to both varieties gave the highest net benefit (33240.82 ETB) with a marginal rate of return (85%) which is economically feasible.

## 4. Conclusions

The results of this study have demonstrated that the application of 150 kg NPS fertilizer ha$^{-1}$to Baate variety produced the highest grain yield. The highest net benefit (44, 850.0 ETB) with the highest marginal rate of return (764 %) was obtained for the Baate variety at 150 kg NPS ha$^{-1}$ application rate in the 2019 cropping season. In addition, the application of 87 kg N to both varieties produced the highest net benefit (33, 240.82 ETB) with a marginal rate of return (85%) which is economically feasible. Therefore, it is concluded that applying 150 kg NPS fertilizer ha$^{-1}$as well as 87 kg N fertilizer ha$^{-1}$ to Baate variety is the optimum fertilizer rate to get economical grain yield in the study area and other similar agroecology in both years. The results imply that the productivity of maize is determined by the availability of sufficient N, P, S in the soil supplied as fertilizer in the study area. The results also indicate that the availability of sufficient moisture in the soil during the growing period is also a vital prerequisite for enhanced production of the crop. Thus, the Baate maize variety is the best for producing the crop in the study area with the aforementioned rates of the fertilizers. Farmers in the study area should, therefore, be advised to use this variety and the aforementioned fertilizer rates to produce the crop. Further research should be conducted to investigate effects of mineral fertilizers integrated with organic fertilizers as well as irrigation water on maize productivity across various locations and growing years.

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