Response of growth, yield components, and yield of hybrid maize (Zea mays L.) varieties to newly introduced blended NPS and N fertilizer rates at Haramaya, Eastern Ethiopia

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Abstract: Reduction of soil fertility from year to year due to natural and human made factors is a serious constraint for crop production in Ethiopia. Therefore, the application of actual balanced recommended fertilizer rates based on soil and crop type is one of the best agronomic practices to maximize production. A field experiment was conducted for two consecutive years to evaluate the response of growth, yield components, and yield of hybrid maize varieties to newly introduced blended NPS and N fertilizer rates. The experiment was comprised of three blended NPS and N levels tested on two hybrid maize varieties. Results showed that individual application of 150 kg NPS and 130.5 kg N gave maximum above-ground biomass yield. The highest grain yield was obtained from variety BHQPY545 where plots fertilized with the higher N application rate (87 kg) in 2019 cropping season. Besides, combined fertilizer application of 150 kg NPS by 87 kg N was produced the highest grain yield (10.7 t ha⁻¹) and closely (10.4 t ha⁻¹) followed by combined fertilizer application of 150 kg NPS by 130.5 kg N in 2019 season. According to partial budget analysis, the highest net benefit (85458.0 ETB) with a higher marginal rate of
return (1658.6%) was obtained from the combined application of 150 kg NPS with 87 kg N in 2019. Based on this result, it can be concluded that using of combined application of 150 kg NPS with 87 kg N in the study area and other similar agroecologies is agronomically optimum and economically feasible levels to maximize maize production.

**Subject:** Agriculture & Environmental Sciences; Botany; Soil Sciences;  
**Keywords:** Blended NPS; hybrid; N; yield  

1. **Introduction**

Maize (*Zea mays L.*) is an important crop in many parts of the developing world. It occupies the third place after wheat and rice (Food and Agriculture Organization of the United Nations [FAO], 2016). Supplying nutritious, safe, and affordable food to a growing population is one of the far most burning issues currently facing Africa to fulfill food security in the region (AGRA, Africa Agriculture Status Report, 2013). However, there are a number of factors which are responsible for the low production and productivity of maize. Among these factors, inappropriate crop nutrition management and poor soil fertility are the most important factors responsible for low yield of maize (Shah et al., 2009). One of the major problems constraining the development of an economically successful agriculture is nutrient deficiency (Fageria & Baligar, 2005).

In many parts of Africa including Ethiopia, repeated cultivation of land with inappropriate farming methods is causing severe depletion of nutrients and soil organic matter, posing a serious threat to agricultural productivity and sustainability (Endris & Dawid, 2015). Declining soil fertility from time to time due to natural and human made factors are serious bottle necks for crop production in Ethiopia. Besides, lack of appropriate fertilizer blends and lack of micronutrients in fertilizer blends are the national problem which is major constraints to crop productivity (Fufa et al., 2011). Farmers in developing countries apply insufficient quantities of N fertilizer due to less access or prohibitive prices or they ill apply the fertilizers in timing and rate. On the other hand, in addition to N and P, S in major Ethiopian soils they studied was found to be very low (Bellete, 2014). This is due to loss of organic matter, macro- and micronutrients’ depletion, soil acidity, topsoil erosion, and deterioration of physical soil properties (Zeleke et al., 2010). Therefore, supply of nutrients at an appropriate amount is always imperative for better growth and development of a crop (Ali & Anjum, 2017). In fact, response of maize plant to application of nitrogen and phosphorus fertilizers varies from variety to variety, location to location, and also depends on the availability of the nutrients (Onasanya et al., 2009). Hybrid maize varieties are more responsive and efficient than cultivars to fertilizers (Kidest, 2013; Taye, 2009). Hybrid maize varieties respond well to nutrient applications, particularly nitrogen and phosphorus and produce high and uniform yield than local varieties if the environment is conducive and better management practices followed. Yield of maize hybrids could be low when grown below optimum management practices. Use of improved varieties and optimum nitrogen fertilizer application practices are unlocking the high-yielding potential of hybrids maize (Abera et al., 2017). Application of essential plant nutrients in optimum quantity and right proportion, through correct method and time of application, is the key to increased and sustained crop production (Cisse & Amar, 2000). Chimdessa (2016) also reported that blended fertilizers increased maize productivity compared to the previously existing NP. Therefore, application of actual balanced recommended fertilizer rates based on soil and crop type is one of the best agronomic practices to maximize production. Still, most research works focus on N and P requirements of crops, limited information is available on various sources of nutrients such as K, S, Zn, B, and other micronutrients. Therefore, the designed objective of this experiment was to evaluate effect of newly introduced blended NPS and N fertilizer rates on growth, yield components, and yield of hybrid maize varieties.
2. Materials and methods

2.1. Description of the experimental site
An experiment was executed under rainfed conditions for two consecutive seasons (2018/19 and 2019/20) under main cropping season at Raare, the research farm of Haramaya University. Geographically, Raare is located at 9° 26′ N latitude and 42° 03′ E longitude at an altitude of 1980 m above sea level. The rain distribution of the area is bimodal. The soil of the experimental site is a well-drained deep alluvial with a subsoil stratified with sandy clay loam (Table 1). Total rainfall in growing seasons (April–October) was 786.6 and 977.8 mm in 2018 and 2019, respectively. Monthly average maximum and minimum temperature during growing seasons (April–October) was 24. °C 5 and 13.4°C in 2018; 25.1°C and 13.6°C in 2019, respectively (Figure 1).

2.2. Treatments and experimental design
The experiment was consisted of factorial combinations of two hybrid maize (MHQ138 and BHQPY-545) varieties, three levels of blended NPS (50, 100, and 150) kg ha\(^{-1}\) and three levels of N (43.5, 87, and 130.5) kg ha\(^{-1}\). The experiment was conducted using a randomized complete block design (RCBD) in factorial arrangements with three replications. Each plot had four rows of which two central rows were used for data collection and analysis and one rows of each plot side was left as border effect. The spacing between rows and plants was 75 and 30 cm, respectively.

2.3. Management of the experiment
The land was ploughed, disked, and harrowed by a tractor. Field leveling was done manually prior to sowing. Then two seeds per hole were sown and then seeds were covered with soil manually. Thinning to a single plant per each hill was done when seedlings produce three to four leaves. The full dose of NPS and half dose of N fertilizers were applied at sowing while the remaining half dose of N was applied 50 days after sowing as a top dressing but other cultural practices were uniformly applied throughout the cropping season.

Soil sampling and analysis was done by taking one representative composite sample at a depth of 0-30 cm from five randomly selected spots diagonally across the experimental field using auger before sowing. The sample was dried at room temperature, thoroughly mixed and ground to pass through a 2 mm sieve in preparation for laboratory analysis. The sample was analyzed for soil texture, pH, organic carbon, total nitrogen, available phosphorus, cation exchange capacity, and exchangeable cations at Central laboratory, Haramaya University, following standard analytical procedures (Table 1).
2.4. Data collection and measurements

2.4.1. Growth parameters

**Leaf area index**: it was recorded by taking a nondestructive sample of five plants from a net plot.

**Plant height**: it was determined by measuring the height of 10 randomly sampled plants from ground level to the base of the tassel at physiological maturity.

**Ear height**: it was recorded from 10 randomly taken plants by measuring the height of the stem from ground level to the point of attachment of upper most ear at physiological maturity.

2.4.2. Yield components and yield

**Number of ears plant**\(^{-1}\): about 10 randomly pretagged plants were taken from the net plot area, and then their ears were counted at harvest and the average was recorded.

**Ear length (cm)**: it was recorded from 10 randomly taken ears from the net plot area and measured from the point where ears attached to the stalk to the tip of the ear with a glass ruler after harvest and the average was recorded.

**Ear diameter (cm)**: about 10 ears were taken randomly from the net plot area, and then their diameter was measured at the middle of the ear with a caliber ruler. The mean was recorded as ear diameter.

**Number of kernels ear**\(^{-1}\): it 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.

**Thousand kernels weight (g)**: about 1,000 kernels were randomly taken and counted by using kernel counter (Contador CE) from the bulk of threshed kernels in each net plot area, then weighed using sensitive balance and adjusted to 12.5% moisture level.

**Above-ground dry biomass yield (t ha**\(^{-1}\)****: plants were harvested from the net plot area, weighed using field balance (Salter Model-235), and recorded biomass yield at harvest.

### Table 1. Physical and chemical properties of the soil of the experimental site at Haramaya, Eastern Ethiopia

| Soil property          | Value | rate       | reference          |
|------------------------|-------|------------|--------------------|
| Sand (%)               | 62    |            |                    |
| Silt (%)               | 17    |            |                    |
| Clay (%)               | 21    |            |                    |
| **Textural class**     |       | Sandy clay loam | Rowell (1994)    |
| **pH (1:2.5 soil/water)** | 7.45 | Slightly alkaline | Jones (2003) |
| **Available P (ppm)**  | 62.8  | Moderate   | Olsen et al. (1954) |
| **K**                  | 0.94  | High       | Debele (1980)     |
| **Ca**                 | 1.88  | Very low   | FAO (2006)         |
| **Mg**                 | 2.6   | Medium     | FAO (2006)         |
| **Na**                 | 0.34  | Medium     | FAO (2006)         |
| **OM (%)**             | 2.3   | Low        | Tadesse (1991)    |
| **Total N (%)**        | 0.11  | Low        | Debele (1980)     |
| **CEC (meq/100 g soil)** | 39.33 | Medium     | Landon (1991)    |
Grain yield (t ha\(^{-1}\)): grain yield from the net plot area was weighed using field balance (Salter Model-235) and adjust to 12.5% moisture, finally, it was converted into hectare basis.

Harvest index: it was calculated as the ratio of grain yield to the total above-ground dry biomass yield per plot \(\times 100\).

2.5. Statistical data analysis
Growth parameters, yield components, and yield of maize data were analyzed by using Gen Stat statistical software Release 17 (VSN International, 2012). Both years’ data were analyzed separately and then F-test was done to test homogeneity according to Gomez and Gomez (1984). Based on test of homogeneity results, data were combined and analyzed. For significant treatment effects, mean separation was done using the least significance difference (LSD) test at 5% level of significance.

2.6. Partial budget analysis
The partial budget analysis were carried out by using the methodology described in Centro Internacional de Mejoramiento de Maíz y Trigo/International Maize and Wheat Improvement Center (CIMMYT) (1988) in which prevailing market prices for inputs at sowing and outputs at harvesting were used. Accordingly, average grain yields were adjusted downward by 10% to close yields obtained under farmers’ management.

3. Results and discussion

3.1. Selected physiochemical soil properties
The result of laboratory analysis of selected physical and chemical properties of soil is presented in Table 1.

3.2. Effect of blended NPS and N rates on growth parameters of hybrid maize varieties

3.2.1. Leaf area index
Combined analysis of variances showed that among treatments, main effect of variety had significant effect on leaf area index. Therefore, variety BHQPY545 had higher leaf area index (4.0) than MHQ138 (3.7) (Table 5). Probably, variety BHQPY545 produces more leaf width and length that attributed to produce more leaf area and leaf area index. Similar, results were reported by Ahmad et al. (2003), Abera et al. (2017), and Nagy (1984). This might be due to the difference in their genetic make up.

On top of this, interaction effect of NPS by year also had significant effect on leaf area index. Therefore, the maximum leaf area index (4.3) was obtained from 150 kg NPS application in 2019 where as the minimum (3.4) was found from the same rate in 2018 (Table 3). This could be due to high NPS may attribute to more vegetative growth as compared to low NPS. Besides, in 2019 cropping season there was good weather condition (Figure 1).

3.2.2. Plant height (cm)
The mean values of plant heights in two main cropping seasons were not consistent as result data were analyzed separately. Based on analysis of variances, only main effect of variety had a high significant effect on plant height during 2018 cropping season. The taller plant height (186.5 cm) was recorded from variety BHQPY545 while shorter plant height (172.0 cm) was obtained from variety MHQ138 (Table 5). This result was in line with Kandil (2013) who reported that significant variation was observed in plant height due to hybrid maize varieties. In addition, Radma and Dagash (2013) also reported that significant variation in plant heights was observed due to varieties. This is probably due to genetic variation in plant height.

The mean values of plant height also numerically varied due to different N application levels but statistically at par. As result, the mean values of plant height were linearly increased from 179.1 to
179.4 cm as N increased from 43.5 to 130.5 kg ha$^{-1}$. Similar result was reported by Cheema et al. (2010), Kandil (2013), Mitiku and Haileyesus (2016) as well as Getnet and Dugasa (2019) also reported that plant height of maize increased with N.

However, in the second cropping season (2019), plant height was significantly affected by interaction effect of variety by NPS and N but other effects were nonsignificant. The tallest plant height was recorded from variety BHQPY545 where plots fertilized with 50 kg NPS and 130.5 kg N ha$^{-1}$ whereas the shortest plant height was recorded from variety MHQ138 where plots received with 100 kg NPS and 43.5 kg N ha$^{-1}$(Table 2). This result implied that though there is varietal difference between two maize varieties, the responses of two hybrid maize varieties to both fertilizers rates are different. On the other hand, variety BHQPY545 is more responsive to N fertilizer whereas variety MHQ138 is more responsive to NPS fertilizer in case of plant height. The tallest plant height recorded at highest N rate might be nitrogen has beneficial effect on plant metabolism which affects physiological process of the crop and thereby increases the growth parameters (Jeet et al., 2012). This result was in harmonized with Workayehu (2000) who found that there was significant effect of P and N fertilizer on maize plant height. Similarly, Chimdessa (2016) also reported that application of blended fertilizer was significantly increased plant height as compared to the recommended NP fertilizers and the control. Yusuf et al. (2019) also stated that plant height varied due to varieties. Plant height increased as N increased, this could be attributed to a mere fact that higher rates of nitrogen may have caused rapid cell division and elongation (Shamim et al., 2015).

3.2.3. Ear height (cm)
Ear height was highly and significantly affected by main effect of variety and interaction of variety by year. As indicated in Table 4, significantly taller ear height (127.1 cm) was recorded from variety BHQPY545 in 2019 cropping season as compared to variety MHQ138 (77.8 cm) in 2018. In fact both varieties gave higher ear heights in 2019 as compared to 2018. This could be due to presence of regular distribution of rain fall throughout growing season in 2019. As N rates increased from 43.5 to 130.5 kg ha$^{-1}$ ear height was increased from 98.53 to 100.75 cm though significant variation was not recorded among rates. Similar results also reported by Olusegun (2015).

3.3. Effect of blended NPS and N rates on yield-related traits and yield of hybrid maize varieties

3.3.1. Number ears per plant
Number of ears per plant was highly and significantly affected by interaction effect of variety by year and N by year, respectively. Maximum number of ears per plant was produced from

| Variety   | NPS rate (kg ha$^{-1}$) | 43.5 | 87   | 130.5 |
|-----------|------------------------|------|------|-------|
| BHQPY545  | 50                     | 234.7$^{a}b$ | 231.3$^{ab}cde$ | 248.7$^{a}$ |
|           | 100                    | 232.7$^{abcde}$ | 237.3$^{abc}$ | 232.7$^{abcde}$ |
|           | 150                    | 205.7$^{ab}$ | 233.7$^{abcd}$ | 243.3$^{ab}$ |
| MHQ138    | 50                     | 209.7$^{defgh}$ | 211.7$^{defgh}$ | 207.7$^{efgh}$ |
|           | 100                    | 197.3$^{c}$ | 208.7$^{cgh}$ | 216.7$^{cd}$ |
|           | 150                    | 221.0$^{i}$ | 206.3$^{gh}$ | 201.0$^{gh}$ |

LSD (0.05) = 23.58
CV (%) = 6.4

Means in table with same letters are not statistically significant at 0.05 probability level. LSD = Least significance difference, CV = Coefficient of variation
BHQPY545 in 2019 while minimum number of ears per plant was produced from MHQ1308 in 2018 (Table 4). On the other hand, as described in Table 3, the maximum number of ears per plant was produced where plots treated with highest level of N (130.5 kg ha\(^{-1}\)) in 2019 cropping season. However, the minimum number of ears per plant was obtained where plots received with lowest level of N (43.5 kg ha\(^{-1}\)). As observed from mean values in 2018, there was no statistical disparity among N levels but significant disparity was observed in number of ears per plant due to N levels in 2019. In general, maximum number of ears per plant was produced in 2019 as compared to 2018. This is probably in 2018; physiological activity of the plant was disturbed due to ice falling at milking stage. In other words, leaves (sources) were highly torn due to ice falling, as result; an adequate carbohydrate was not translocated to the growing ears. This result is supported by Radma and Dagash (2013) significant variation was observed in number of ears per plant due to varieties and N levels.

### 3.3.2. Ear length (cm)

As combined data analysis of variance indicated that only main effect of variety had highly significant effect on ear length while other treatments were nonsignificant. Variety BHQPY545 was produced longer ear length (15.9 cm) while shorter ear length (15.3 cm) was produced from

### Table 3. Mean values of leaf area index and number of ears per plant as influenced by interaction effect of NPS and year as well as N by year

| Treatments | Leaf area index | Number of ears per plant |
|------------|----------------|--------------------------|
|            | Year           | 2018 | 2019 | 2018 | 2019 | 2018 | 2019 |
| NPS rate (kg ha\(^{-1}\)) | | | | | | | |
| 50         | 3.6\(\text{b}\) | 4.2\(\text{a}\) | 1.6 | 1.8 |
| 100        | 3.5\(\text{bc}\) | 4.2\(\text{a}\) | 1.4 | 1.9 |
| 150        | 3.4\(\text{c}\) | 4.3\(\text{a}\) | 1.6 | 1.8 |
| LSD (0.05) | 0.31 | NS |
| N rate (kg ha\(^{-1}\)) | | | | | | | |
| 43.5       | 3.5 | 4.1 | 1.45\(\text{d}\) | 1.79\(\text{d}\) |
| 87         | 3.5 | 4.3 | 1.59\(\text{c}\) | 1.75\(\text{b}\) |
| 130.5      | 3.5 | 4.2 | 1.52\(\text{cd}\) | 1.93\(\text{a}\) |
| LSD (0.05) | NS | 0.11 |
| CV (%)     | 7.4 | 10.2 |

Means in table with same letters are not statistically significant at 0.05 probability level. NS = Nonsignificant, LSD = Least significance difference, CV = Coefficient of variation

### Table 4. Mean values of ear height, number of ears per plant, and biomass yield as affected by interaction of variety by year

| Variety | Ear height | Number of ears per plant | Biomass yield (t ha\(^{-1}\)) |
|---------|------------|--------------------------|-----------------------------|
|         | Year       | 2018 | 2019 | 2018 | 2019 | 2018 | 2019 |
| BHQPY545 | 94.2\(\text{c}\) | 127.1\(\text{a}\) | 1.7\(\text{b}\) | 2.1\(\text{c}\) | 22.3\(\text{b}\) | 31.8\(\text{a}\) |
| MHQ138  | 77.8\(\text{d}\) | 99.2\(\text{b}\) | 1.4\(\text{c}\) | 1.6\(\text{b}\) | 17.1\(\text{b}\) | 21.2\(\text{a}\) |
| LSD (0.05) | 3.57 | 0.09 | 2.6 |
| CV (%) | 7.9 | 10.2 | 10.6 |

Means in table with same letters are not statistically significant at 0.05 probability level. LSD = Least significance difference, CV = Coefficient of variation
variety MHQ138 (Table 5). This could be due to genetic variation of two hybrid maize varieties for this trait. This result was similar to Arif et al. (2010) and Delibaltova et al. (2009).

3.3.3. Ear diameter (cm)
Analysis of variance indicated that ear diameter was significantly affected by interaction of variety × NPS × year, variety × N × year as well as NPS by N. As mean values indicated in Table 6, the thickest ear diameter (4.77 cm) was found from variety MHQ138 where plots fertilized with 100 kg NPS ha⁻¹ in 2019 while the thinnest ear diameter (4.35 cm) was obtained from variety BHQPY545 where plots fertilized with lowest NPS level (50 kg ha⁻¹) in 2018. The mean values in Table 6 is clearly showed that ear diameter produced from variety BHQPY545 was not significantly responded to different NPS levels in both seasons where as significant responses was observed from MHQ138 in both seasons.

Besides, three-way interaction of variety × N × year had significant effect on ear diameter. Therefore, variety MHQ138 gave the thickest ear diameter (4.73 cm) from the application of 87 kg N ha⁻¹ in 2019 but the thinnest ear diameter (4.33 cm) was obtained from BHQPY545 where plots

| Treatments       | NPS rate (kg ha⁻¹) | 2018      | 2019      |
|------------------|--------------------|-----------|-----------|
| BHQPY545         | 50                 | 4.35‴      | 4.46‴″    |
|                  | 100                | 4.38‴      | 4.46‴‴    |
|                  | 150                | 4.39‴      | 4.53‴‴    |
| MHQ138           | 50                 | 4.58‴‴      | 4.65‴‴    |
|                  | 100                | 4.39‴‴      | 4.77‴‴    |
|                  | 150                | 4.60‴‴      | 4.67‴‴‴‴    |
| N rate (kg ha⁻¹) |                    |           |           |
| BHQPY545         | 43.5               | 4.61‴‴‴‴      | 4.48‴‴‴‴    |
|                  | 87                 | 4.38‴‴‴‴      | 4.70‴‴‴‴    |
|                  | 130.5              | 4.33‴‴‴‴      | 4.50‴‴‴‴    |
| MHQ138           | 43.5               | 4.49‴‴‴‴‴‴      | 4.72‴‴‴‴‴‴    |
|                  | 87                 | 4.49‴‴‴‴‴‴‴‴      | 4.73‴‴‴‴‴‴    |
|                  | 130.5              | 4.60‴‴‴‴‴‴‴‴      | 4.65‴‴‴‴‴‴‴‴    |
| LSD (0.05)       | 0.12               |           |           |
| CV (%)           | 2.7                |           |           |

Means in table with same letters are not statistically significant at 0.05 probability level. LSD = Least significance difference, CV = Coefficient of variation
treated with 130.5 kg N in 2018 (Table 6). In variety BHQPY545 observed that the thickness of ear diameter was decreased as N rate increased in 2018 but not statistically significant. On the other hand, variety MHQ138 was well responded to different N levels as compared to BHQPY545 for this trait. This might be due to varietal disparity for response of different N levels.

Interaction effect of NPS by N was brought significant effect on ear diameter and the thickest ear diameter (4.60 cm) was obtained where plots treated with 150 kg NPS and 87 kg N ha$^{-1}$, however, the thinnest ear diameter (4.47 cm) was found where plots treated with 50 kg NPS and 43.5 kg N ha$^{-1}$ (Table 7). The thickest ear diameter produced from the highest levels of NPS and N is obviously due to the fact that more P is useful to root formations and extensions whereas N is useful to produce more leaves and undertake more photosynthesis. Therefore, more carbohydrates produced from leaves translocated to growing reproductive parts that attribute to better ear diameter. Similar results also reported by Olusegun (2015) ear diameter increased as P and N increased. Shamim et al. (2015) reported that ear diameter increased significantly up to a certain level of P and N rates.

### 3.3.4. Number of kernels per ear

Based on the analysis of variances, number of kernels per ear was significantly influenced by interaction of NPS × N × year but other effects were nonsignificant. Therefore, the maximum number of kernels per ear (540.1) was recorded where plots fertilized with 100 kg NPS and 87 kg N kg ha$^{-1}$ in 2019 where as the minimum number of kernels per ear (444.7) was recorded at the same rate of N but at the lowest NPS rate in 2018 (Table 8). Similarly, Maqsood et al. (2001) found that number of kernels per ear was increased as P and N increased to a certain level. This variation is probably NPS might have more contribution to number of kernels per ear as compared to N. Besides, as indicated in Table 8, at 43.5 and 87 N rates number of kernels per ear was increased as NPS increased from 50 to 100 kg then declined in 2019. Therefore, application of 100 kg NPS with 87 kg N was optimum rate to produce high number of kernels per ear in 2019 cropping season whereas application of 150 kg NPS by 87 kg N gave maximum number of kernels per ear in 2018. Therefore, response of ear diameter to NPS is different across seasons. Likewise, this may be due to larger cob size, proper pollination, translocation of sugars and starch, and finally proper grain set due to higher nitrogen fertilizer dose and high nitrogen use efficiency and sulfur provides better nutrition to reproductive parts being a qualitative nutrient.

### 3.3.5. Above-ground biomass yield (t ha$^{-1}$)

Interaction effect of variety by year as well as main effect NPS and N had significant effect on above-ground biomass yield where as other main and interaction effects were not statistically significant. Higher above-ground biomass yield (31.8 t ha$^{-1}$) was obtained from variety BHQPY545 during 2019 while lower above-ground biomass yield (17.1 t ha$^{-1}$) was obtained from variety MHQ138 in 2018 (Table 9). This result showed that the responses of above-ground biomass yield to growing seasons is quite different among and within varieties.

| NPS rate (kg ha$^{-1}$) | N rate (kg ha$^{-1}$) | Ear diameter (cm) |
|-------------------------|----------------------|-------------------|
| 50                      | 43.5                 | 4.47$^{b}$        |
| 100                     | 4.56$^{ab}$          | 4.48$^{a}$        |
| 150                     | 4.53$^{ab}$          | 4.60$^{a}$        |

LSD (0.05) = 0.1
CV (%) = 2.7

Means in table with same letters are not statistically significant at 0.05 probability level. LSD = Least significance difference, CV = Coefficient of variation
In 2019 cropping season, Baate gave 29.9% more biomass yield over 2018 whereas in variety MHQ138, above-ground biomass yield was increased by 19.3% in 2019 over 2018 (Table 9). In general, higher above-ground biomass yield was obtained in 2019 as compared to 2018 in both varieties. Above-ground biomass yield obtained from variety BHQPY545 is 46% higher than above-ground biomass yield obtained from variety MHQ138. This is mainly due to weather variability in both seasons and varietal difference between two varieties.

On the other hand, significant disparity was observed in biomass yield due to NPS and N levels. Therefore, application of the highest NPS (150 kg) level was given higher above-ground biomass yield (24.0 t ha\(^{-1}\)) where as lowest biomass yield (22.2 t ha\(^{-1}\)) was found where plots treated with the lowest NPS level (50 kg). Plots fertilized with 150 kg NPS gave 7.5% more biomass yield than where plots fertilized with 50 kg NPS (Table 9).

Similarly, the highest above-ground biomass yield (24.2 t ha\(^{-1}\)) was obtained from the highest N (130.5 kg) level and the lowest biomass yield (21.8 t ha\(^{-1}\)) was obtained where plots treated with the lowest N (43.5 kg). Above-ground biomass yield was increased by 5.6% and 9.9% from the application of 87 and 130.5 kg N over 43.5 kg N, respectively (Table 9). Generally, above-ground biomass yield was increased as both fertilizer increased. This result is in accordance with Ahmad et al. (2003).

### 3.3.6. Grain yield (t ha\(^{-1}\))

Both cropping season grain yield data were combined and analyzed. Therefore, combined data analyses of variances depicted that grain yield was significantly influenced by interaction of variety by N and year as well as NPS × N × year.

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**Table 8. Mean values of number of kernels per ear and grain yield as affected by three-way interactions of NPS × N × year**

| Number of kernels per ear | Treatments | N rate (kg ha\(^{-1}\)) | NPS rate (kg ha\(^{-1}\)) |
|---------------------------|------------|--------------------------|---------------------------|
|                           | Year       | 43.5                     | 87                        | 130.5                     |
|                           | 2018       | 50                       | 503.7\(^{abcd}\)          | 444.7\(^{f}\)             | 493.4\(^{bcde}\)          |
|                           |            | 100                      | 492.5\(^{bcde}\)          | 460.0\(^{df}\)            | 481.2\(^{cdef}\)          |
|                           |            | 150                      | 479.2\(^{cdef}\)          | 519.5\(^{abc}\)           | 460.6\(^{d}\)            |
|                           | 2019       | 50                       | 471.3\(^{cdef}\)          | 517.7\(^{abcd}\)          | 494.8\(^{abcde}\)         |
|                           |            | 100                      | 531.6\(^{ab}\)            | 540.1\(^{a}\)             | 495.5\(^{abcde}\)         |
|                           |            | 150                      | 511.1\(^{abcd}\)          | 530.1\(^{ab}\)            | 535.0\(^{ab}\)            |

LSD (0.05) = 45.5  
CV (%) = 8.2

| Grain yield (t ha\(^{-1}\)) | NPS rate (kg ha\(^{-1}\)) | N rate (kg ha\(^{-1}\)) |
|-----------------------------|---------------------------|--------------------------|
|                             | 2018                      | 50                       | 6.4\(^{g}\)              | 7.3\(^{defg}\)            | 8.3\(^{cd}\)              |
|                             |                           | 100                      | 6.6\(^{fg}\)             | 7.8\(^{cde}\)             | 8.1\(^{cde}\)            |
|                             |                           | 150                      | 7.6\(^{cdef}\)           | 7.2\(^{defg}\)            | 8.3\(^{cd}\)             |
|                             | 2019                      | 50                       | 8.2\(^{cde}\)            | 9.9\(^{ab}\)              | 10.3\(^{ab}\)            |
|                             |                           | 100                      | 10.0\(^{ab}\)            | 9.5\(^{a}\)               | 9.9\(^{ab}\)             |
|                             |                           | 150                      | 9.7\(^{b}\)              | 10.7\(^{a}\)              | 10.4\(^{ab}\)            |

LSD (0.05) = 1.0  
CV (%) = 9.8

Means in table with same letters are not statistically significant at 0.05 probability level. LSD = Least significance difference, CV = Coefficient of variation
Therefore, the highest grain yield (11.7 t ha\(^{-1}\)) was obtained from variety BHQPY545 where plots fertilized with the higher N application rate (87 kg) and nearly followed (11.3 t ha\(^{-1}\)) by 130.5 kg N application in 2019 cropping season. However, the lowest grain yield (6.4 t ha\(^{-1}\)) was found where plots treated with 43.5 kg N from variety MHQ138 in 2018 (Table 10). Obtaining thickest ear diameter and maximum number of kernels per ear at 87 kg N had a high contribution for giving high grain yield at 87 kg N. As presented in Table 10, grain yields were increased from 2018 to 2019 in both varieties at all fertilizer application levels. This is because in 2019 there was no ice falling and better amount as well as distribution of rainfall was recorded (Figure 1). However, grain yield from variety BHQPY545 was increased by 21.5% and 22.6% over MHQ138 in 2018 and 2019, respectively. This is due to varietal differences between two maize varieties. Similarly, Singh and Daoudi (2017) reported that grain yield of hybrid maize varieties was increased as N increased. Jena et al. (2015) also reported that grain yield was not affected by interaction effect of N by P but grain yield was increased as N increased.

In addition, significant grain yield variation was also observed due to interaction of NPS × N and year. Combined fertilizer application of 150 kg NPS by 87 kg N was produced the highest

| Variety   | Biomass (t ha\(^{-1}\)) | Grain yield (t ha\(^{-1}\)) | Harvest index (%) |
|-----------|-------------------------|----------------------------|------------------|
| BHQPY 545 | 27.0\(^{a}\)           | 9.9\(^{a}\)                | 35.0             |
| MHQ138    | 19.1\(^{b}\)           | 7.5\(^{b}\)               | 40.0             |
| LSD (0.05)| 0.9                    | 0.3                       | 2.0              |

| NPS rate (kg ha\(^{-1}\)) | Biomass (t ha\(^{-1}\)) | Grain yield (t ha\(^{-1}\)) | Harvest index (%) |
|---------------------------|-------------------------|----------------------------|------------------|
| 50                        | 22.2\(^{b}\)           | 8.4\(^{b}\)               | 39.0             |
| 100                       | 23.1\(^{ab}\)          | 8.7\(^{ac}\)             | 38.0             |
| 150                       | 24.0\(^{a}\)           | 9.0\(^{a}\)              | 38.0             |

| N rate (kg ha\(^{-1}\)) | Biomass (t ha\(^{-1}\)) | Grain yield (t ha\(^{-1}\)) | Harvest index (%) |
|--------------------------|-------------------------|----------------------------|------------------|
| 43.5                     | 21.8\(^{a}\)           | 8.1\(^{a}\)               | 37.0             |
| 87                       | 23.1\(^{a}\)           | 8.7\(^{ab}\)             | 38.0             |
| 130.5                    | 24.2\(^{a}\)           | 9.3\(^{a}\)              | 39.0             |
| LSD (0.05)               | 1.2                     | 0.4                       | NS               |

| CV (%)                   | 10.6                    | 9.8                       | 11.5             |

Means in columns with same letters are not statistically significant at 0.05 probability level. LSD = Least significance difference, CV = Coefficient of variation, NS = nonsignificant

Therefore, the highest grain yield (11.7 t ha\(^{-1}\)) was obtained from variety BHQPY545 where plots fertilized with the higher N application rate (87 kg) and nearly followed (11.3 t ha\(^{-1}\)) by 130.5 kg N application in 2019 cropping season. However, the lowest grain yield (6.4 t ha\(^{-1}\)) was found where plots treated with 43.5 kg N from variety MHQ138 in 2018 (Table 10). Obtaining thickest ear diameter and maximum number of kernels per ear at 87 kg N had a high contribution for giving high grain yield at 87 kg N. As presented in Table 10, grain yields were increased from 2018 to 2019 in both varieties at all fertilizer application levels. This is because in 2019 there was no ice falling and better amount as well as distribution of rainfall was recorded (Figure 1). However, grain yield from variety BHQPY545 was increased by 21.5% and 22.6% over MHQ138 in 2018 and 2019, respectively. This is due to varietal differences between two maize varieties. Similarly, Singh and Daoudi (2017) reported that grain yield of hybrid maize varieties was increased as N increased. Jena et al. (2015) also reported that grain yield was not affected by interaction effect of N by P but grain yield was increased as N increased.

In addition, significant grain yield variation was also observed due to interaction of NPS × N and year. Combined fertilizer application of 150 kg NPS by 87 kg N was produced the highest

Table 9. Mean values of biomass yield, grain yield, and harvest index as affected by main effect of variety, NPS and N

| Variety   | Biomass (t ha\(^{-1}\)) | Grain yield (t ha\(^{-1}\)) | Harvest index (%) |
|-----------|-------------------------|----------------------------|------------------|
| BHQPY 545 | 27.0\(^{a}\)           | 9.9\(^{a}\)                | 35.0             |
| MHQ138    | 19.1\(^{b}\)           | 7.5\(^{b}\)               | 40.0             |
| LSD (0.05)| 0.9                    | 0.3                       | 2.0              |

| NPS rate (kg ha\(^{-1}\)) | Biomass (t ha\(^{-1}\)) | Grain yield (t ha\(^{-1}\)) | Harvest index (%) |
|---------------------------|-------------------------|----------------------------|------------------|
| 50                        | 22.2\(^{b}\)           | 8.4\(^{b}\)               | 39.0             |
| 100                       | 23.1\(^{ab}\)          | 8.7\(^{ac}\)             | 38.0             |
| 150                       | 24.0\(^{a}\)           | 9.0\(^{a}\)              | 38.0             |

| N rate (kg ha\(^{-1}\)) | Biomass (t ha\(^{-1}\)) | Grain yield (t ha\(^{-1}\)) | Harvest index (%) |
|--------------------------|-------------------------|----------------------------|------------------|
| 43.5                     | 21.8\(^{a}\)           | 8.1\(^{a}\)               | 37.0             |
| 87                       | 23.1\(^{a}\)           | 8.7\(^{ab}\)             | 38.0             |
| 130.5                    | 24.2\(^{a}\)           | 9.3\(^{a}\)              | 39.0             |
| LSD (0.05)               | 1.2                     | 0.4                       | NS               |

| CV (%)                   | 10.6                    | 9.8                       | 11.5             |

Means in columns with same letters are not statistically significant at 0.05 probability level. LSD = Least significance difference, CV = Coefficient of variation, NS = nonsignificant

Table 10. Mean values of grain yield as affected by interaction of variety by N and year

| Variety   | N rate (kg ha\(^{-1}\)) | 2018     | 2019     |
|-----------|-------------------------|----------|----------|
| BHQPY 545 | 43.5                    | 7.2\(^{b}\) | 10.7\(^{a}\) |
|           | 7                       | 8.5\(^{ab}\) | 11.7\(^{a}\) |
|           | 130.5                   | 9.3\(^{c}\) | 11.5\(^{ab}\) |
| MHQ138    | 43.5                    | 6.4\(^{b}\) | 7.3\(^{ab}\) |
|           | 87                      | 6.6\(^{b}\) | 8.3\(^{ad}\) |
|           | 130.5                   | 7.3\(^{b}\) | 8.9\(^{cd}\) |

LSD (0.05) = 0.83
CV (%) = 9.8

Means in table with same letters are not statistically significant at 0.05 probability level. LSD = Least significance difference, CV = Coefficient of variation
grain yield and closely followed by combined fertilizer application of 150 kg NPS by 130.5 kg N in 2019 season (Table 8). However, plots fertilized with the lowest combination rate gave the lowest grain yield in 2018 cropping season. It was observed that combined application of 150 kg NPS by 87 kg ha\(^{-1}\) gave 11.2% more yield advantage than from existing recommendation rate (100 kg NPS by 87 kg) (Table 8). Similarly, Olusegun (2015) reported that application of the combination of N at 90 kg ha\(^{-1}\) and P at 30 kg ha\(^{-1}\) gave the highest grain yield of maize. This result is also in line with Ahmad et al. (2003) who stated that the highest grain yield was obtained from combined application of 150 kg N and 125 kg P. This is probably increased in grain yield per hectare in response to increasing levels of NPS and N is due to increased number of grains per ear and 1,000-grain weight. Similar, findings also found by Shamim et al. (2015).

As mean values indicated in Table 8 revealed that in 2019 cropping season grain yield was considerably increased as compared to 2018. This is perhaps, falling of ice at milking stage causes a significant yield reduction in 2018 cropping season. This result was in line with Nour and Lazin (2000) who found that grain yield was affected by interaction of P × N. Similar results also reported by Ali (1994).

3.3.7. Harvest index (%)
Harvest index was highly affected by main effect of variety but other effects were nonsignificant. The maximum harvest index (40%) was obtained from variety MHQ138 while the minimum harvest index (35%) was obtained from variety BHQPS545 (Table 9). This could be due to more photosynthetic assimilates converted into grain yield than vegetative growth in case of variety MHQ138 as compared to BHQPS545. Similarly, Ahmad et al. (2003) stated that there is significant variation on harvest index due to varieties.

3.4. Partial economic analysis
The partial budget analysis was applied on the average grain yields of two hybrid maize varieties to assess the most economically feasible rates of NPS and N according to the procedure described by CIMMYT (1988). Based on partial budget analysis of all treatments in both seasons, the highest net benefit (59562.0 ETB) or 1985.4 USD with highest marginal rate of return (1348.3%) was obtained where plots fertilized with 150 kg NPS with 130.5 kg N ha\(^{-1}\) in 2018 cropping season. On the other hand, in 2019 cropping season, the maximum net benefit (85458.0 ETB) or 2848.6 USD with the highest marginal rate of return (1658.6%) was obtained from combined application of 150 kg NPS with 87 kg N ha\(^{-1}\) which was by far economically more feasible as compared to 2018.

4. Conclusions
Application of 150 kg NPS with 87 kg N ha\(^{-1}\) gave maximum number of kernels per ear and thickest ear diameter in 2018 growing season. Likewise, the thickest ear diameter was obtained from MHQ138 from the application of 100 kg NPS with 87 kg N. Higher above-ground biomass yield was obtained in 2019 cropping season. Individual application of 150 kg NPS and 130.5 kg N gave maximum above-ground biomass yield. The highest grain yield (11.7 t ha\(^{-1}\)) was obtained from variety BHQPS545 where plots fertilized with the higher N application rate (87 kg) and nearly followed (11.5 t ha\(^{-1}\)) by 130.5 kg N application in 2019 cropping season. Besides, combined fertilizer application of 150 kg NPS by 87 kg N was produced the highest grain yield and closely followed by combined fertilizer application of 150 kg NPS by 130.5 kg N in 2019 season. According to partial budget analysis, the highest net benefit (85458.0 ETB) with higher marginal rate of return (1658.6%) was obtained from the combined application of 150 kg NPS with 87 kg N in 2019. Based on this result, it can be concluded that using of combined application of 150 kg NPS with 87 kg N in study area and other similar agroecologies are agronomically optimum and economically affordable levels to increase maize production.
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