Growth and yield of high protein corn (*Zea mays* L.) as influenced by plant spacing and NPK levels

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ABSTRACT

In crop production, major production variables that a producer can manipulate to influence the production of a given crop are agronomic practices, fertilizer levels and plant spacing which require special attention in the changing climatic condition. This study aimed to establish appropriate plant spacing and NPK levels. The following treatments were used: plant spacing (P1 70 cm × 20 cm; P2 60 cm × 25 cm; P3 60 cm × 20 cm) were used as the main treatments and the NPK levels (F1 100-40-20 kg ha\(^{-1}\); F2 130-40-20 kg ha\(^{-1}\); F3 160-40-20 kg ha\(^{-1}\); F4 100-40-60 kg ha\(^{-1}\); F5 130-40-60 kg ha\(^{-1}\); F6 160-40-60 kg ha\(^{-1}\)) were utilized as sub-treatments. Standard conventional procedure in corn production (land preparation, irrigation, weeding and pest management) (planting and fertilizer application is based on the treatments procedure) was followed throughout the duration of the study. The results of study showed that there was significant interaction effect of plant height, ear height, ear length and ear diameter, ear harvest per plot, kernel row per ear, number of kernels per ear, weight of 1000 kernels on growth and yield of high protein corn. Based on the results of the study, plant spacing of 60 cm × 25 cm and 60 cm × 20 cm and NPK levels at the rate of 130-40-60 kg NP\(_2\)O\(_5\)K\(_2\)O ha\(^{-1}\) and 160 – 40 – 60 kg NP\(_2\)O\(_5\)K\(_2\)O ha\(^{-1}\) increased growth and yield parameters (plant stand at harvest, plant height, days to tasseling, ear height, ear harvest per plant, kernel row per ear, number of kernels per row, ear length, weight of 1000 kernels, computed kernel yield and shelling recovery) and showed significant effects on the high protein corn. Application of fertilizer combinations during the crop production was effective which contributed to the increased yield.

Keywords: Plant spacing, NPK levels, high protein corn, climate change.

INTRODUCTION

The Philippines has been affected by globalization. Economically, it has to compete with other developed nations in the efficient production and marketing of agricultural products. It also has to contend with the increasing demand of the consumers with changing tastes and preferences. To meet this demand, innovative production methods applicable to our country economic conditions must be employed. Thus, the role of researchers is very important in attaining innovations in agricultural production to meet the demands of a fickle market (Damaso, 2013).

Corn (*Zea mays* L.), known as “Queen of cereals”, has the highest genetic yield potential among cereals. It is considered as one of the most versatile emerging crops having wider adaptability under varied agro-climatic conditions and successful cultivation in diverse seasons and ecologies for various purposes. White corn on the other hand, can be a substitute for rice and commonly referred to as the poor man’s rice, in places where rice is the main staple food. It is cultivated on nearly 150 M ha in about 160
countries having wider diversity of soil, climate, biodiversity and management practices that contributes 36% (782 Mt) of the global grain production (Rao, 2013). Corn is the only grain which is totally dependent on human intervention for survival and that exists in thousands of different varieties (Labios, 2010). Although seen as food for the less privileged, corn has high nutritional value. It is rich in protein, fat, fiber and other essential vitamins and minerals including folate, iron, niacin, phosphorus, magnesium, copper and zinc. Corn also contains two essential amino acids, lysine and tryptophan, which provide numerous health benefits (Salazar, 2016).

The plant spacing and NPK levels of corn production have great impact on climate change in agriculture. It adds significantly to the development and challenges of ensuring food security and reducing poverty. Increasing corn production has undergone constant change over the years with the purpose of enhancing crop yield. Increasing population density of plant is an agronomical practice that has been studied. This crop technique has evolved and will continue to evolve over the years and it is agronomic management factor that has changed (Tollenaar, 1992). Climate change urgently needs to be assessed at the level of the household, so that poor and vulnerable people dependent on agriculture can be appropriately targeted in research and development activities whose object is poverty alleviation.

**Statement of the problem**

After recognizing the value of white corn as a staple food, several government programs work alternatives to rice (Salazar, 2016). Example is the “Adaptation and Dissemination of Newly Developed Improved White Corn Varieties as Alternative Source of Staple Food”.

This study was established to support the production of white corn and to expand its promotion at a national level including the establishment of a more stable supply of white corn for the preferences of the different regions.

Practicing a reduced tillage system typically had problems related to the forming of natural compaction, which is common when proper rotation is not followed. The situation could even worsen under smallholder farming activities where recommended plant density depends on the quantity of seed obtained due to cost. Considering the high demand of white corn and the low production to variably narrow and wide spacing, intensity of high density of corn production and plant population is thus, influenced by factors such as yield level, the amount of solar radiation, light intensity and the weather conditions can affect the plant spacing and nutrient management (NPK levels). However, within – row plant spacing uniformity does impact the grain yield, which is relatively small, averaging about 1 – 2% (Doerge et al., 2002).

Proper fertilizer management strategy is very important for optimizing crop productivity, food production sustainability, maximizing farm economic returns and reducing the adverse impacts of nutrients on soil fertility, health and the environment. Among agronomic practices, planting technique is of considerable importance as proper adjustment of plants in the field does not only ensures optimum plant population but also enables the plants to utilize the land and other input resources more efficiently and resolutely towards growth and development (Imran et al, 2015).

Conducting a research study to increase production using the plant spacing and NPK levels can help farmers increase their yield; crop quality and can enhance the nutrient value of corn.

**Objectives of the study**

Generally, this study was conducted to evaluate the growth, yield performance and quality of high protein corn as influenced by plant spacing and nutrient management (NPK levels).

Specifically, it aimed to:

1. determine the growth and yield response of high protein corn under different NPK levels and plant spacing;
2. determine the interaction effect of plant spacing and NPK levels on the growth and yield of high protein corn; and
3. identify the plant population density of high protein corn that will give the highest yield.

**Time and place of the study**

This study was conducted at the Integrated Sustainable Agri-Techno Demo Farm (ISATDF) of Pangasinan State University-Sta. Maria Campus, Sta. Maria, Pangasinan from January 21 to May 5, 2017.

**MATERIALS AND METHODS**

**Land preparation**

A field with an area of 2,000 m² with a net area of 1,739 m², fairly leveled, well drained and suitable for corn growing was selected for this study. With the use of conventional tillage, the land was plowed twice with a one week interval to allow the weeds to germinate. The field was properly harrowed until the desired tilt was attained.

**Experimental design**

The experiment was laid out following the Split Plot in Randomized Complete Block Design (RCBD). The area was
equally divided into 3 blocks. Each block was subdivided into 3 plots that represent the main treatment (plant spacing). The resulting plots were further sub-divided into 6 sub-plots to represent the sub – treatment (nutrient management). Each plot had an area of 20 m², 4 m wide and 5 m long (4 m x 5 m), consists of 5 to 6 rows. A 1.5 m distance between blocks and 1 m between plots were provided and maintained to ensure full confinement of the applied fertilizers and for the wide provision of the root system and to avoid fertilizer absorption and contamination of adjacent plants. The treatments were as follows : Main Treatment – Plant Spacing: P₁ – 70 cm x 20 cm; P₂ – 60 cm x 25 cm; P₃ – 60 cm x 20 cm. Sub-Treatment – NPK Levels: F₁ – 100 – 40 – 20 kg ha⁻¹; F₂ – 130 – 40 – 20 kg ha⁻¹; F₃ – 160 – 40 – 20 kg ha⁻¹; F₄ – 100 – 40 – 60 kg ha⁻¹; F₅ – 130 – 40 – 60 kg ha⁻¹; F₆ – 160 – 40 – 60 kg ha⁻¹.

Source of plant materials

The Quality Protein Maize – IPB Var 6 was obtained from the University of the Philippines – Los Baños, Institute of Plant Breeding - Crop Science Cluster.

Quality Protein Maize (QPM) Var 6 is a new variety of high-yielding, protein-packed corn. This variety yielded 5.84, 5.45 and 4.47 t ha⁻¹ from Luzon, Visayas and Mindanao, respectively. They are harvestable after 105 days during dry season and 110 days during wet season with 76% shelling recovery. As to agronomic characteristics, the plant height of 196 cm on dry season and 217 cm for wet season, ear length is at 13.86 cm, with an excellent ear fill and with 14-16 kernel rows. It is resistant to lodging in spite of its relatively tall stature. Furthermore, the variety is resistant to insect pest and diseases (borer, rust, stalkrot and earworm). The variety has drooping leaves and therefore not suitable for high population density planting particularly during wet season. It performs better during dry season and gives adequate water supply particularly during the critical growth stages (Salazar, et al., 2017). Nutritional composition of QPM contains nearly twice as much usable protein specifically lysine (474.91 mg) and tryptophan (0.51 mg), crude fat (2.55 g), crude protein (10.76 g); crude fiber (3.85 g), total ash (1.60 g), starch (76.94%) and amyllose (32.30%). It has gel consistency of 32.50 mm, (hard, very flaky cooked grains). The values stated were compared to rice to QPM corn composites (Hurtada and Nagares, 2007).

Fertilizer application and management

Recommended application rate of fertilizer in the area was based on the residual nutrients in the soil. The Soil test values obtained from chemical analysis were used to formulate fertilizer recommendations. The rates of each treatment (NPK levels) were as follows: F₁ (100 – 40 – 20 kg ha⁻¹); F₂ (130 – 40 – 20 kg ha⁻¹); F₃ (160 – 40 – 20 kg ha⁻¹); F₄ (100 – 40 – 60 kg ha⁻¹); F₅ (130 – 40 – 60 kg ha⁻¹) and F₆ (160 – 40 – 60 kg ha⁻¹). Half of the requirement for Nitrogen with all the Phosphorous and Potassium requirement were applied at 10 DAE. The application of the remaining N and K₂O was done at 25 DAE. The fertilizer materials applied were the complete fertilizer (16-16-16), urea (46-0-0), ammophos (16-20-0) and muriate of potash (0-0-60).

Harvesting and post-harvest operation

The crops were harvested manually. This was done when the husk and silk were brownish in color and the ears were matured with kernels of hard starch layer, following the number of days of maturity (105 days). The ear was threshed manually the day after harvesting and was dried in a cement pavement.

Data gathered

1. Plant stand at harvest (%): This was recorded by counting the number of standing plants at harvest and was computed using the formula:

\[
\% \text{Plant stand} = \frac{\text{Actual number of standing plants at harvest}}{\text{Initial number of plants in harvestable area}} \times 100
\]

2. Plant height at harvest (cm): The average height of the plants in the plot was measured from ground level to the base of the tassel.

3. Days to tasseling (50% tasseling): This parameter was recorded by counting the days from emergence until 50 percent of the tassels have appeared in every plot.

4. Ear height (cm): Ten randomly selected plant samples were used to measure the ear height from the ground level up to the node bearing of the first lower ear.

5. Ear length (cm): The length of the ear was measured from the base to the tip of the ear of 10 randomly selected plant samples.

6. Ear diameter (cm): The ear diameter was measured at the mid-section of the ear using a Vernier caliper of 10 randomly selected plant samples.

7. Ear harvest per plot (%): This parameter was determined by counting the number of ears per plot at harvest and was computed using the formula:

\[
\% \text{Ear harvest per plot} = \frac{\text{Number of ear harvest per plot}}{\text{Actual of plants in harvestable area}} \times 100
\]

8. Kernel row per ear: Counting the average of 10 randomly selected corn ears was used to determine the kernel row per ear.
9. **Number of kernels per ear**: This parameter was determined by counting the average number of kernels per ear of 10 sample plants.

10. **Weight of 1000 kernels (kg)**: This was determined by weighing 1000 randomly selected kernels from each treatment combination. The weighing of 1000 kernels was adjusted at 14% moisture content using the formula:

\[
\text{Adjusted kernel yield at 14\% MC} = \frac{(100 - \text{Actual MC}) \times \text{Actual grain yield}}{86}
\]

Moisture content was determined using moisture meter (Kett® Grain Moisture Tester Ricter f511).

11. **Shelling recovery (SR) (%):** These were obtained by weighing dehusked harvested ears in each net plot before and after the kernels were detached from the cob. Shelling recovery was computed using the formula:

\[
\text{SR} = \frac{\text{Total weight of grains}}{\text{Total weight of the unshelled ears}} \times 100
\]

12. **Computed kernel yield (ton ha\(^{-1}\))**: This was determined by weighing the total seed yield per net plot and was converted to a hectare basis. The yield from the harvest area was computed per hectare and was adjusted to 14% MC using this formula:

\[
\text{Kernel yield/ha} = \frac{\text{Yield of net plots harvest (kg)}}{\text{Harvest area (sq.m)}} \times \frac{10,000 \text{ sq.m}}{1 \text{ ha}} \times \frac{1 \text{ ton}}{1000 \text{ kg}} \times \frac{100 - \text{MC}}{86}
\]

13. **Light intensity (Lux)**: This was recorded using the light meter. It measures the amount of light (20, 000 lux) received by the experimental plots from 45 to 60 DAE (maturity of tassel).

**Statistical analysis of data**

Data collected were organized, tabulated and analyzed using Analysis of Variance (ANOVA) for split plot in Randomized Complete Block Design (RCBD) except the agro-climatic parameters, soil analysis data and sensory attributes. The IRRI STAR (version 2.0.1) was used to run the ANOVA. Means were compared using Turkey’s Honest Significant Difference (HSD) Test at 0.05 level of confidence.

**RESULTS AND DISCUSSION**

**Plant stand at harvest (%)**

Table 1 shows the plant stand at harvest of high protein corn as influenced by plant spacing and NPK levels. The analysis of variance showed that the different NPK levels significantly \((p \leq 0.05)\) affected the plant stand at harvest but no significant interaction was noted between the plant spacing and NPK levels. The results showed that NPK levels at the rate of 160-40-60 kg N\(\text{P}_2\text{O}_5\text{K}_2\text{O}\) ha\(^{-1}\) significantly gave the highest plant survival with a mean of 98.99% within the harvested plot, while the lowest plant survival was recorded in NPK levels at the rate of 160-40-20 kg N\(\text{P}_2\text{O}_5\text{K}_2\text{O}\) ha\(^{-1}\) with a mean of 97.13%. Results of the study revealed that there was a significant difference on plant survival on NPK levels due to the condition of stem lodging increases and intense of interplant competition for incident photosynthetic photon flux density, soil nutrients and soil water. There is also a possibility that at narrower row spacing (with higher population density) smaller plants would crowd out and disappear. At lower population availability of more spaces might have resulted in less competition for resources (nutrients, moisture and light). Similar results were found in studies by Tollenaar (1992), Lemcoff and Loomis (1994), Sangoi and Salvador (1998), Abuzaret al. (2011); Zamiret al.(2011) and Parmar (2015).

**Plant height at harvest (cm)**

The interaction of plant height was significantly affected \((p \leq 0.01)\) by plant spacing and NPK levels (Table 2). Tallest plant with 263.98 cm was registered by plants planted at a distance of 60 cm \(\times\) 25 cm at the rate of 160-40-60 kg N\(\text{P}_2\text{O}_5\text{K}_2\text{O}\) ha\(^{-1}\). Results of the study revealed that the high amount of applied fertilizer (160-40-60 kg N\(\text{P}_2\text{O}_5\text{K}_2\text{O}\) ha\(^{-1}\)) compared to 100-40-20 kg N\(\text{P}_2\text{O}_5\text{K}_2\text{O}\) ha\(^{-1}\) and 130-40-20 kg N\(\text{P}_2\text{O}_5\text{K}_2\text{O}\) ha\(^{-1}\) improved the height of corn. The increase in plant height and the increase in the rate of nitrogen application could be attributed to positive effect of N on vigorous vegetative growth due to more availability of N throughout the growing period. The increase in plant height and increase of N application rate indicated maximum vegetative growth of the plants under higher N availability as nitrogen is essential for plant growth process including chlorophyll which is responsible for dark green color of stem and leaves which enhance vigorous vegetative growth, branching and or tillering. Adequate quantity of fertilizer and row spacing might have enhanced the cell elongation, cell division, photosynthesis and translocation of photosynthesis to respective part of growth and development and thus resulted in more plant height. These results are similar to those reported in studies by Abmad (1980), Javed et al. (1985) and Bakht et al., (1989), Anjum et al. (1992), Gasim (2001), Nanjappa et al. (2001), and Kumar and Singh (2002) who showed that plant height increased, indicating that the nitrogen fertilizer promoted plant growth, increased the number of internodes and length of the internodes which resulted in progressive increase in plant height.
Analysis showed that the plant density that allowed the highest ear height of high protein corn was recorded at a distance of 70 cm × 20 cm at the rate of 130-40-60 kg NPK ha⁻¹ with a mean of 90.13 cm, while the shortest ear height was recorded for plants planted at a distance of 60 cm × 25 cm at the rate of 100-40-20 kg NPK ha⁻¹ with a mean of 85.90 cm. Generally, this trend indicated consistent increment in ear height with increment of different fertilizer rates and plant spacing. An increase in ear height at higher NPK levels could be attributed to lower competition for nutrient that allowed the plants to accumulate more biomass with higher capacity to convert more photosynthesis resulting in taller ear height. This result is also similar findings of Jehan et al. (2006), Ali and Raouf (2012), Maral et al. (2012), Imran et al. (2015) and Ayman and Samier (2015).

**Ear length**

The ear length of high protein corn as influenced by plant spacing and NPK levels is shown in Table 5. The plant spacing, NPK levels and its interaction significantly affected (p ≤ 0.01) ear height of high protein corn. The tallest ear height was recorded for plants planted at a distance of 60 cm × 20 cm at the rate of 130-40-60 kg NPK ha⁻¹ with a mean of 90.13 cm, while the shortest ear height was recorded for plants planted at a distance of 60 cm × 25 cm at the rate of 100-40-20 kg NPK ha⁻¹ with a mean of 85.90 cm. Generally, the trend indicated consistent increment in ear height with increment of different fertilizer rates and plant spacing. An increase in ear height at higher NPK levels could be attributed to lower competition for nutrient that allowed the plants to accumulate more biomass with higher capacity to convert more photosynthesis resulting in taller ear height. This result is also similar findings of Jehan et al. (2006), Ali and Raouf (2012), Maral et al. (2012), Imran et al. (2015) and Ayman and Samier (2015).

### Days to tasseling (50% tasselng)

Data regarding the number of days to tasseling (50% tasselng) are reported in Table 3. Analysis showed that NPK levels significantly affected (p ≤ 0.05) the days to tasseling (Appendix Table 3). However, no significant interaction was noted between plant spacing and NPK levels. Fertilizer 6 at the rate of 160-40-60 kg NPK ha⁻¹ registered the longest days in terms of tasseling with a mean of 61.21, while Fertilizer 1 at the rate of 100-40-20 kg NPK ha⁻¹ registered the shortest days in terms of tasseling with a mean of 59.49. Mean values of the data showed that increasing the fertilizer levels consistently increased the number of days to tasseling. The different treatment combination of fertilizer application enhanced the time to reach 50% tasseling. The nutrients might have reduced the rate of phenological development that ultimately delayed maturity period and that the application of mineral N sustained leaf photosynthesis during active crop growth stage and extended the duration of vegetative growth (days to tasseling). It clearly indicated that ever-increasing nitrogen levels have momentous effect on growth, development, and yield parameters. These results are similar to the findings of Cassman et al. (2003), Orkaido (2004), Akmal et al. (2010), Geremewu (2009); Kawser et al. (2012), Hafiz et al. (2012), Jiban (2013) and Imran et al. (2015).

### Ear height

The ear height of high protein corn as influenced by plant spacing and NPK levels is shown in Table 4. The analysis of variance showed that plant spacing, NPK levels and its interaction significantly affected (p ≤ 0.01) ear height of high protein corn. The tallest ear height was recorded for plants planted at a distance of 60 cm × 20 cm at the rate of 130-40-60 kg NPK ha⁻¹ with a mean of 90.13 cm, while the shortest ear height was recorded for plants planted at a distance of 60 cm × 25 cm at the rate of 100-40-20 kg NPK ha⁻¹ with a mean of 85.90 cm. Generally, this trend indicated consistent increment in ear height with increment of different fertilizer rates and plant spacing. An increase in ear height at higher NPK levels could be attributed to lower competition for nutrient that allowed the plants to accumulate more biomass with higher capacity to convert more photosynthesis resulting in taller ear height. This result is also similar findings of Jehan et al. (2006), Ali and Raouf (2012), Maral et al. (2012), Imran et al. (2015) and Ayman and Samier (2015).
Table 3: Days to tasseling (50% tasseling) of high protein corn as influenced by plant spacing and NPK levels.

<table>
<thead>
<tr>
<th>Plant spacing</th>
<th>NPK levels</th>
<th>Mean</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>F1</td>
<td>F2</td>
</tr>
<tr>
<td>P1 (70cm × 20cm)</td>
<td>59.53</td>
<td>60.57</td>
</tr>
<tr>
<td>P2 (60cm × 25cm)</td>
<td>59.13</td>
<td>60.03</td>
</tr>
<tr>
<td>P3 (60cm × 20cm)</td>
<td>59.80</td>
<td>60.33</td>
</tr>
<tr>
<td><strong>Mean</strong></td>
<td>59.49</td>
<td>60.31</td>
</tr>
</tbody>
</table>

*Means with the same letter(s) are not significantly different at 1% level, HSD.

Table 4: Ear height (cm) of high protein corn as influenced by plant spacing and NPK levels.

<table>
<thead>
<tr>
<th>Plant spacing</th>
<th>NPK levels</th>
<th>Mean</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>F1</td>
<td>F2</td>
</tr>
<tr>
<td>P1 (70cm × 20cm)</td>
<td>86.13</td>
<td>89.73</td>
</tr>
<tr>
<td>P2 (60cm × 25cm)</td>
<td>85.30</td>
<td>88.00</td>
</tr>
<tr>
<td>P3 (60cm × 20cm)</td>
<td>88.17</td>
<td>87.33</td>
</tr>
<tr>
<td><strong>Mean</strong></td>
<td>86.53</td>
<td>88.36</td>
</tr>
</tbody>
</table>

*Means with the same letter(s) are not significantly different at 1% level, HSD.

Table 5: Ear length (cm) of high protein corn as influenced by plant spacing and NPK levels.

<table>
<thead>
<tr>
<th>Plant spacing</th>
<th>NPK levels</th>
<th>Mean</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>F1</td>
<td>F2</td>
</tr>
<tr>
<td>P1 (70cm × 20cm)</td>
<td>18.27</td>
<td>17.50</td>
</tr>
<tr>
<td>P2 (60cm × 25cm)</td>
<td>19.00</td>
<td>20.50</td>
</tr>
<tr>
<td>P3 (60cm × 20cm)</td>
<td>19.27</td>
<td>18.97</td>
</tr>
<tr>
<td><strong>MEAN</strong></td>
<td>18.84</td>
<td>18.99</td>
</tr>
</tbody>
</table>

*Means with the same letter(s) are not significantly different at 5% level, HSD.

effect on the formation of ear length. This can be attributed to the effects of inter plants competition for light, water, nutrient and other potential environmental factors. Similar results were observed in the findings of Sangoi (2000), Adeniyan (2005) and Khah et al. (2012).

Ear diameter (cm)

Table 6 shows the ear diameter of high protein corn as influenced by plant spacing and NPK levels. The analysis of variance showed that plant spacing, NPK levels and its interaction significantly (p ≤0.05) affected ear diameter of high protein corn. Bigger ear diameter was registered in plants planted with a distance of 60 cm × 25 cm at the rate of 160-40-60 kg N,P,O,K;O ha−1 with a mean of 4.50 cm, while the smallest ear diameter was registered from plants planted with a distance of 60 cm × 20 cm at the rate of 160-40-20 kg N,P,O,K;O ha−1 with a mean of 4.02 cm. The result showed that higher plant density due to the comparatively less competition for resources of the plants resulted to a significant size of ear diameter. The greater plant population per unit area at this condition means that the plants competed for nutrients, sunlight, water and space for good growth and development and effective suppression of fertilizer levels and plant spacing of the corn. These results were consistent with the findings of Akman (2002) that reported plant densities affecting ear diameter and thinner ears obtained at high densities.

Ear harvest per plot (%)

Presented in Table 7 is the ear harvest per plot of high protein corn. The analysis of variance showed that the NPK levels significantly (p ≤0.05) affected the ear harvest per plot, but no significant interaction was observed between plant spacing and NPK levels. The maximum ears harvest per plot was recorded at Fertilizer 6 with a mean of 101.29%, while the minimum ear harvest per plot was recorded at Fertilizer 1 with a mean of 98.33%. The increase in ear harvest per plot with higher nitrogen rate due to the increased uptake of all the nutrients that helps the translocation of photosynthetic materials and the
quantity of fertilizer combinations applied showed the positive effect of number of ear produced. However, the nutrient management affects the significant reduction in ear harvest per plot due to the supply of nitrogen, photosynthesis and water to the growing ear. Similar results were observed in the findings of Nandal and Agarwal (1989), Bangarwa et al. (1992), Roy and Biswas (1990), and Hashemi-Dezfouli and Herbert (1992).

Kernel row per ear

Table 8 shows the kernel row per ear of high protein corn as influenced by plant spacing and NPK levels. The analysis of variance showed that plant spacing, NPK levels and its interaction significantly ($p \leq 0.01$) affected the kernel row per ear of high protein corn. The highest number of kernel row per ear was recorded by plants planted at a distance of 60 cm × 25 cm at the rate of 160-40-60 kg NPK ha$^{-1}$ with a mean of 18.93, while the lowest number of kernel row per ear was recorded by plants planted at a distance of 60 cm × 20 cm at the rate of 100-40-60 kg NPK ha$^{-1}$ with a mean of 14.50. The increase of kernel per row affected by plant spacing and NPK levels could be attributed to the plant competition at higher plant densities leading to availability of nutrients that affect the increase of kernel formation. These results are further claimed by Bavec and Bavec (2002), Baron (2006), Abuzar et al. (2001) and Niket al. (2012).

Number of kernels per ear

Presented in Table 9 is the number of kernels per ear of high protein corn as influenced by plant spacing and NPK levels. The analysis of variance showed that plant spacing, NPK levels and its interaction significantly ($p \leq 0.01$) affected the number of kernels per ear of high protein corn. The highest number of kernels per ear was recorded for plants planted at a distance of 70 cm × 20 cm at the rate of 1160.73 kg ha$^{-1}$ with a mean of 1160.73, while the lowest number of kernel per ear was recorded for plants planted at a distance of 70 cm × 20 cm at the rate of 672.23. Results showed that the increased in number of kernels per ear was due to higher NPK levels with average competition for nutrients and other growth factors credited to the plant population density. It allowed the accumulation of more biomass, caused by the assimilation of absorbed nutrients from the soil that affects the kernel formation. These results are in agreement with the findings of Khan et al. (2012), Below et al. (2000), Fanadzoet al. (2010), Muhammad et al. (2010), Masood et al. (2011), Ali and Raouf (2012), Subbaiah (2013) and Ayman and Samier (2015).

Weight of 1000 kernels (kg)

Table 10 shows the weight of 1000 kernels of high protein corn as influenced by plant spacing and NPK levels. The analysis of variance showed that plant spacing, NPK levels and its interaction significantly ($p \leq 0.05$) affected weight of 1000 kernels of high protein corn. The heaviest weight of 1000 kernels was recorded by plants planted at a distance of 70 cm × 20 cm at the rate of 100-40-60 kg NPK ha$^{-1}$ with a mean of 0.302 kg, while the lightest weight of 1000 kernels was recorded for plants planted at a distance of 70 cm × 20 cm at the rate of 100-40-60 kg NPK ha$^{-1}$ with a mean of 0.302 kg.
cm × 20 cm at the rate of 160-40-60 kg \(\text{NP}_2\text{O}_5\text{K}_2\text{O}\) ha\(^{-1}\) with a mean of 0.259 kg. The significant results showed that the determinative effect of moisture availability in the forthcoming grain filling, providing relatively favorable moisture conditions for the major part of the growing season was due to partly less competition for water, light, plant spacing (wider) and fertilizer levels which assimilate the kernels during the process of kernel filling. The results obtained are also in line with the study of Ahmad (1980), NeSmith and Ritchie (1992), Lemcoff and Loomis (1994), Arif et al. (2006), Luque et al. (2006) and Zamiret al. (2011).

### Shelling recovery (SR) (%)

Table 11 shows the shelling recovery as influenced by plant spacing and NPK levels. The NPK levels significantly \((p < 0.05)\) affected the shelling recovery of high protein corn, but no significant interaction was observed between the plant spacing and NPK levels. The highest shelling recovery applied with different NPK levels was recorded to Fertilizer 4 at the rate of 100-40-60 kg \(\text{NP}_2\text{O}_5\text{K}_2\text{O}\) ha\(^{-1}\) with a mean of 82.10%, while the lowest shelling recovery applied with different NPK levels was recorded to Fertilizer 6 at the rate of 160-40-60 kg \(\text{NP}_2\text{O}_5\text{K}_2\text{O}\) ha\(^{-1}\) with a mean of 79.49%. In terms of plant spacing, plants planted at a distance of 60 cm × 25 cm obtained the highest shelling recovery with a mean of 82.01%, while plants planted at a distance of 70 cm × 20 cm garnered the lowest shelling recovery with a mean of 79.79%. The results of the study showed that the kernel formation was highly and strongly affected by different treatment combinations especially the NPK levels and since increase of percentage of shelling recovery had a greater improvement corresponding to the economic yield and there was more availability of growth factors and better penetration of light at wider row spacing. In line with this results were reported by Casmanet al.(2003), Pagano and Maddoni (2007), Tahmasbi and Mohasel (2010) and Salazar et al. (2017) that the average corn shelling recovery posed a yield increment of 68 to 76%.

### Computed kernel yield (ton ha\(^{-1}\))

Presented in Table 12 is the computed kernel yield of high

---

### Table 8: Kernel row per ear of high protein corn as influenced by plant spacing and NPK levels.

<table>
<thead>
<tr>
<th>Plant spacing</th>
<th>F1</th>
<th>F2</th>
<th>F3</th>
<th>F4</th>
<th>F5</th>
<th>F6</th>
<th>Mean</th>
</tr>
</thead>
<tbody>
<tr>
<td>P1 (70 cm × 20 cm)</td>
<td>17.45abc</td>
<td>16.27abc</td>
<td>15.27abc</td>
<td>16.27abc</td>
<td>16.50abc</td>
<td>16.27abc</td>
<td>16.40abc</td>
</tr>
<tr>
<td>P2 (60 cm × 25 cm)</td>
<td>16.55abc</td>
<td>16.27abc</td>
<td>15.27abc</td>
<td>16.27abc</td>
<td>16.50abc</td>
<td>16.27abc</td>
<td>16.40abc</td>
</tr>
<tr>
<td>P3 (60 cm × 20 cm)</td>
<td>15.27abc</td>
<td>16.27abc</td>
<td>15.27abc</td>
<td>16.27abc</td>
<td>16.50abc</td>
<td>16.27abc</td>
<td>16.40abc</td>
</tr>
</tbody>
</table>

*Means with the same letter(s) are not significantly different at 5% level, HSD.

### Table 9: Number of kernels per ear of high protein corn as influenced by plant spacing and NPK levels.

<table>
<thead>
<tr>
<th>Plant spacing</th>
<th>F1</th>
<th>F2</th>
<th>F3</th>
<th>F4</th>
<th>F5</th>
<th>F6</th>
<th>Mean</th>
</tr>
</thead>
<tbody>
<tr>
<td>P1 (70 cm × 20 cm)</td>
<td>17.45abc</td>
<td>16.27abc</td>
<td>15.27abc</td>
<td>16.27abc</td>
<td>16.50abc</td>
<td>16.27abc</td>
<td>16.40abc</td>
</tr>
<tr>
<td>P2 (60 cm × 25 cm)</td>
<td>16.55abc</td>
<td>16.27abc</td>
<td>15.27abc</td>
<td>16.27abc</td>
<td>16.50abc</td>
<td>16.27abc</td>
<td>16.40abc</td>
</tr>
<tr>
<td>P3 (60 cm × 20 cm)</td>
<td>15.27abc</td>
<td>16.27abc</td>
<td>15.27abc</td>
<td>16.27abc</td>
<td>16.50abc</td>
<td>16.27abc</td>
<td>16.40abc</td>
</tr>
</tbody>
</table>

*Means with the same letter(s) are not significantly different at 1% level, HSD.

### Table 10: Weight of 1000 kernels (kg) of high protein corn as influenced by plant spacing and NPK levels.

<table>
<thead>
<tr>
<th>Plant spacing</th>
<th>F1</th>
<th>F2</th>
<th>F3</th>
<th>F4</th>
<th>F5</th>
<th>F6</th>
<th>Mean</th>
</tr>
</thead>
<tbody>
<tr>
<td>P1 (70 cm × 20 cm)</td>
<td>17.45abc</td>
<td>16.27abc</td>
<td>15.27abc</td>
<td>16.27abc</td>
<td>16.50abc</td>
<td>16.27abc</td>
<td>16.40abc</td>
</tr>
<tr>
<td>P2 (60 cm × 25 cm)</td>
<td>16.55abc</td>
<td>16.27abc</td>
<td>15.27abc</td>
<td>16.27abc</td>
<td>16.50abc</td>
<td>16.27abc</td>
<td>16.40abc</td>
</tr>
<tr>
<td>P3 (60 cm × 20 cm)</td>
<td>15.27abc</td>
<td>16.27abc</td>
<td>15.27abc</td>
<td>16.27abc</td>
<td>16.50abc</td>
<td>16.27abc</td>
<td>16.40abc</td>
</tr>
</tbody>
</table>

*Means with the same letter(s) are not significantly different at 5% level, HSD.
protein corn as influenced by plant spacing and NPK levels. The analysis of variance showed that the NPK levels significantly ($p \leq 0.05$) affected computed kernel yield of high protein corn, but no significant interaction was observed between plant spacing and NPK levels. Results showed that Fertilizer 6 at the rate of 160-40-60 kg NP$_2$O$_5$K$_2$O ha$^{-1}$produced higher yield with a mean of 4.115 t ha$^{-1}$, while Fertilizer 2 at the rate of 130-40-20 kg NP$_2$O$_5$K$_2$O ha$^{-1}$registered the lowest produced yield with a mean of 3.426 t ha$^{-1}$. The results showed that the kernel yield was significantly influenced by different fertilizer levels due to high plant density that can be ascribed to more number of plants and number of ears produced per unit area. Increase in kernel yield at optimum planting densities can be attributed the availability of more nutrients which led to more growth and development of kernels. Similar results were obtained by Bangarwa et al. (1988), Khalil et al. (1988), Farnham (2001), Aziz et al. (2007), Khan et al. (2012) and Khah et al. (2012).

Light intensity (Lux)

Table 13a-d shows the light intensity of high protein corn as influenced by plant spacing and NPK levels. Table 13a and b shows the middle position of light intensity at AM and PM. The analysis of variance showed that NPK levels significantly ($p \leq 0.05$) affected the light intensity middle position at AM and PM, but no significant interaction was observed between plant spacing and NPK levels. The results showed that Fertilizer 4 at the rate of 100-40-60 kg NP$_2$O$_5$K$_2$O ha$^{-1}$was observed with the highest light intensity at middle position (AM) with a mean of 838.51 Lux, while the lowest light intensity at middle position (AM) was recorded at Fertilizer 1 at the rate of 100-40-20 kg NP$_2$O$_5$K$_2$O ha$^{-1}$with a mean of 765.69 Lux. However, in terms of light intensity middle position (PM), Fertilizer 1 at the rate of 100-40-20 kg NP$_2$O$_5$K$_2$O ha$^{-1}$was observed with the highest light intensity at middle position (PM) with a mean of 752.47 Lux, while the lowest light intensity at middle position (PM) was registered at Fertilizer 6 at the rate of 160-40-60 kg NP$_2$O$_5$K$_2$O ha$^{-1}$with a mean of 649.00 Lux.

Table 13c shows the light intensity at bottom portion (AM). The analysis of variance showed that plant spacing, NPK levels and its interaction significantly ($p \leq 0.01$) affected the light intensity of bottom position at AM of high protein corn. Plant spacing at 70 cm × 20 cm at the rate of 100-40-60 kg NP$_2$O$_5$K$_2$O ha$^{-1}$registered the highest light intensity at bottom position (AM) with 544.20 Lux, followed by plants planted at a distance of 70 cm × 20 cm at the rate of 160-40-20 kg NP$_2$O$_5$K$_2$O ha$^{-1}$registered the lowest light intensity at bottom position (AM) with 410.07 Lux.

Table 13d shows the light intensity at bottom position (PM). The analysis of variance showed that plant spacing significantly ($p \leq 0.01$) affected the light intensity of bottom position at PM, but no significance was noted in terms of NPK levels and its interaction. The highest light intensity was recorded for plants planted at a distance of 60 cm × 25 cm with a mean of 431.56 Lux, while the lowest light intensity was recorded for plants planted at a distance of 60 cm × 20 cm with a mean of 374.98 Lux.

The results of this study showed that the light intercepted was significantly lower in plants planted at a distance of 70 cm × 20 cm and increased as the plant density decreased at...
Table 13a: Middle position (AM) of light intensity (Lux) of high protein corn as influenced by plant spacing and NPK levels.

<table>
<thead>
<tr>
<th>Plant spacing</th>
<th>NPK levels</th>
<th>Mean</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>F1</td>
<td>F2</td>
</tr>
<tr>
<td>P1 (70cm × 20cm)</td>
<td>768.67</td>
<td>794.47</td>
</tr>
<tr>
<td>P2 (60cm × 25cm)</td>
<td>742.07</td>
<td>796.27</td>
</tr>
<tr>
<td>P3 (60cm × 20cm)</td>
<td>786.33</td>
<td>822.27</td>
</tr>
<tr>
<td>Mean</td>
<td>765.69b</td>
<td>804.33ab</td>
</tr>
</tbody>
</table>

Means with the same letter(s) are not significantly different at 5% level, HSD.

Table 13b: Middle position (PM) of light Intensity (Lux) of high protein corn as influenced by plant spacing and NPK levels.

<table>
<thead>
<tr>
<th>Plant spacing</th>
<th>NPK levels</th>
<th>Mean</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>F1</td>
<td>F2</td>
</tr>
<tr>
<td>P1 (70cm × 20cm)</td>
<td>715.47</td>
<td>753.33</td>
</tr>
<tr>
<td>P2 (60cm × 25cm)</td>
<td>779.07</td>
<td>677.33</td>
</tr>
<tr>
<td>P3 (60cm × 20cm)</td>
<td>762.87</td>
<td>730.60</td>
</tr>
<tr>
<td>Mean</td>
<td>752.47a</td>
<td>720.42ab</td>
</tr>
</tbody>
</table>

Means with the same letter(s) are not significantly different at 5% level, HSD.

Table 13c: Bottom position (AM) of light Intensity (Lux) of high protein corn as influenced by plant spacing and NPK levels.

<table>
<thead>
<tr>
<th>Plant spacing</th>
<th>NPK levels</th>
<th>Mean</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>F1</td>
<td>F2</td>
</tr>
<tr>
<td>P1 (70cm × 20cm)</td>
<td>496.73b</td>
<td>459.80ab</td>
</tr>
<tr>
<td>P2 (60cm × 25cm)</td>
<td>426.53b</td>
<td>430.00b</td>
</tr>
<tr>
<td>P3 (60cm × 20cm)</td>
<td>509.33a</td>
<td>507.53a</td>
</tr>
<tr>
<td>Mean</td>
<td>477.53</td>
<td>465.78</td>
</tr>
</tbody>
</table>

Means with the same letter(s) are not significantly different at 1% level, HSD.

Table 13d: Bottom position (PM) of light Intensity (Lux) of high protein corn as influenced by plant spacing and NPK levels.

<table>
<thead>
<tr>
<th>Plant spacing</th>
<th>NPK levels</th>
<th>Mean</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>F1</td>
<td>F2</td>
</tr>
<tr>
<td>P1 (70cm × 20cm)</td>
<td>372.13</td>
<td>408.27</td>
</tr>
<tr>
<td>P2 (60cm × 25cm)</td>
<td>476.93</td>
<td>429.33</td>
</tr>
<tr>
<td>P3 (60cm × 20cm)</td>
<td>343.13</td>
<td>374.20</td>
</tr>
<tr>
<td>Mean</td>
<td>397.40</td>
<td>403.93</td>
</tr>
</tbody>
</table>

Means with the same letter(s) are not significantly different at 5% level, HSD.

A distance of 60 cm × 25 cm. Based on the results of light intensity of the plants, the actual amount of light intercepted by a plant crown at any one point in time is a function of: (1) the angular distribution of light intensity around the crown (light directionality); and (2) the spatial distribution of leaves within the crown. Therefore, light interception by individual crown changes with time of day, atmospheric conditions, and season. According to Zhang et al. (2006), increasing plant density is one of the ways to increase the capture of solar radiation within the canopy. However, with the efficiency of the conservation of intercepted solar radiation into the maize, yield decreases with a high plant population density because of mutual shading in the plants.

CONCLUSIONS

Based on the results of the study, plant spacing of 60 cm × 25 cm and 60 cm × 20 cm and NPK levels at the rate of 130-40-60 kg NP2O5K2O ha⁻¹ and 160 – 40 – 60 kg NP2O5K2O...
ha$^{-1}$ increased growth parameters (plant stand at harvest, plant height, days to tasseling, ear height), and yield and yield components (ear harvest per plant, kernel row per ear, number of kernels per row, ear length, weight of 1000 kernels, computed kernel yield and shelling recovery) showed significant effects on the high protein corn. Application of fertilizer combinations during the crop production was effective which contributed to the increased yield. This indicated that supplemental fertilizer combinations (chemical fertilizers) also improved and nurtured the plant growth and development, thus higher yield was attained. The correlation coefficient between the light intensity and computed kernel yield is influenced by plant spacing and NPK levels. Results showed that there is a moderately negative relationship between kernel yield and light intensity at middle PM (45 to 65 DAE until maturity of tassel) as shown by the r-value of -0.3285 with corresponding p-value of 0.0167.

REFERENCES


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