Maize Response to Population under High Levels of Nitrogen Fertilization

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INTRODUCTION

Maize or corn is the third most important staple food crop in terms of area and production after wheat and rice in Egypt. Also, in the world, it is one of the important cereal crops in the world after wheat and rice (Gerpacio and Pingali, 2007).

The plant population is an important factor that affects crop yield. The yield was increased by 4% with increasing plant density (Shapiro and Wortmann, 2006). Higher plant density produces 25% more grain yield and 38% more biomass as compared with low plant density and early sown crop produce 19% more grain yield and 11% more biomass than late-planted crop (Abdul-Rehman et al., 2007).

Matching the functions of optimum plant density and adequate N fertilizer application to produce the highest possible yields with the greatest maize hybrid efficiency has been the aim of many researchers (Bahatt, 2012; Clark, 2013; Tajul et al., 2013). Modern hybrids have shown tendencies to withstand higher levels of stresses (such as low N and high plant densities), allowing them to better sustain suitable photosynthetic rates and sufficient assimilate supplies and to maintain plant growth rates attributable to enhanced...
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nitrogen use efficiency (O’Neill et al., 2004).

Cultural practices can play an important role in augmenting the yield of corn crops. Suitable plant spacing for optimum leaf growth by controlling water, fertilizer and chemical inputs is essential for improving the growth variables responsible for high yield. Optimum plant densities ensure the plants to grow in their aerial and underground parts through different utilization of solar radiation and nutrients. The optimum plant population recorded the highest mean values for most studied characters and protein %., and reduced weeds spread (Kandil, 2014, Shrestha, 2015, Shoaib et al., 2018 and Xuelian et al., 2018). High plant population with crowding stress decrease the ability of plants to use soil N through the post-silking period, and high rate of N- fertilizer was needed to rise grain yield. Selecting the appropriate plant density combined with optimal N management could enhance grain yields (Yan et al., 2017).

Nitrogen is an essential nutrient for maize crop growth. It is the principal nutrient required for the growth of plants and is an essential constituent of metabolian of active compounds such as amino acids, proteins, enzymes, coenzymes, and some non-proteinaceous compounds (Brady and Weil, 2002). N- Consider a key factor for plant photosynthesis, ecosystem productivity and leaf respiration (Martin et al., 2008). Low N stress is one of the factors most frequently occurring under high plant density and limits maize production. Low N availability in soils is an important yield-limiting factor frequently found in farmers’ fields where fertilization is not commonly used and organic matter is rapidly mineralized (Banziger and Lafitte, 1997). Nitrogen stress may affect the light use efficiency and consequently influence long-term changes in vegetation biomass and carbon sequestration (Peng et al., 2012). Increase nitrogen fertilization levels increased plant height, grain and straw yields of maize (Dawadi and Sah, 2012, and Shrestha, 2015). The highest ear weight was recorded by the highest nitrogen rate, while there was no significant difference among nitrogen levels was observed on the harvest index (Hoshang, 2012). Nitrogen fertilization levels and their interactions showed significant effects on yield and its components of maize. The maximum plant height, number of rows/ear, number of kernels/row, number of kernels/ear, 1000 grain weight, stover, grain, biological yields, harvest index, and protein content were produced by the application either of 429 or 357 kg N/ha (Kandil, 2013). There were gradual and significant increases in grain yield by raising N- fertilizer. The maize hybrid treated with 288 N/ha., produced the maximum values of plant height and grain yield (Faheed et al., 2016).

Keeping in view the importance of plant density and nitrogen fertilization levels, this study was conducted to find out the optimum plant population and nitrogen fertilization level for getting the higher yield of maize.

MATERIALS AND METHODS

This present investigation was conducted at the Experimental Farm, Faculty of Agriculture (Saba Basha), Alexandria University, Egypt, during the two successive summer seasons of 2018 and 2019, to study the response of maize to plant population and nitrogen fertilization rates at factorial experiments (two factors) in randomized complete block design (RCBD). Whereas, the first factor was the plant population (50000, 75000 and 100000 plants/ha), while, the second-factor nitrogen fertilization rates (216, 288, 360, and 432 kg N/ha).
The preceding crop was Egyptian clover (berseem) in the first season and second season.

A surface sample (0-30 cm) was collected before planting to identify some physical and chemical properties of this soil, as shown in Table (1) according to Page et al. (1982) and Klute (1986).

The grains of the hybrids (3444) were obtained from Maize Research Section Agriculture Research Center, Ministry of Agriculture. The grains were sown on May 10\textsuperscript{th} and 8\textsuperscript{th} of 2018 and 2019 seasons, respectively.

Phosphorus fertilizer was added at rate of 200 kg calcium superphosphate (12.5\% P\textsubscript{2}O\textsubscript{5}) just before sowing. Mineral nitrogen fertilizer at the different rates (216, 288, 360, and 432 kg N/ha) was given at two equal doses in the form of urea (46\% N) the first one after thinning before the first irrigation and the second dose was before the second irrigation.

Each plot size was 10.50 m\textsuperscript{2} included 5 ridges each 3.5 m in length and 0.60 m.

Table 1. Some Physical and chemical properties of the experimental soil in 2018 and 2019 seasons.

| Soil properties | Season | 2018 | 2019 |
|-----------------|--------|------|------|
| A) Mechanical analysis : |        |      |      |
| Clay %          |        | 41.00| 40.00|
| Sand %          |        | 29.00| 28.00|
| Silt %          |        | 30.00| 32.00|
| Soil texture    |        | Clay loam soil | Clay loam soil |
| B) Chemical properties |        |      |      |
| pH (1 : 1)      |        | 8.00 | 8.01 |
| E.C. (dS/m) (1:2)|       | 2.60 | 2.50 |
| 1) Soluble cations (1:2) (cmol/kg soil) |        |      |      |
| K\textsuperscript+ |        | 1.52 | 1.44 |
| Ca\textsuperscript++ |     | 8.40 | 9.11 |
| Mg\textsuperscript++ |      | 12.03| 12.20|
| Na\textsuperscript++ |     | 11.30| 10.50|
| 2) Soluble anions (1 : 2) (cmol/kg soil) |        |      |      |
| CO\textsubscript{3}\textsuperscript-- + HCO\textsubscript{3}-- | | 1.90 | 1.80 |
| Cl\textsuperscript-- |        | 19.4 | 18.90|
| SO\textsubscript{4}\textsuperscript-- |       | 12.00| 12.5 |
| Calcium carbonate (%) |     | 6.50 | 6.00 |
| Total nitrogen % |        | 1.00 | 0.91 |
| Available phosphate (mg/kg) |     | 3.70 | 3.55 |
| Organic matter (%) |      | 1.41 | 1.40 |

The most important yield and yield components traits: Grain yield and yield components as ear length (cm), number of rows/ear, number of kernels/row, number of kernels/ear,100-kernel weight (g), straw yield (t/ha), grain yield (t/ha), biological yield (t/ha), harvest index (H.I.\%) are measurements were measured average mean values of yield of the two middle ridges of each plot.
Protein percentage was determined by estimating the total nitrogen in the grains and multiplied by 6.25 to obtain the percentage according to grains protein percentage to A.O. A.C. (1990).

Data obtained was exposed to the proper method of statistical analysis of variance as described by Gomez and Gomez (1984). The treatment means were compared using the least significant differences test (L.S.D.) at 5% level of probability by using the RCBD model as obtained by CoStat 6.311 (2005) as statistical program.

RESULTS AND DISCUSSION

The results obtained in Tables (2 and 3) showed that the ear length (cm), number of rows/ear, number of grains/row, number of grains/ear, 100-grains weight (g), grain yield (t/ha), straw yield, biological yield (t/ha), harvest index (%) and grain protein content (%) of maize hybrid were, significantly, affected by plant population and nitrogen fertilizer rates in 2018 and 2019 seasons.

Results presented in the same Tables (2 and 3) demonstrated that planting maize hybrid at 75000 plants/ha spacing had higher value for the yield and its components i.e. ear length (cm), number of rows/ear, number of grains/row, number of grains/ear, 100-grains weight (g), grain yield (t/ha), straw yield, and biological yield (t/ha) except harvest index (%), and grain protein content (%) followed by Plant population 100000/ha plants/ha which had no significant difference between plant population (75000 plants/ha) as compared with plant population (Plant population 100000/ha) which gave the lowest values of these traits in the first and second seasons. However, the highest harvest index (HI%) was observed with plant population (75000 plants/ha) in the first season, and with 100000 plants/ha in the second season. On the other hand, the highest values of protein were recorded with spacing between hill (100000 plants/ha), while the lowest ones obtained with plant population 100000/ha between plants in both seasons. The difference may be attributed to plant population which plays an important role in the maize hybrids. These findings are in agreement with those obtained by Kandil (2014), Shrestha (2015), Yan et al. (2017), Shoaib et al. (2018) and Xuelian et al. (2018).

In addition results in Tables (2 and 3) demonstrated that increasing nitrogen fertilizer level up to 432 kg/ha., significantly, increased ear length (cm), number of rows/ear, number of grains/row, number of grains/ear, 100-grains weight (g), grain yield (t/ha), straw yield (t/ha), as well as biological yield (t/ha), except harvest index (%) and grain protein content (%) followed by the rates of nitrogen fertilization at 360 and 288 kg/ha which had significant difference between the higher rate in comparison with 216 kg N/ha.

The results in Table (4) indicated that the highest HI % recorded with the application of nitrogen fertilizer at the rate of 288 kg/ha in both seasons. On the other hand, the highest protein content in grain was given with nitrogen application at the rate of 360 followed by the higher rate of nitrogen fertilization in the two seasons. It can be noticed generally that grain yield and its components affected by nitrogen fertilizer which play an important role in plant growth and finally appeared in higher grain yield for two hybrids of maize. These findings were consistent with those obtained by Dawadi and Sah (2012), Kandil (2013) and Shrestha (2015) who indicated that increasing N- level caused an increase in yield and its components of maize.
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Table 2. Plant attributes of maize as affected by plant population and nitrogen fertilization rates and their interaction in both seasons.

| Treatment       | Ear length (cm) | No. of rows/ear | No. of grains/row | No. of grains/ear | 100-grain weight |
|-----------------|-----------------|-----------------|-------------------|-------------------|------------------|
|                 | 2018 | 2019 | 2018 | 2019 | 2018 | 2019 | 2018 | 2019 | 2018 | 2019 |
| A) Plant population (cm): |
| 100000         | 16.67 | 17.54 | 14.17 | 14.17 | 38.50 | 41.30 | 677.57 | 585.17 | 42.54 | 42.34 |
| 75000          | 18.17 | 19.35 | 14.83 | 14.83 | 41.25 | 43.77 | 801.88 | 651.77 | 47.35 | 48.77 |
| 50000          | 14.25 | 14.93 | 14.00 | 14.00 | 33.42 | 35.18 | 498.88 | 651.77 | 47.35 | 48.77 |
| LSD0.05 (A)    | 0.98  | 0.92  | 0.39  | 0.39  | 1.89  | 1.80  | 51.56  | 32.50  | 2.34  | 1.52  |
| B) Nitrogen levels |
| 216            | 16.44 | 17.61 | 14.00 | 14.00 | 37.11 | 38.96 | 666.10 | 545.38 | 38.27 | 39.08 |
| 288            | 16.33 | 16.87 | 14.22 | 14.22 | 35.22 | 37.42 | 598.03 | 533.20 | 43.11 | 43.13 |
| 360            | 15.89 | 16.71 | 14.44 | 14.44 | 40.78 | 40.58 | 633.94 | 588.22 | 43.11 | 43.56 |
| 432            | 16.78 | 17.90 | 14.67 | 14.67 | 49.78 | 43.38 | 739.70 | 639.20 | 47.60 | 48.00 |
| LSD0.05 (B)    | 0.01  | 0.6   | 0.45  | 0.46  | 2.18  | 2.08  | 59.53  | 37.53  | 2.71  | 1.76  |
| A x B          | *     | *     | *     | *     | *     | *     | *     | *     | *     | *     |

The interaction between plant population and nitrogen fertilization levels significantly affected plant traits under this study as shown in Tables (4 and 5). In this respect, the results in Table (4) revealed that the highest mean values of all studied characters i.e. plant attributes, grain, straw, and biological yields were obtained with plant maize at 75000 plants/ha with soil application of nitrogen fertilizer at the rate of 432 kg N/ha which had no significant difference between it and the rate of 360 kg N/ha. In contrast, growing maize plants at Plant population 100000/ha with nitrogen rate at 216 kg/ha produced the lowest ones during two cropping seasons (Table 5). On the other side, planting maize at spacing 10 with nitrogen rate at 288 kg/ha gave the highest harvest index (HI%) followed by plant population (75000 plants/ha) + 216 kg N/ha gave the same trend in both seasons. On the other hand, Plant population 100000/ha plants/ha + 360 kg N/ha recorded the highest
protein % followed by the same plant population (100000 plants/ha) + 432 kg N/ha in both seasons.

Table 4. The interaction effect between plant populations of plant attributes for maize hybrid in both seasons.

| Treatments | Ear length (cm) | No. of rows/ear | No. of grains/row | No. of grains/ear | 100- grain weight |
|------------|-----------------|-----------------|------------------|------------------|------------------|
| Plant population: N-rate (kg/ha) | 2018 | 2019 | 2018 | 2019 | 2018 | 2019 | 2018 | 2019 |
| 100000 | 216 | 15.67 | 16.80 | 14.00 | 14.00 | 38.00 | 40.80 | 638.50 | 571.20 | 36.67 | 38.3 |
| | 288 | 17.33 | 17.57 | 14.67 | 14.67 | 39.67 | 42.47 | 697.40 | 622.40 | 46.33 | 45.02 |
| | 360 | 15.67 | 16.90 | 14.00 | 14.00 | 36.00 | 38.80 | 608.50 | 534.20 | 44.00 | 42.00 |
| | 432 | 18.00 | 18.90 | 14.00 | 14.00 | 40.33 | 43.13 | 765.87 | 603.87 | 43.15 | 44.00 |
| 75000 | 216 | 19.67 | 21.47 | 14.00 | 14.00 | 42.67 | 54.77 | 912.70 | 636.53 | 41.00 | 42.67 |
| | 288 | 17.00 | 17.80 | 14.00 | 14.00 | 35.67 | 37.93 | 635.60 | 531.07 | 45.33 | 47.67 |
| | 360 | 17.33 | 18.00 | 15.33 | 15.33 | 41.00 | 43.80 | 739.67 | 673.60 | 46.73 | 48.73 |
| | 432 | 18.67 | 20.13 | 16.00 | 16.00 | 45.67 | 47.87 | 919.57 | 765.87 | 56.33 | 56.00 |
| 50000 | 216 | 14.00 | 14.57 | 14.00 | 14.00 | 30.67 | 30.60 | 447.10 | 428.40 | 37.13 | 36.23 |
| | 288 | 16.67 | 15.23 | 14.00 | 14.00 | 30.33 | 31.87 | 461.10 | 446.13 | 37.67 | 38.00 |
| | 360 | 14.67 | 15.23 | 14.00 | 14.00 | 36.33 | 39.31 | 553.67 | 547.87 | 39.67 | 38.67 |
| | 432 | 13.67 | 14.67 | 14.00 | 14.00 | 36.33 | 39.31 | 553.67 | 547.87 | 43.33 | 44.00 |
| LSD0.05 (A x B) | 1.96 | 1.84 | 0.78 | 0.77 | 3.77 | 3.61 | 103.11 | 65.00 | 4.69 | 3.04 |

Table 5. The interaction effect between plant populations of plant attributes for maize hybrid in both seasons.

| Treatments | Grain yield (t/ha) | Straw yield (t/ha) | Biological yield (t/ha) | Harvest index (%) | Grain Protein (%) |
|------------|-------------------|-------------------|------------------------|-------------------|------------------|
| Plant population: N-rate (kg/ha) | 2018 | 2019 | 2018 | 2019 | 2018 | 2019 | 2018 | 2019 |
| 100000 | 216 | 6.55 | 6.95 | 7.92 | 7.40 | 14.47 | 14.35 | 45.27 | 48.43 | 7.92 | 7.67 |
| | 288 | 7.94 | 7.64 | 8.60 | 8.10 | 16.54 | 15.74 | 48.00 | 48.54 | 9.04 | 8.83 |
| | 360 | 7.07 | 7.17 | 9.21 | 8.74 | 16.28 | 15.91 | 43.43 | 45.07 | 9.79 | 9.33 |
| | 432 | 7.79 | 7.47 | 9.52 | 9.07 | 17.31 | 16.54 | 45.00 | 45.16 | 9.38 | 9.13 |
| 75000 | 216 | 7.72 | 7.53 | 8.58 | 8.03 | 16.30 | 15.56 | 47.16 | 48.39 | 7.38 | 7.38 |
| | 288 | 6.33 | 7.00 | 9.15 | 9.10 | 15.48 | 16.10 | 46.52 | 45.64 | 8.76 | 7.29 |
| | 360 | 7.96 | 7.64 | 9.74 | 9.34 | 17.70 | 16.98 | 39.39 | 46.14 | 9.40 | 9.15 |
| | 432 | 9.06 | 8.59 | 10.72 | 10.15 | 19.78 | 18.74 | 45.80 | 45.84 | 9.04 | 8.67 |
| 50000 | 216 | 4.81 | 4.72 | 7.27 | 7.06 | 12.08 | 11.78 | 39.82 | 40.07 | 7.17 | 6.92 |
| | 288 | 6.23 | 5.91 | 8.03 | 7.31 | 14.26 | 13.22 | 43.69 | 44.70 | 7.56 | 7.23 |
| | 360 | 6.66 | 6.15 | 8.44 | 7.66 | 15.10 | 13.81 | 44.11 | 44.53 | 7.90 | 7.94 |
| | 432 | 5.61 | 5.57 | 7.19 | 6.57 | 12.80 | 11.94 | 43.83 | 44.97 | 7.50 | 7.29 |
| LSD0.05 (A x B) | 0.81 | 0.88 | 0.96 | 0.53 | 1.17 | 0.95 | 4.04 | 3.46 | 0.98 | 1.15 |

Conclusions

Considering the observed results, it can be concluded that the application of 432 kg N/ha and with plant population of 75000 plants/ha to the maize hybrid ‘3444’ is optimal for obtaining a higher grain yield of maize under the conditions of Alexandria governatorate, Egypt.

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ARABIC SUMMARY

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Agriculture field trials were conducted in the research farm at the Faculty of Agriculture, Saba Pasha Branch of Alexandria University during the seasons 2012 and 2013, in order to study the effect of planting densities and nitrogen fertilization levels on some traits of the barley hybrid 0222 and its components.

The treatments were distributed in a complete randomized design in three replicates, where the first factor was planting densities (111111, 00111, 01111), and the second factor was nitrogen fertilization amounts (212, 222, 021, 202) kg N/ha and distributed randomly to all the treatments so that each treatment included all treatments.

The most important results were:

- It was shown that planting distances (planting density) and nitrogen fertilization levels and their interaction had a statistically significant effect on some of the traits of the barley hybrid 0222 and its components.
- It was found that planting at a planting density of 111111 plants/ha gave the highest values for the studied traits and was followed by planting distances at a planting density of 01111 plants/ha, while there were no significant differences between them, whereas planting density of 00111 plants/ha gave the lowest values for the studied traits and its components during the seasons under study. While the highest grain yield and protein percentage were recorded with planting at a planting density of 00111 plants/ha with nitrogen fertilization of 222 kg N/ha during the seasons under study.
- An increase in nitrogen fertilization levels from 212 to 021 kg N/ha resulted in a statistically significant increase in barley yield and its components, while nitrogen fertilization at a rate of 021 kg N/ha did not differ significantly from nitrogen fertilization at a rate of 202 kg N/ha. While the highest grain yield was recorded with nitrogen fertilization at a rate of 222 kg N/ha during the seasons of study. While the highest protein content in barley grains was achieved with planting at a planting density of 111111 plants/ha + 021 kg N/ha during the seasons under study.

Recommendation:

The results recommend obtaining the highest barley yield and its components and quality of the barley hybrid 0222 by planting at a planting density of 00111 plants/ha with nitrogen fertilization of 021 kg N/ha under Alexandria conditions.