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# Response of Popcorn *(Zea mays everta)* to Nitrogen Rates and Plant Densities

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**Abstract:** The objective of this study was to evaluate grain yield and yield components of popcorn with different nitrogen rates and plant densities. Field studies were conducted in 1995 and 1996 at Kazova Plain in Tokat. The experiment was designed in a randomized-complete-block design with a split-plot arrangement with three replications. The treatments comprised six levels of nitrogen (0, 50, 100, 150, 200 and 250 kg N / ha) and four plant densities (5.7, 7.0, 9.5 and 14.0 plants / $m^2$). Nitrogen rates were in the main plots, and planting densities were in the sub-plots. An open pollinated was used as the material in the experiment. In general, significant differences were determined in the investigated plant characteristics. Plant height tended to increase as the nitrogen rate increased. The tasseling period was reduced as the nitrogen level and sowing density increased. The maximum ear length was obtained from low planting densities (5.7 and 7.0 plants / $m^2$). The number of kernels per ear was not affected by nitrogen application or population density. The 1000-grain weight increased with N application and decreasing plant density. Nitrogen application and plant densities had positive effects on the grain weight per ear. Nitrogen significantly increased the grain yield, but there were no significant differences in yield at the doses of 100, 150, 200 and 250 kg N / ha. The highest grain yield was obtained from 7.0 plants / $m^2$ when averaged over two years. Our findings indicate that, for maximum grain yield of popcorn, 100-150 kg N/ha should be applied, and the plant density should be 7.0 plants / $m^2$.

### Cinmısırının *(Zea mays evarta)* Azot Dozları ve Bitki Sıklığına Tepkisi

**Özet:** Bu çalışmanın amacı, farklı azot dozları ve bitki sıklıklarının cinmısırında tane verimi ve verim unsurlarına etkisini belirlemektir. Tarla çalışmaları 1995 ve 1996 yıllarında Tokat-Kazova bölgesinde yürütülmüştür. Deneme, "Tesadüf Blokları Bölünmüş Parseller Deneme" desenine göre üç tekerrürlü olarak kurulmuştur. Araştırmada altı azot seviyesi (0, 50, 100, 150, 200 ve 250 kg / ha N) ve dört bitki sıklığı (5.7, 7.0, 9.5 ve 14.0 bitki / $m^2$) kullanılmıştır. Azot dozları ana parsellerde, bitki sıklıkları alt parsellerde yeralmıştır. Denemede bitki materyali olarak açık tozlanan bir populasyon kullanılmıştır. Araştırma sonuçlarına göre; azot dozları ve ekim sıklıklarının incelenen özelliklere etkisi genellikle önemli bulunmuştur. Bitki boyu, azot miktarındaki artışla birlikte artma eğilimi göstermiştir. Tepe püskülü çıkarma süresi ise artan azot oranı ve ekim sıklığı ile kısalmıştır. En uzun koçan boyu, düşük ekim sıklıklarından (5.7 ve 7.0 bitki / $m^2$) elde edilmiştir. Koçan başına tane sayısı, azot uygulaması ve bitki sıklığından etkilenmemiştir. Bin tane ağırlığı cinmısırında azot uygulamasıyla ve bitki sıklığının azalmasıyla artmıştır. Azot uygulaması ve bitki sıklığı koçan başına tane verimini olumlu yönde etkilemiştir. Azot artışı tane verimini önemli şekilde artırmasına rağmen, azot dozları arasındaki fark (100, 150, 200 ve 250 kg / ha N) önemli bulunmamıştır. İki yılın ortalamasına göre en yüksek tane verimi 7.0 bitki / $m^2$ sıklığından elde edilmiştir. Çalışmadan elde ettiğimiz sonuçlar, cinmısırında maksimum tane verimi için 100-150 kg/ha N uygulaması ve 7.0 bitki / $m^2$ ekim sıklığının uygun olduğunu göstermektedir.

## Introduction

Nitrogen is the main plant nutrient which limits plant growth. Therefore, the use efficiency of nitrogen is an increasingly important aspect of crop management systems. Corn shows large responses to nitrogen fertilizer applications depending on weather, soil characteristics, water supply, the uniformity of the crop and the nutrient responses of the cultivated variety (1).

Generally, the grain yield of corn that is grown on soils low in fertility increases with increments of N until yield is maximized, after which point additional N either has no effect or cause decreases in grain yield (1-3). Decreased grain yield from excessive N application is also associated with lodging (4). Experienced commercial popcorn growers apply somewhat less fertilizer than is recommended for dent corn because the yield of popcorn is lower than that of dent corn. Thus, less fertilizer is needed (5). Many researchers (6-9) have reported that increasing levels of N fertilizer increase the grain yield, but the highest grain yield is obtained from different N levels.

Corn grain yield is a product of the yield components, including the number of plants per unit area, number of ears per plant, kernels per ear and 1000-grain weight. Rising nitrogen rates increase the number of cobs /ha, 1000-grain weight, and grain weight / cob (6-10).

One of the most important factors in corn production, as with all higher plants, is utilization of solar radiation. Photosynthetic efficiency and growth in maize are strongly related to the effect of canopy architecture on the vertical distribution of light within the canopy (11). Increasing plant density is one of the ways of increasing the capture of solar radiation within the canopy (12). However, the efficiency of the conversion of intercepted solar radiation into maize yield decreases with a high plant population density because of mutual shading in the plants (13). In addition, a plant population density resulting in interplant competition affects vegetative and reproductive growth (14).

Many studies have been conducted with the aim of determinig the optimum plant density for maize. Unfortunately, there is no single recommendation for all conditions, because the optimum plant density varies depending on environmental factors such as soil fertility, moisture supply, genotype, planting date, planting pattern, plant protection, and harvest time (15, 16). Sencar (7) reported that grain yield and many plant characteristics were affected by plant density, and that a plant population above a critical density had a negative effect on many characters.

Generally, the yield of a single maize plant decreases with increasing plant population density whereas the yield per unit area increases (7, 10). Field trials conducted on dent and popcorn plants have shown that grain yield increases up to an optimum plant density and then declines as the population increases (7, 17). On the other hand, a significant linear increase in the grain yield of popcorn has been observed with increases in plant density (6, 8).

Generally, the cultural practices used for dent and flint maize are applied for growing popcorn because experimental data for popcorn are limited. The objective of this study was to evaluate the grain yield and yield components of popcorn with different nitrogen rates and plant densities.

## Materials and Methods

Field studies were conducted in 1995 and 1996 in Kazova Plain in Tokat. The results of some basic physical and chemical analyses of the surface soils (0-20 cm), which were taken a few days before maize planting, are given in Table 1. The monthly rainfall and mean temperature during the study are summarized in Table 2.

The experiment was designed in a randomized-complete-block design with a split-plot arrangement with three replications. The treatments comprised six levels of nitrogen (0, 50, 100, 150, 200 and 250 kg N / ha) and four plant densities (5.7, 7.0, 9.5 and 14.0 plants / $m^2$). Nitrogen rates were in the main plots and planting densities were in the sub-plots. Each plot consisted of four rows, 5.0 m long, and these were spaced 70 cm apart. The seeds were planted five cm apart in the rows. After emergence, seedlings in all the plots were thinned to obtain 10, 15, 20 and 25 cm distances between the plants, which resulted in 5.7, 7.0, 9.5 and 14.0 plants / $m^2$.

The harvest area of each plot was 5.6 $m^2$. The seeds were drilled on May 5, 1995 and May 14, 1996. A population developed through mass selection was used as the plant material in the experiment. This cultivar was obtained from the Field Crop Department of the Agricultural Faculty of Çukurova University. The full dose of phosphate (6 kg $P_2O_5$ / da) along with the half dose of N were applied at sowing. The remaining half of the nitrogen was applied at the stage when the plants were 40-50 cm. Four irrigations were applied at the post-emergence, knee-high, tasseling and grain-filling stages of growth. In each experiment, weeds were controlled through harrowing.

Table 1. Physical and chemical properties of soil in the 0-20 cm layer.

| | Year | |
|---|---|---|
| | 1995 | 1996 |
| Particle Size Analysis | | |
| % Clay | 37.66 | 31.12 |
| % Silt | 41.34 | 50.00 |
| % Sand | 21.00 | 18.88 |
| % Lime | 7.4 | 8.0 |
| Texture | CL | SICL |
| pH | 7.75 | 7.26 |
| % C (Organic) | 1.18 | 1.10 |
| Available $P_2O_5$ (kg/ha) | 33.3 | 11.4 |
| Available $K_2O$ (kg/ha) | 339.0 | 620.0 |

The traits studied in this research were determined in the following ways:

*Plant height:* Mature plant heights of 10 random plants / plot were measured in cm as the distances from ground level to the lowest branch of the panicle.

*Tasseling period:* The number of days from planting to 50 % tasseling of the plants in a plot were recorded.

*Ear length:* The husked ear length of 10 random ears / plot was measured in cm.

*Number of kernels per ear:* The number of kernels in 10 ears was counted after they had been shelled, and was divided by the number of ears.

*1000-grain weight:* 1000-grain weight was calculated by taking four different samples of 100 grains from the grain yield per plot and by weighing and averaging these samples.

*Grain weight per ear:* The grain of the same ten ears mentioned above was weighed and divided by the number of ears.

*Grain yield:* Ears from each plot were dried for about three months at room temperature, then the grain was shelled and weighed. Consequently, the grain yield / ha was calculated by multiplying the computed grain weight for each plot.

All the data were analysed with analysis of variance (ANOVA) procedures using the Statistical Software Package. The comparison of the treatment means was made using the Least Significant Difference (LSD) test.

## Results and Discussion

### Plant height

The nitrogen application significantly increased the plant height in both years, but the planting density increased only in the second year (Table 3). In general, the maximum plant height was obtained with the highest dose of N while the lowest values were recorded at the control level or 50 kg N ha$^{-1}$. Plant height tended to increase as the nitrogen rate increased because nitrogen

Table 2. Monthly mean temperature, accumulated rainfall in each site year in the maize growing seasons (May through October).

| | Years | May | June | July | August | September | October |
|---|---|---|---|---|---|---|---|
| Mean | 1995 | 17.4 | 21.3 | 21.0 | 22.9 | 18.9 | 12.9 |
| temperature | 1996 | 17.2 | 19.4 | 22.3 | 21.1 | 14.2 | 11.1 |
| (°C) | 1962-1988 | 16.4 | 19.5 | 22.0 | 21.6 | 18.0 | 12.5 |
| | 1995 | 53.3 | 75.8 | 35.6 | 2.5 | 21.0 | 21.0 |
| Rainfall | 1996 | 30.8 | 107.5 | 2.7 | 27.0 | 6.3 | 28.3 |
| (mm) | 1950-1988 | 55.2 | 34.9 | 11.0 | 6.3 | 16.5 | 30.0 |

Table 3. Analysis of variance showing the effect of N rates and plant densities on plant height, tasseling period and ear length.

| Source of Variation | Plant height (cm) | | | Tasseling period (day) | | | Ear length (cm) | | |
|---|---|---|---|---|---|---|---|---|---|
| | 1995 | 1996 | Mean | 1995 | 1996 | Mean | 1995 | 1996 | Mean |
| Main plots | | | | | | | | | |
| Blocks | * | NS | NS | NS | NS | NS | NS | NS | NS |
| N rates (N) | * | ** | ** | ** | ** | ** | NS | ** | ** |
| $Error_1$ | | | | | | | | | |
| Sub-plots | | | | | | | | | |
| Plant / m$^2$ (D) | NS | * | NS | ** | * | ** | * | ** | ** |
| N x D | NS | NS | NS | NS | ** | NS | NS | * | NS |
| $Error_2$ | | | | | | | | | |
| CV % | 2.83 | 3.25 | 3.06 | 1.23 | 0.74 | 1.00 | 6.10 | 3.88 | 5.09 |

*, **, indicates significance at 0.05 and 0.01, respectively, NS indicates not significant.

promoted vegetative growth in the maize. Similar results have been reported by other researchers (7, 9, 10).

Although plant density affected the plant height in 1996 and combination height over two years, the effect of plant population on the plant height was not clear. These findings are in agreement with the observations made by Bangarwa et al. (10). This can probably be explained by the fact that individual plant evaluations do not represent all plants in the populations. However, Sencar (7), and Sade and Çalış (17) reported that plant height increased up to a certain plant density with increases in sowing density, then declined as the population increased.

### Tasseling Period

There was a significant difference in the days up to 50 % tasseling of popcorn with various nitrogen rates and plant densities (Table 3). The tasseling period became shorter as the nitrogen level increased in both years and in the pooled results. Low N delayed tasseling by about 2.5 days compared to the highest N rate. Martin et al. (18) also reported that abundant nitrogen stimulated flowering in corn, which is a nitropositive crop. Paradkar and Sharma (9), Tollenaar et al. (21) and Sencar (7) also reported that the flowering period was shorter with higher nitrogen levels.

In general, 14.0 plants / $m^2$ had the longest tasseling period while 5.7 plants / $m^2$ had the shortest. The number of days from planting to tasseling was greater with high density than with low density (Table 5). Male flowering was retarded by the increase in sowing density because the interplant competition for light with the high density was greater than with the low density, so the vegetative growth of the plants prolonged (7). These findings are in agreement with previous reports (7, 12, 19).

### Ear (Cob) Length

There was a significant difference in cob lengths with different N rates in 1996 and in the pooled results. The mean cob length varied between 15.6 and 16.6 cm in 1995, and between 15.8 and 17.3 cm in 1996 depending upon the nitrogen rates. The control plots not receiving N fertilizer had the lowest value. The greatest ear length was obtained from 250 kg N $ha^{-1}$ (Table 6). This confirms the findings of Paradkar and Sharma (9).

The ears of plants grown at densities of 5.7 and 7.0 plants / $m^2$ were better developed than high population plants (Table 6). Such a decrease in cob length in the two high-density populations (9.5 and 14.0 plants / $m^2$) might be a result of interplant competition for light, soil nutrients and soil water. In fact, Williams et al. (11) also reported that photosynthetic efficiency and growth in maize were strongly related to the effect of canopy architecture on the vertical distribution of light within the canopy. Similar effects of plant density on ear length were reported by Sade and Çalış (17) in popcorn.

Table 4. Analysis of variance showing the effect of N rates and plant densities on yield and yield components of popcorn.

| Source of Variation | Number of kerne per ear | | | 1000 grain weight (g) | | | Grain weight per ear (g) | | | Grain yield (kg / ha) | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 1995 | 1996 | Mean | 1995 | 1996 | Mean | 1995 | 1996 | Mean | 1995 | 1996 | Mean |
| Main plot | | | | | | | | | | | | |
| Blocks | NS | NS | NS | NS | NS | NS | NS | NS | NS | NS | NS | NS |
| N rates (N) | NS | NS | * | NS | ** | * | * | NS | * | ** | ** | |
| $Error_1$ | | | | | | | | | | | | |
| Sub-plots | | | | | | | | | | | | |
| Plant/$m^2$(D) | NS | NS | * | ** | * | ** | ** | ** | ** | ** | ** | ** |
| N x D | NS | NS | NS | * | NS | NS | * | NS | NS | NS | NS | NS |
| $Error_2$ | | | | | | | | | | | | |
| CV % | 5.97 | 7.55 | 6.95 | 1.91 | 2.14 | 2.02 | 4.83 | 7.93 | 6.81 | 9.75 | 7.66 | 8.73 |

*, ** , indicates significance at 0.05 and 0.01, respectively, NS indicates not significant.

Table 5. Effect of N rates and plant densities on plant height and tasseling period.

| Treatments | Plant height (cm) | | | Tasseling period (day) | | |
|---|---|---|---|---|---|---|
| N (kg/ha) | 1995 | 1996 | Mean | 1995 | 1996 | Mean |
| 0 | 196.4 bc | 208.7 b | 202.6 b | 84.6 a** | 89.4 a** | 87.0 a** |
| 50 | 195.8 c | 208.9 b | 202.3 b | 84.4 ab | 88.8 ab | 86.6 ab |
| 100 | 203.4 ab | 220.4 ab | 211.9 a | 83.2 bc | 88.6 ab | 85.9 bc |
| 150 | 206.6 a* | 223.7 a | 215.1 a | 83.0 c | 87.5 b | 85.3 cd |
| 200 | 203.7 a | 225.5 a | 214.6 a | 82.3 c | 88.5 ab | 85.4 cd |
| 250 | 203.9 a | 228.9 a** | 216.4 a** | 81.9 c | 87.3 b | 84.6 d |
| LSD | 7.30 | 13.63 | 7.69 | 1.33 | 1.51 | 0.91 |
| (plants / $m^2$) | | | | | | |
| 5.7 | 202.5 | 217.6 b | 210.1 ab | 82.4 c | 87.9 b | 85.2 c |
| 7.0 | 199.6 | 224.0 a* | 211.8 a* | 82.7 bc | 88.4 a | 85.6 bc |
| 9.5 | 200.3 | 216.8 b | 208.6 b | 83.3 b | 88.4 a | 85.9 b |
| 14.0 | 204.0 | 219.0 b | 211.5 ab | 84.5 a** | 88.6 a* | 86.5 a** |
| LSD | NS | 4.82 | 3.03 | 0.93 | 0.44 | 0.54 |

*, ** , indicates significance at 0.05 and 0.01, respectively, NS indicates not significant.

### Number of Kernels per Ear

Neither nitrogen application nor population density appeared to affect the number of grains / ear in either year, but it was significantly affected in terms of the mean over two years (Table 4). However, the number of kernels per ear increased with reduced sowing density. Similarly, in 1995 and 1996, little response to N was observed. Furthermore, the kernel number per ear increased by about 6 % as nitrogen increased from zero to 250 kg N $ha^{-1}$, and it declined by about 5 % as the plant density increased from 5.7 to 14.0 plants / $m^2$ in terms of the mean over two years. The lowest kernel number was obtained from the control and the highest population density. A combined analysis over both years for kernel number indicated that there was a significant difference between the control and the N application and between 14.0 plants / $m^2$ and the other plant densities.

Flowering and pollination is the most critical period in the development of the corn plant. Drought, nutrient deficiency (especially nitrogen), serious injury from insects, and overcrowding at this stage, 10 days to 2 weeks prior to silking and pollen shed, can greatly reduce the number of developed kernels (20, 21). Schussler and Westgate (22) also reported that kernel set has been associated with assimilate flux to the ear around silking. Our results concur partly with observations made by Paradkar and Sharma (9), who reported that the kernel number increased with increments of N. In addition, Tetio-Kagho and Gardner (14) and Sade and Çalış (17) showed that it increased with a decline in plant density.

### 1000-Grain Weight

The application of nitrogen increased the 1000-grain weight when compared with the control (Table 7). There was a significant increase in this trait with N application, except in 1995. When the mean results were taken into consideration, no significant difference was observed among nitrogen doses in 1995, but a significant difference was observed in 1996. High N rates can promote leaf area development during vegetative development and can help maintain functional leaf area during the growth period (23). They can also increase the rate of dry matter accumulation during the grain-filling period (21). Similarly, some researchers have reported that the 1000-grain weight increased with N application in popcorn (8, 10, 17) and in dent corn (7).

Table 6. Effect of N rates and plant densities on ear length and number of kernel per ear.

| Treatments | Ear length (cm) | | | Number of kernel per ear | | |
|---|---|---|---|---|---|---|
| N (kg/ha) | 1995 | 1996 | Mean | 1995 | 1996 | Mean |
| 0 | 15.6 | 15.8 b | 15.7 b | 395.5 | 463.9 | 429.7 c |
| 50 | 16.2 | 16.2 b | 16.2 ab | 396.4 | 473.9 | 435.2 bc |
| 100 | 16.6 | 16.2 b | 16.4 ab | 416.2 | 490.3 | 453.3 ab |
| 150 | 16.5 | 17.1 a | 16.8 a | 417.7 | 503.6 | 460.7 a* |
| 200 | 16.3 | 17.3 a | 16.8 a | 420.9 | 478.5 | 449.7 ab |
| 250 | 16.6 | 17.3 a** | 16.9 a** | 419.6 | 489.1 | 454.4 ab |
| LSD | NS | 0.87 | 0.87 | NS | NS | 19.82 |
| (plants / $m^2$) | | | | | | |
| 5.7 | 16.8 a* | 17.2 a** | 17.0 a** | 415.7 | 491.1 | 453.4 a |
| 7.0 | 16.5 ab | 17.0 ab | 16.7 a | 414.5 | 492.9 | 453.7 a* |
| 9.5 | 15.7 c | 16.4 bc | 16.1 b | 409.7 | 484.2 | 446.9 ab |
| 14.0 | 16.1 bc | 16.1 c | 16.1 b | 404.4 | 464.6 | 434.5 b |
| LSD | 0.67 | 0.59 | 0.52 | NS | NS | 14.61 |

*, ** , indicates significance at 0.05 and 0.01, respectively, NS indicates not significant.

The plant density significantly affected the 1000-grain weight in both years of the study (Table 4). The 14.0 plants / $m^2$ density produced the lowest values, while the low plant density (5.7 plants / $m^2$) produced the highest. An increase in plant population had an adverse effect on the 1000-grain weight. Similar results have been found by other researchers (7, 8, 10, 17). This finding can be explained by the fact that increments in the density of plants / unit area increased the leaf-area index (10), and soil nutrients, light density and soil water were more available at the low plant density than at the high plant density (21).

### Grain Weight per Ear

Nitrogen application had positive effects on the single ear weight in both years and in the pooled results. However, in 1996, significant differences were not observed among N rates and between control and N doses (Table 4). In general, the lowest grain weight / ear was obtained from the control plots. These results are in agreement with those of many other workers (6 - 8, 10). An increment in the N level increased its availability in the soil, resulting in higher uptake by the plants and production of larger leaves, more photosynthesis and dry matter accumulation (10).

There was a significant difference in the single ear weight of popcorn due to various plant densities (Table 4). Generally, a significant linear decrease in grain weight per ear was observed with an increase in plant population from 5.7 to 14.0 plants / $m^2$. This is primarily a consequence of the effects of interplant competition for light, water, nutrition, and other potentially yield limiting environmental factors (12). At high population densities, the lower leaves contribute little to carbohydrate production and may be parasitic (24). This might also be on account of plant barrenness in the higher density plant populations Decreases in grain weight per ear with increasing plant population density is in agreement with that of previous reports by Roy and Sing (6), Thakur and Malhotra (8), and Bangarwa et al., (10).

### Grain Yield

The grain yield was significantly affected by both N application and plant density in 1995 and 1996. A combined analysis over both years for grain yield indicated that the grain yield was affected either by N or by plant density (Table 4).

The grain yield varied between 3727 kg / ha and 5081 kg / ha in the first year and between 3937 kg / ha

Table 7. Effect of N rates and plant densities on 1000-grain weight and grain weight per ear.

| Treatments | 1000 grain weight (g) | | | Grain weight per ear (g) | | |
|---|---|---|---|---|---|---|
| N (kg/ha) | 1995 | 1996 | Mean | 1995 | 1996 | Mean |
| 0 | 154.9 | 147.2 c | 151.0 b | 61.5 bc | 68.5 | 65.0 c |
| 50 | 160.7 | 147.2 c | 153.9 ab | 59.3 c | 72.7 | 66.0 bc |
| 100 | 162.4 | 148.6 bc | 155.5 a | 66.8 a* | 73.8 | 70.3 a |
| 150 | 158.2 | 151.4 ab | 154.8 a | 61.7 bc | 79.4 | 70.6 a |
| 200 | 160.3 | 151.9 ab | 156.1 a | 66.0 ab | 73.6 | 69.8 ab |
| 250 | 160.1 | 152.4 a** | 156.3 a* | 66.3 ab | 76.1 | 71.2 a* |
| LSD | NS | 3.57 | 3.38 | 4.92 | NS | 4.11 |
| (plants / m$^2$) | | | | | | |
| 5.7 | 161.8 a** | 151.3 a* | 156.5 a** | 68.8 a** | 75.6 a | 72.2 a** |
| 7.0 | 158.0 b | 150.9 ab | 154.4 b | 66.3 a | 77.1 a** | 71.7 a |
| 9.5 | 159.8 ab | 148.8 bc | 154.3 b | 61.9 b | 73.2 ab | 67.6 b |
| 14.0 | 157.9 b | 148.1 c | 153.0 b | 57.4 c | 70.2 b | 63.8 c |
| LSD | 2.77 | 2.17 | 1.95 | 2.79 | 5.32 | 2.92 |

*, ** , indicates significance at 0.05 and 0.01, respectively, NS indicates not significant.

Table 8. Effect of N rates and plant densities on grain yield.

| Treatments | Grain yield (kg/ha) | | |
|---|---|---|---|
| N (kg/ha) | 1995 | 1996 | Mean |
| 0 | 3774 bc | 3937 b | 3855 b |
| 50 | 3727 c | 4336 ab | 4032 b |
| 100 | 4660 abc | 4560 ab | 4610 a |
| 150 | 4316 abc | 4935 a** | 4625 a |
| 200 | 4760 ab | 4797 a | 4779 a |
| 250 | 5081 a** | 4859 a | 4970 a** |
| LSD | 1007 | 670 | 543 |
| (plants / m$^2$) | | | |
| 5.7 | 4812 b | 4189 c | 4501 b |
| 7.0 | 5475 a** | 4676 ab | 5075 a** |
| 9.5 | 3982 c | 4932 a** | 4457 b |
| 14.0 | 3277 d | 4485 bc | 3881 c |
| LSD | 388 | 318 | 244 |

*, ** , indicates significance at 0.05 and 0.01, respectively.

and 4935 kg / ha in the second year. Nitrogen significantly increased the grain yield over that of the control. There were not, however, significant differences in the yield between 100, 150, 200 and 250 kg N / ha applications. Such an increase in grain yield over that of the control might have been resulted from the significant improvement in yield-attributing characters, such as-1000 grain weight, kernel number and single cob weight. Ziegler and Ashman (4) reported that the grain yield did not increase at high N rates, but it decreased due to lodging. Corn exhibits large grain yield responses to nitrogen applications depending on weather, soil characteristics, water supply, the uniformity of the crop and the nutrient responses of the cultivated variety (1). The grain yield of maize grown on soils low in fertility has been found to increase with increments of N until it reaches a peak, and additional N has either not affected it or decreased it (1 - 3).

7.0 plants / $m^2$ gave the highest grain yield (5075 kg / ha) followed by 5.7 plants / $m^2$ (4501 kg / ha), in terms of the average of the two years. The lowest grain yield was obtained from the highest density in 1995 and from the lowest density in 1996. Ziegler and Ashman (4) also cited the findings of Stevens (1985), that grain yields increased as plant density increased from 34000 to 74000 plants / ha, but decreased after 74000 plants /ha. Since yield reduction / ha at high plant densities is due to the effects of interplant competition for light, water, nutrition, and other potentially yield-limiting environmental factors, a plant population above a critical density has a negative effect on yield per plant (12). It has also been found that increasing the maize plant population on soil of the same productivity decreases the strength of stalks and increases the likelihood of lodging or stalk breakage or barrenness (6). Our findings are in agreement with observations made by many researchers (6-10, 17).

In conclusion, it can be suggested that in the case of popcorn 100-150 kg N / ha should be applied, and the plant density should be adjusted to 7.0 plants / $m^2$ based on the soil productivity, fertilization and irrigation possibilities in Tokat-Kazova conditions.

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