ISSN 1807-1929
Revista Brasileira de Engenharia Agrícola e Ambiental
v.21, n.10, p.703-708, 2017
Campina Grande, PB, UAEA/UFCG – http://www.agriambi.com.br

DOI: http://dx.doi.org/10.1590/1807-1929/agriambi.v21n10p703-708

# Nitrogen as top-dressing and sowing densities on agronomic characteristics of maize crop

Antoniele de F. Serpa[1], Marcelo C. Mendes[1], Marcos V. Faria[1], Fabricio W. de Ávila[1], Kathia Szeuczuk[1] & Carlos J. B. Albuquerque[2]

[1] Universidade Estadual do Centro Oeste/Departamento de Agronomia. Guarapuava, PR. E-mail: teleserpa@yahoo.com.br (Corresponding author); mcmendes@unicentro.br; mfaria@unicentro.br; fwavila@unicentro.br; kahh.szeuczuk@gmail.com
[2] Universidade Federal de Minas Gerais/Instituto de Ciências Agrárias. Montes Claros, MG. E-mail: carlosjuliano@ufmg.br

**Key words:**
plant architecture
grain yield
*Zea mays*

**ABSTRACT**
The main objective of this study was to evaluate the agronomic characteristics of commercial maize hybrids with modern and old architecture, under the influence of nitrogen (N) as top dressing with different plant populations. Two independent experiments were conducted, one in the municipality of Guarapuava (reduced spacing = 0.45 m) and the other in the municipality of Laranjeiras do Sul (conventional spacing = 0.90 m), in the Paraná state, Brazil, in the 2012/2013 growing seasons. The experiments were set in a randomized block design, with three replicates, in a factorial scheme (6 x 3 x 3), corresponding to six maize hybrids (with modern and old architecture), three plant populations (60000, 75000 and 90000 plants $ha^{-1}$) and three N doses as top dressing (0, 90 and 180 kg $ha^{-1}$ of N), both installed in October. N doses as top dressing and sowing density influenced the thousand-grain weight in maize hybrids with modern and old architecture. The increase in sowing density reduced stem diameter in the groups of modern and old architecture in Laranjeiras do Sul. Grain yield was positively influenced by N fertilization, being higher at the N dose of 180 kg $ha^{-1}$ in Guarapuava and Laranjeiras do Sul.

**Palavras-chave:**
arquitetura de planta
produtividade de grãos
*Zea mays*

# Adubação nitrogenada de cobertura e densidades de semeadura em caracteres agronômicos na cultura do milho

**RESUMO**
Objetivou-se, neste estudo, avaliar as características agronômicas de híbridos de milho comerciais, com arquitetura moderna e antiga sob influência de níveis de adubação nitrogenada de cobertura em diferentes densidades de semeadura, nos municípios de Guarapuava (espaçamento 0,45 m) e Laranjeiras do Sul (espaçamento 0,90 m), no estado do Paraná, na safra 2012/2013. O delineamento foi de blocos ao acaso, com três repetições, em esquema fatorial (6 x 3 x 3), sendo utilizados seis híbridos simples de milho, divididos em dois grupos (arquitetura moderna e antiga), três densidades de plantas (60.000, 75.000 e 90.000 plantas $ha^{-1}$) e três doses de adubação nitrogenada em cobertura (0, 90 e 180 kg $ha^{-1}$ de N), instalados em outubro. A densidade de semeadura e as doses de nitrogênio em cobertura influenciaram o peso de mil grãos dos híbridos de arquitetura moderna e antiga, nos municípios de Guarapuava e Laranjeiras do Sul. O aumento da densidade de semeadura reduz o diâmetro de colmo nos grupos de arquitetura de plantas moderna e antiga, em Laranjeiras do Sul. A produtividade de grãos foi influenciada positivamente pela adubação nitrogenada de cobertura sendo maior na dose de 180 kg $ha^{-1}$ de N, em Guarapuava e Laranjeiras do Sul.

Ref. 227-2016 – Received 15 Jan, 2017 • Accepted 7 Apr, 2017 • Published 25 Aug, 2017

## Introduction

Every growing season, new maize genotypes are being offered in the market, along with the requirements of the consumer market and the search for high crop yield, and the farmers have been increasingly prudent in the choice of the maize hybrid to be cultivated. Considering the innovations of the characteristics in the current maize hybrids, there are modifications in plant architecture that can influence spacing and sowing density, promoting significant increments in grain yield at reduced spacing (Mendes et al., 2013).

This modern plant architecture stands out for having more erect leaves, which are ideal to increase light capture, serving as reservoirs of nitrogen (N) for grain filling, and the better leaf angle of these modern hybrids also allows a better air circulation under conditions of high plant densities, reducing the level of interference of one plant over the other (Li et al., 2015).

Maize hybrids with old architecture, which normally have longer cycles, late, usually have leaves in a higher number, larger and decumbent, are tall, produce a lot of mass and do not benefit from smaller spacings due to the large vegetative development right in the beginning of the cycle, with possibility of shading in the interrow spacing (Sangoi et al., 2002).

Regarding plant nutrition, N is of great importance in the management of the maize crop, which is highly responsive in production, being applied in considerable amounts in top-dressing fertilization (Dhital & Raun, 2016). Urea has been the most used N fertilizer in maize plantations, due to its cost/benefit per unit of the nutrient, associated with the agronomic efficiency, and there is a large amplitude of application, from 50 to 200 kg ha$^{-1}$ (Mota et al., 2015).

This study aimed to evaluate the influence of plant architecture (modern and old) of maize hybrids, associated with sowing densities and different levels of top-dressing N fertilization, in the municipalities of Guarapuava (spacing of 0.45 m) and Laranjeiras do Sul (spacing of 0.90 m) in the Paraná state.

## Material and Methods

Two independent experiments were conducted in the first season of the 2012/2013 agricultural years, in no-till system stabilized in the Mid-South region of Paraná, where the climate is Cfb (humid mesothermal subtropical), according to Köppen's classification. The first experiment was installed on October 12, 2012, in the municipality of Guarapuava, PR, at the Três Capões Farm (980 m of altitude, latitude 25º 25' S and longitude 51° 39' W), whereas the second experiment was installed on October 20, 2012, in the municipality of Laranjeiras do Sul, PR, at the Rio Almoço Farm (700 m of altitude, latitude 25° 33' S and longitude 52° 24' W).

The soils in the experimental areas were classified as typic dystroferric Brown Latosol with very clayey texture and typic eutrophic Red Latosol with clayey texture (EMBRAPA, 2013), for the municipalities of Guarapuava and Laranjeiras do Sul, respectively, and the results of the soil analyses, according to Raij et al. (1996), are presented in Table 1.

Both experiments were set in a randomized block design with three replicates, in a 6 x 3 x 3 factorial scheme, composing 54 treatments in a total of 162 experimental plots. The experiments used six single-cross hybrids of maize, for grain purposes (AG8025Y, DKB240Y, P1630H, P30R50H, DKB390Y, P32R48H), three plant densities (60,000, 75,000 and 90,000 plants ha$^{-1}$) and three doses of N fertilization as top-dressing (0, 90 and 180 kg ha$^{-1}$). The hybrids AG 8025Y, DKB 240Y and P 1630H are considered to have modern architecture; however, the hybrids P 30R50H, DKB 390Y and P 32R48H show old architecture. The experiment in Guarapuava used a reduced spacing (0.45 m) and the one in Laranjeiras do Sul used the conventional spacing (0.90 m).

After emergence, the plant stands were adjusted to populations of 60,000, 75,000 and 90,000 plants ha$^{-1}$, and basal fertilization consisted of 350 kg ha$^{-1}$ of the NPK formulation 12-30-10, for all treatments. Urea was used for top-dressing N fertilization, at three doses: 0, 90 and 180 kg ha$^{-1}$ of N. The first top-dressing N fertilization was applied when plants reached the stage of three to four leaves, using 200 kg ha$^{-1}$ of urea (45% N), thus applying 90 kg ha$^{-1}$ of N. The treatments with 180 kg ha$^{-1}$ of N received a second top-dressing fertilization when plants reached the stage of six to seven leaves, with application of more 200 kg ha$^{-1}$ of urea (45% N). The N fertilizer was applied manually, broadcast on soil surface (without incorporation) and under adequate moisture conditions. In both experiments (Guarapuava and Laranjeiras do Sul), after the physiological maturation of the grains (165 days after sowing, approximately), the agronomic characteristics were evaluated: stem diameter (SD) using a caliper (mm), in the second internode above the soil, 1000-grain weight (1000GW) and grain yield (Y), using the following expression Eq. 1:

$$Y = GY \times \frac{(100 - U)}{87} \quad (1)$$

where:

Y - grain yield, kg ha$^{-1}$, corrected for standard moisture of 13%;

GY - grain yield, kg ha$^{-1}$; and,

U - water content of the grains at harvest.

Table 1. Results of the soil analysis before installing the experiments in Guarapuava and Laranjeiras do Sul

| Local | pH | P-Mehlich | $K^+$ | $Ca^{2+}$ | $Mg^{2+}$ | $Al^{3+}$ | $H^+ + Al^{3+}$ | CEC | V | OM |
|---|---|---|---|---|---|---|---|---|---|---|
| | | mg dm$^{-3}$ | cmol$_c$ dm$^{-3}$ | | | | | | % | g dm$^{-3}$ |
| Laranjeiras do Sul | 5.2 | 6.3 | 0.40 | 5.7 | 2.9 | 0 | 5.0 | 14.1 | 64.2 | 69.6 |
| Guarapuava | 5.0 | 2.6 | 0.18 | 3.9 | 2.3 | 0 | 5.1 | 11.51 | 55.2 | 42.9 |

*Analyses performed at the Laboratories Maravilha Ltda and Tecsolo, respectively; pH - pH in calcium chloride; SB - Sum of bases; CEC - Cation exchange capacity at pH 7.0; V - Base saturation; OM - Organic matter

The obtained data were subjected to analysis of variance and the means were compared by Scott-Knott test at 0.05 probability level, using the statistical program SISVAR® (Ferreira, 2011). Subsequently, for each experiment (Guarapuava and Laranjeiras do Sul), seven orthogonal contrasts were made (G1 x G2; 0 x 90; 0 x 180; 90 x 180; 60 x 75, 60 x 90 and 75 x 90), to compare the different groups of hybrids (G1 = group of hybrids with modern architecture; and G2 = group of hybrids with old architecture), doses of top-dressing N fertilization (0, 90 and 180 kg $ha^{-1}$) and plant densities (60,000, 75,000 and 90,000 plants $ha^{-1}$) regarding the evaluated agronomic characteristics.

## Results and Discussion

Firstly, it is important to point out that the total rainfall and air temperature data along the experimental period in both sites (Guarapuava and Laranjeiras do Sul) were considered as adequate to obtain maximum maize grain yield, since the rainfall exceeded 1000 mm and the temperatures were close to 20 ºC. However, in the experiment conducted in Laranjeiras do Sul, from November 10 to 30, the rainfall volume in the region was considered as low (72 mm) and may have affected crop yield, because in this period plants were in the V8 stage, which is of great importance to define the productive potential. These data and the other values of rainfall and mean temperatures of both experimental sites are shown in Figure 1.

For the characteristics stem diameter (SD) and thousand-grain weight (1000GW), there was significant effect between hybrids, plant densities and groups of hybrids (with modern and old architecture) in both experiments (Guarapuava and Laranjeiras do Sul) (Table 2).

For the characteristic stem diameter (SD), in the experiment of Laranjeiras do Sul (conventional spacing of 0.90 m) (Table 2), Group 2 (hybrids with old architecture) showed higher SD at the three plant densities (60,000, 75,000 and 90,000 plants $ha^{-1}$) in comparison to Group 1 (hybrids with modern architecture), leading to the conclusion that the old architecture favors the hybrids at larger spacings, since plants are taller and have leaves with larger size and in greater number (Sá et al., 2002), probably resulting in higher efficiency of solar radiation interception to increase SD.

In both experiments (Guarapuava and Laranjeiras do Sul), in the comparison of Groups 1 and 2 at each plant density, the increase from 60,000 to 75,000 and 90,000 plants $ha^{-1}$ led to significant reduction in stem diameter and the highest value was obtained at density of 60,000 plants $ha^{-1}$ (Guarapuava, Group 1: 25.05 mm and Group 2: 25.70 mm; Laranjeiras do Sul, Group 1: 19.03 mm and Group 2: 20.24 mm). However, there was no significant difference for stem diameter at densities of 75,000 and 90,000 plants $ha^{-1}$, demonstrating that higher plant densities can reduce stem diameter, regardless of the spacing between rows and architecture of maize hybrids.

According to Takasu et al. (2014), the increment of density in large populations leads to reduction in stem diameter and leaf area, because plants need to grow above the canopy to avoid shading, using the resources for a greater growth. Other studies indicate that the higher number of plants $ha^{-1}$ causes a reduction in stem diameter (Silva et al., 2014; Kappes et al., 2011). Mendes et al. (2013) also observed significant reduction in SD with the increase in plant density from 75,000 to 90,000 plants $ha^{-1}$, for the single-cross hybrid DKB 240Y (modern architecture), in the same municipality of cultivation.

For thousand-grain weight in the experiment of Guarapuava, Group 1 showed lower values, statistically, at the densities of 60,000 and 75,000 plants $ha^{-1}$ (371.36 and 349.38 g, respectively) in comparison to Group 2 at the same densities (371.36 and 349.38 g, respectively) . In the experiment of

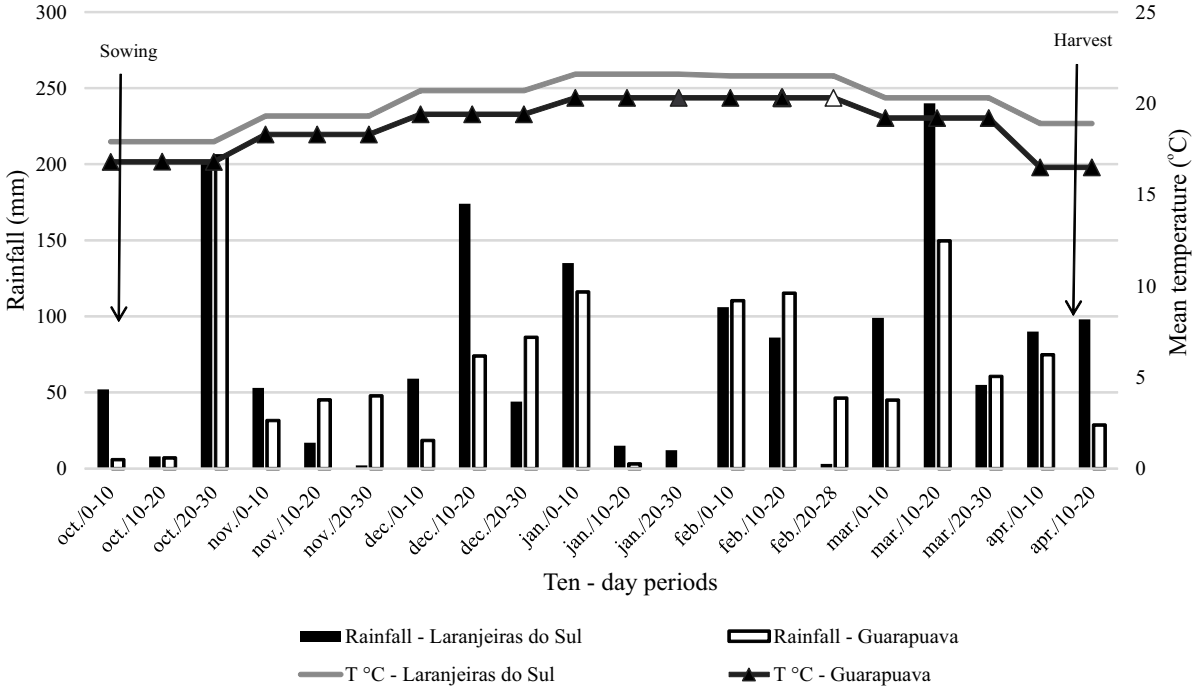


Figure 1. Data of rainfall (mm) and mean temperature (ºC) per ten-day period, in the municipalities of Guarapuava and Laranjeiras do Sul, PR, from October to April in the 2012/2013 growing season

Table 2. Mean values of stem diameter (SD) and thousand-grain weight (1000GW), obtained for the different maize hybrids associated with plant densities, in the municipalities of Guarapuava (spacing of 0.45 m) and Laranjeiras do Sul (spacing of 0.90 m)

| Hybrids | SD (mm) | | | 1000GW (g) | | |
|---|---|---|---|---|---|---|
| | 60000 | 75000 | 90000 | 60000 | 75000 | 90000 |
| Guarapuava - 0.45 m | | | | | | |
| AG 8025Y | 25.49 aA | 24.28 aA | 23.99 aA | 412.59 aA | 390.37 bA | 397.04 aA |
| DKB 240Y | 25.70 aA | 24.61 aA | 24.00 aA | 352.59 bA | 333.33 cA | 357.41 bA |
| P 1630H | 23.96 aA | 22.42 bA | 22.45 aA | 348.89 bA | 324.44 cA | 318.52 bA |
| Group 1* | 25.05 aA | 23.77 aB | 23.48 aB | 371.36 bA | 349.38 bA | 357.65 aA |
| P 30R50H | 25.36 aA | 24.19 aA | 23.56 aA | 442.22 aA | 405.93 bB | 390.37 aB |
| DKB 390Y | 26.23 aA | 24.59 aA | 24.99 aA | 377.04 bA | 344.44 cB | 335.93 bB |
| P 32R48H | 25.52 aA | 24.59 aA | 23.07 aB | 430.37 aA | 448.15 aA | 391.11 aB |
| Group 2* | 25.70 aA | 24.45 aB | 23.87 aB | 416.54 aA | 399.51 aA | 372.47 aB |
| Laranjeiras do Sul - 0.90 m | | | | | | |
| AG 8025Y | 20.33 aA | 18.02 bB | 17.73 bB | 382.11 aA | 354.04 aB | 335.56 aB |
| DKB 240Y | 19.32 aA | 18.67 aA | 17.16 bB | 310.37 bA | 314.64 bA | 303.66 bA |
| P 1630H | 17.44 bA | 17.07 bA | 16.23 bA | 274.20 cA | 272.98 cA | 270.40 cA |
| Group 1* | 19.03 bA | 17.92 bB | 17.04 bB | 322.22 bA | 313.89 bA | 303.21 bA |
| P 30R50H | 19.49 aA | 18.78 aA | 18.93 aA | 354.64 aA | 365.22 aA | 336.44 aA |
| DKB 390Y | 20.64 aA | 20.26 aA | 19.46 aA | 364.60 aA | 365.67 aA | 344.42 aA |
| P 32R48H | 20.59 aA | 19.19 aA | 17.75 bB | 368.00 aA | 363.34 aA | 363.75 aA |
| Group 2* | 20.24 aA | 19.41 aB | 18.72 aB | 362.41 aA | 364.74 aA | 348.20 aA |

Means followed by the same lowercase letters in the columns for each plant population and uppercase letter in the rows in each plant population do not differ statistically by the Scott-Knott test at 0.05 probability level; *Group 1 - Hybrids with modern architecture; Group 2 - Hybrids with old architecture

Laranjeiras do Sul, the values of thousand-grain weight in Group 2 were 10% higher than those in Group 1, at the three plant densities, which can be related to the old architecture of the hybrids. In addition, the presence of larger leaf area may have caused increase in the photosynthetic activity of the crop and efficiency in the conversion of photoassimilates for greater grain filling.

In Group 2, comparing the mean values at the different densities in the experiment of Guarapuava (reduced spacing), there were significant differences and the density of 90,000 plants $ha^{-1}$ led to the lowest thousand-grain weight (372.47 g), demonstrating that the old architecture is less favorable to increasing solar radiation interception in dense stands, resulting in greater intraspecific shading (Sangoi et al., 2007). Silva et al. (2014) observed that the density of 80,000 plants $ha^{-1}$ caused reduction of 4.7% in grain weight in comparison to the treatment with density of 40,000 plants $ha^{-1}$. Similar results were obtained by Ubert et al. (2014), who observed reduction in 1000GW proportional to the increase of plant population. Uate et al. (2014), evaluating the maize hybrids Dow 2B587, AG 4051, CD 384 HX and GNZ 2004, concluded that there was no statistical difference for 1000GW with the increment in population density.

Regarding the characteristics thousand-grain weight (1000GW) and yield (Y), there was significant effect between hybrids, top-dressing N fertilization and groups of hybrids (modern and old architecture), in both experiments (Guarapuava and Laranjeiras do Sul) according to Table 3.

Table 3. Mean values of thousand-grain weight (1000GW) and grain yield (Y), obtained for different maize hybrids associated with top-dressing N fertilization in the municipalities of Guarapuava (spacing of 0.45 m) and Laranjeiras do Sul (spacing of 0.90 m)

| Hybrids | 1000GW (g) | | | Y (kg $ha^{-1}$) | | |
|---|---|---|---|---|---|---|
| | 0N | 90N | 180N | 0N | 90N | 180N |
| Guarapuava - 0.45 m | | | | | | |
| AG 8025Y | 394.81 aA | 395.55 aA | 409.63 aA | 13275 aA | 13932 aA | 14196 aA |
| DKB 240Y | 337.04 bA | 358.15 bA | 348.15 bA | 12511 aB | 14108 aA | 14095 bA |
| P 1630H | 311.85 bA | 342.96 bA | 337.04 bA | 10073 bB | 11506 bA | 11931 aA |
| Group 1* | 347.90 bA | 365.55 bA | 364.94 bA | 11953 aB | 13182 aA | 13407 bA |
| P 30R50H | 411.11 aA | 402.22 aA | 425.19 aA | 13423 aA | 14373 aA | 15057 aA |
| DKB 390Y | 338.89 bA | 358.52 bA | 360.00 bA | 12359 aA | 12684 bA | 13570 aA |
| P 32R48H | 418.52 aA | 411.11 aA | 440.00 aA | 12602 aB | 12465 bB | 14399 aA |
| Group 2* | 389.51 aA | 390.62 aA | 408.40 aA | 12795 aB | 13173 aB | 14342 aA |
| Laranjeiras do Sul - 0.90 m | | | | | | |
| AG 8025Y | 345.57 aA | 362.75 aA | 363.40 aA | 4406 aB | 5986 aA | 6399 aA |
| DKB 240Y | 313.79 bA | 305.70 bA | 309.17 bA | 5122 aB | 5843 aA | 6167 aA |
| P 1630H | 249.80 cB | 272.19 cB | 295.59 bA | 4199 aB | 5642 aA | 5455 bA |
| Group 1* | 303.05 bA | 313.55 bA | 322.72 bA | 4576 aB | 5824 aA | 6007 aA |
| P 30R50H | 344.64 aA | 345.28 aA | 366.37 aA | 4080 aC | 5173 aB | 6121 aA |
| DKB 390Y | 363.74 aA | 342.73 aA | 368.21 aA | 4800 aB | 5661 aA | 6423 aA |
| P 32R48H | 346.78 aA | 372.59 aA | 375.72 aA | 4505 aB | 5555 aA | 5575 bA |
| Group 2* | 351.72 aA | 353.54 aA | 370.10 aA | 4462 aC | 5463 aB | 6040 aA |

Means followed by the same lowercase letters in the columns for each top-dressing fertilization treatment and uppercase letter in the rows for the treatments with different nitrogen doses as top-dressing do not differ statistically by the Scott-Knott test at 0.05 probability level; *Group 1 - Hybrids with modern architecture; Group 2 - Hybrids with old architecture

For thousand-grain weight (1000GW), in the experiments of both Guarapuava and Laranjeiras do Sul, there was statistical difference between Groups (Table 3). The values of 1000GW in Group 2 were approximately 10% higher (Guarapuava: 389.51; 390.62 and 408.40 g; Laranjeiras do Sul: 351.72; 353.54 and 370.10 g), statistically differing from Group 1 (Guarapuava: 347.90; 365.55 and 364.94 g; Laranjeiras do Sul: 303.05; 313.55 and 322.72 g), at the three levels of top-dressing N fertilization (0, 90 and 180 kg ha$^{-1}$ of N), respectively. According to Farinelli & Lemos (2012), thousand-grain weight is a characteristic influenced by the genotype, availability of nutrients and climatic conditions during the grain filling stage.

When Groups 1 and 2 were analyzed separately, there were no significant differences for the different treatments with top-dressing N fertilization (Table 3). Opposite results were found in the same region of this experiment by Caires & Milla (2016), who observed linear increment of 1000GW working with interrow spacing of 0.50 m for the modern-architecture maize hybrid P1630, subjected to different N doses as top-dressing.

Still according to Table 3 for the variable grain yield in the experiment of Guarapuava, Group 2, when cultivated with the highest N dose as top-dressing (180 kg ha$^{-1}$) showed higher yield (14,342 kg ha$^{-1}$) in comparison to Group 1 (13,407 kg ha$^{-1}$). The individual analysis of each Group indicated that Group 1 showed the same behavior in both experiments (Guarapuava and Laranjeiras do Sul). The fertilizations of 90 and 180 kg ha$^{-1}$ of N for this Group did not result in statistical differences for grain yield (Guarapuava: 13,182 and 13,407 kg ha$^{-1}$; Laranjeiras do Sul: 5,824 and 6,007 kg ha$^{-1}$, respectively), but both N doses resulted in higher yields in comparison to the control (treatment with 0 kg ha$^{-1}$ of N), whose values for the N fertilizations of 90 and 180 kg ha$^{-1}$ were 11,953 kg ha$^{-1}$ for Guarapuava and 4,576 kg ha$^{-1}$ for Laranjeiras do Sul (Table 3). Other studies conducted with reduced spacing demonstrated that higher N doses as top-dressing result in higher grain yields for the maize crop (Mendes et al., 2013; Caires & Milla, 2016).

For Group 2, in the experiment of Laranjeiras do Sul, grain yield increased with the increment in the doses of top-dressing N fertilization, showing differences of 20 and 30% between the control and the N doses of 90 and 180 kg ha$^{-1}$, respectively. Higher grain yields have also been observed in other studies conducted using interrow spacing of 0.90 m (Kappes et al., 2014; Lana et al., 2014).

In general, the grain yield obtained in the experiment of Guarapuava was much higher than that relative to Laranjeiras do Sul (50 to 60%), possibly due to the water deficit that occurred in Laranjeiras do Sul in the beginning of the crop development, as previously highlighted.

Table 4 shows the seven orthogonal contrasts (G1 x G2; 0 x 90; 0 x 180; 90 x 180; 60 x 75, 60 x 90 and 75 x 90), comparing the different groups of hybrids: Group 1 (with modern architecture) and Group 2 (with old architecture), levels of top-dressing N fertilization (0, 90 and 180 kg ha$^{-1}$) and plant densities (60,000, 75,000 and 90,000 plants ha$^{-1}$), regarding the agronomic characteristics evaluated in both experiments (Guarapuava, with interrow spacing of 0.45 m, and Laranjeiras do Sul, with interrow spacing of 0.90 m).

Table 4. Probability of significance of the contrasts for stem diameter (SD), thousand-grain weight (1000GW) and grain yield (Y), obtained for the different hybrids, levels of top-dressing N fertilization and plant densities, in the experiments conducted in the municipalities of Guarapuava (spacing of 0.45 m) and Laranjeiras do Sul (spacing of 0.90 m)

| Contrasts | Agronomic characteristics | | |
|---|---|---|---|
| | SD | 1000GW | Y |
| Guarapuava - 0.45 m | | | |
| G1 X G2 | 0.03 | 0.01 | 0.02 |
| 0 x 90 | 0.72 | 0.17 | 0.01 |
| 0 x 180 | 0.13 | 0.01 | 0.01 |
| 90 x 180 | 0.06 | 0.21 | 0.02 |
| 60 x 75 | 0.01 | 0.01 | 0.06 |
| 60 x 90 | 0.01 | 0.01 | 0.49 |
| 75 x 90 | 0.19 | 0.17 | 0.22 |
| Laranjeiras do Sul - 0.90 m | | | |
| G1 X G2 | 0.01 | 0.01 | 0.27 |
| 0 x 90 | 0.11 | 0.35 | 0.01 |
| 0 x 180 | 0.12 | 0.01 | 0.01 |
| 90 x 180 | 0.96 | 0.05 | 0.02 |
| 60 x 75 | 0.01 | 0.65 | 0.45 |
| 60 x 90 | 0.01 | 0.01 | 0.06 |
| 75 x 90 | 0.02 | 0.04 | 0.26 |

G1 (Group 1 - Hybrids with modern architecture); G2 (Group 2 - Hybrids with old architecture); 0 (0 kg ha$^{-1}$ of N); 90 (90 kg ha$^{-1}$ of N); 180 (180 kg ha$^{-1}$ of N); 60 (60,000 plants ha$^{-1}$); 75 (75,000 plants ha$^{-1}$); 90 (90,000 plants ha$^{-1}$)

In the contrasts involving the evaluated agronomic characteristics (Table 4) and, based on the contrast G1 x G2, it is once again evident the response of the maize hybrids evaluated for plant architecture, which was expected, because of the genetic modifications of the cultivars. Most of the evaluated agronomic characteristics were significant for this contrast, in both experiments (Guarapuava and Laranjeiras do Sul).

According to the analysis of the contrasts between the levels of top-dressing N fertilization 0 x 90, 0 x 180 and 90 x 180, there was significance of more than 95% for grain yield (Y). Similar results were found by Mota et al. (2015), who observed that grain yield showed a linear increment in response to the increase in the N doses applied as top-dressing.

## Conclusions

1. Sowing densities and top-dressing N doses influenced the thousand-grain weight of hybrids with modern and old architecture, in the municipalities of Guarapuava and Laranjeiras do Sul, in the Paraná state.

2. The increase in sowing density reduces stem diameter in the groups of modern and old architecture, in Laranjeiras do Sul.

3. Grain yield was positively influenced by top-dressing N fertilization, being higher at the N dose of 180 kg ha$^{-1}$ in Guarapuava and Laranjeiras do Sul.

## Literature Cited

Caires, E. F.; Milla, R. Adubação nitrogenada em cobertura para o cultivo de milho com alto potencial produtivo em sistema de plantio direto de longa duração. Bragantia, v.75, p.87-95, 2016.

Dhital, S.; Raun, W. R. Variability in optimum nitrogen rates for maize. Agronomy Journal, v.108, p.2165-2173, 2016. https://doi.org/10.2134/agronj2016.03.0139

EMBRAPA - Empresa Brasileira de Pesquisa Agropecuária. Centro Nacional de Pesquisa de Solos. Sistema brasileiro de classificação de solos. 3.ed. Brasília: EMBRAPA, 2013. 306p.

Farinelli, R.; Lemos, L. B. Nitrogênio em cobertura na cultura do milho em preparo convencional e plantio direto consolidados. Pesquisa Agropecuária Tropical, v.42, p.63-70, 2012. https://doi.org/10.1590/S1983-40632012000100009

Ferreira, D. F. Sisvar: A computer statistical analysis system. Ciência e Agrotecnologia, v.35, p.1039-1042, 2011. https://doi.org/10.1590/S1413-70542011000600001

Kappes, C.; Andrade, J. A. da C.; Arf, O.; Oliveira, A. C. de; Arf, M. V; Ferreira, J. P. Desempenho de híbridos de milho em diferentes arranjos espaciais de plantas. Bragantia, v.70, p.334-343, 2011. https://doi.org/10.1590/S0006-87052011000200012

Kappes, C.; Arf, O.; Dal Bem, E. A.; Portugal, J. R.; Gonzaga, A. R. Manejo do nitrogênio em cobertura na cultura do milho em sistema plantio direto. Revista Brasileira de Milho e Sorgo, v.13, p.201-217, 2014.

Lana, M. do C.; Rampim, L.; Ohland, T.; Fávero, F. Espaçamento, densidade populacional e adubação nitrogenada na cultura do milho. Revista Ceres, v.61, p.424-433, 2014. https://doi.org/10.1590/S0034-737X2014000300018

Li, C.; Li, Y.; Shi, Y.; Song, Y.; Zhang, D.; Buckler, E. S.; Zhang, Z.; Wang, T.; Li, Y. Genetic control of the leaf angle and leaf orientation value as revealed by ultra-high density maps in three connected maize populations. Plos One, p.1-13, 2015. https://doi.org/10.1371/journal.pone.0121624

Mendes, M. C.; Matchula, P. H.; Rossi, E. S.; Oliveira, B. R. de; Silva, C. A. da; Sékula, C. R. Adubação nitrogenada em cobertura associada com densidades populacionais de híbridos de milho em espaçamento reduzido. Revista Brasileira de Milho e Sorgo, v.12, p.92-101, 2013. https://doi.org/10.18512/1980-6477/rbms.v12n2p92-101

Mota, M. R.; Sangoi, L.; Schenatto, D. E.; Giordani, W.; Boniatti, C. M.; Dall'Igna, L. Fontes estabilizadas de nitrogênio como alternativa para aumentar o rendimento de grãos e a eficiência de uso do nitrogênio pelo milho. Revista Brasileira de Ciência do Solo, v.39, p.512-522, 2015. https://doi.org/10.1590/01000683rbcs20140308

Raij, B. van; Cantarella, H.; Quaggio, A. J.; Furlani, A. M. C. (ed.). Recomendação de adubação e calagem para o Estado de São Paulo. 2.ed. Campinas: Instituto Agronômico, 1996. 285p. Boletim Técnico, 100

Sá, M. de; Ramalho, M. A. P.; Souza Sobrinho, F. de. Aspectos morfológicos e fisiológicos de cultivares modernas e antigas de milho. Ciência e Agrotecnologia, v.26, p.1082-1091, 2002.

Sangoi, L.; Almeida, M. L. de; Silva, P. R. F. da; Argenta, G. Bases morfofisiológicas para maior tolerância dos híbridos modernos de milho a altas densidades de plantas. Bragantia, v.61, p.101-110, 2002. https://doi.org/10.1590/S0006-87052002000200003

Sangoi, L.; Schmitt, A.; Zanin, C. G. Área foliar e rendimento de grãos de híbridos de milho em diferentes populações de plantas. Revista Brasileira de Milho e Sorgo, v.6, p.263-271, 2007. https://doi.org/10.18512/1980-6477/rbms.v6n3p263-271

Silva, A. F. da; Schoninger, E. L.; Caione, G.; Kuffel, C.; Carvalho, M. A. C. de. Produtividade de híbridos de milho em função do espaçamento e da população de plantas em sistema de plantio convencional. Revista Brasileira de Milho e Sorgo, v.13, p.162-173, 2014. https://doi.org/10.18512/1980-6477/rbms.v13n2p162-173

Takasu, A. T.; Rodrigues, R. A. F.; Goes, R. J.; Haga, K. I.; Arf, O.; Gitti, D. C. Características agronômicas da cultura do milho em função do preparo de solo e arranjo espacial de plantas. Revista Agrarian, v.7, p.485-495, 2014.

Uate, J. V.; Pinho, R. G. von; Cancellier, L. L. Efeito do espaçamento entre linhas e densidade de plantas na produção da cultura de milho. Revista Científica da UEM, v.1, p.13-20, 2014.

Ubert, I. de P.; Almeida, C. A. S. de; Chiodelli, E.; Bresolin, F.; Castanho, M.; Soligo, S.; Camillo, M. F. Efeito de diferentes densidades na produtividade de grãos de milho (*Zea mays* L.) em espaçamento reduzido. Revista de Agronomia e Medicina Veterinária do Instituto de Desenvolvimento Educacional do Alto Uruguai - RAMVI, v.1, p.1-20, 2014.