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AGRONOMIC CHARACTERISTICS AND GRAIN YIELD OF SORGHUM AND MAIZE HYBRIDS GROWN WITH DIFFERENT SOWING TIMES[1]

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ABSTRACT - Sorghum is a commonly grown plant in the Central-West region of Brazil as a second crop; however, it is grown almost exclusively as a second crop after maize in the state of Paraná (South region). The growth of sorghum crops is an option for areas or times in which the growth of maize crops can be risky. Thus, the objective of this work was to evaluate the agronomic characteristics of eight sorghum hybrids (ADV-123, ADV-114, 1G100, 50A10, 1G244, 50A40, 50A50, and 1G282) grown in three sowing times in two agricultural years: 2014 (February 20, March 02, and March 03) and 2015 (February 09, February 19, and March 01), and four maize hybrids in 2014 (DKB-330-Pro, P-3431-HX, Formula-TL, and AG-9010-Pro) and five maize hybrids in 2015 (DKB-330-Pro, P-3431-HX, Formula-TL, DKB-275-Pro, and DKB-290-Pro), in the same sowing times used for sorghum. A randomized complete block experimental design with a split-plot factorial arrangement was used, with the sowing times in the plots and the hybrids in the sub-plots. The variables evaluated were: number of days from sowing to flowering, leaf area index, 1,000-grain weight, grain yield, number of spikelets per panicle, for the sorghum crop; and number of rows per ear and number of grains per row, for the maize crop. The comparison between the two crops showed that the sorghum maintained higher production stability in the different sowing times.

Keywords: Paraná. Winter crop. *Sorghum bicolor*. *Zea mays*.

CARACTERÍSTICAS AGRONÔMICAS E PRODUTIVIDADE DE HÍBRIDOS DE SORGO E MILHO CULTIVADOS EM DIFERENTES DATAS DE SEMEADURA

RESUMO - O sorgo é uma cultura muito utilizada no Centro-Oeste brasileiro em cultivo de segunda safra, contudo, no Paraná a mesma é feita quase exclusivamente com a cultura do milho. O cultivo de sorgo pode ser uma opção de semeadura em áreas ou épocas cuja a cultura do milho possa ser considerada de risco. Assim, objetivou-se com trabalho avaliar as características agronômicas de oito híbridos de sorgo (ADV 123, ADV 114, 1G100, 50A10, 1G244, 50A40, 50A50 e 1G282), em três datas de semeadura nos anos agrícolas de 2014 (20/02, 02/03 e 12/03) e 2015 (09/02, 19/02 e 01/03) e quatro híbridos de milho em 2014 (DKB 330 Pro, P 3431 HX, Formula TL e AG 9010 Pro) e cinco híbridos no ano de 2015 (DKB 330 Pro, P 3431 HX, Formula TL, DKB 275 Pro e DKB 290 Pro), nas mesmas datas de semeadura utilizada para o sorgo. O delineamento experimental foi em blocos completos casualizados em esquema fatorial em parcelas subdivididas, sendo nas parcelas alocadas as datas de semeadura e nas sub parcelas os híbridos. Foi avaliado o número de dias da semeadura até o florescimento (DAP), índice de área foliar (IAF), massa de mil grãos (MMG), produtividade (kg ha^{-1}) número de espiguetas por panícula no sorgo (EPP), e no milho o número de fileiras por espiga (NFE) e número de grãos por fileira (NGF). Ao comparar as culturas, o sorgo conseguiu manter maior estabilidade produtiva em diferentes datas de semeadura.

Palavras-chave: Paraná. Safrinha. *Sorghum bicolor*. *Zea mays*.

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INTRODUCTION

The central-west region of the state of Paraná, Brazil, has stood out in the Brazilian agricultural scenario; it is a pioneer region for the practice of two harvests in the same agricultural year, namely, first crop and second crop. The second crop is characterized by higher risks of occurrence of frosts and dry spells.

A late sowing of maize (*Zea mays* L.) affects negatively yield components and grain yield, mainly due to the unfavorable climate conditions, mainly temperature, solar radiation, and rainfall (TSIMBA et al., 2014; BONELLI et al., 2016; ZHOU et al., 2016; LU; XUE; GUO, 2017). The sowing time for the second crop is between January and March, when the temperature, solar radiation, and rainfall volume and frequency are usually insufficient and oscillate, decreasing the probability to meet the adequate water demand of most crops (GOES et al., 2011).

Zucareli et al. (2013) evaluated 12 maize hybrids as second crop in northern state of Paraná and found mean grain yield of 6.648 kg ha^{-1}. Shioga and Gerage (2010) evaluated sowing times for maize in different locations in Paraná and reported that the weather conditions affected the flowering (days) and grain yield (kg ha^{-1}) responses; the low temperature was the main factor that affected the flowering due to the low degree-day accumulation. In addition, they found that the lowest temperatures, with occurrence of frosts, and dry spell periods had more effect on grain yield as the sowing time is delayed.

Therefore, the search for alternative crops to substitute maize as second crop for this region, is needed. Tardin et al. (2013) pointed out several reasons that make grain sorghum crop (*Sorghum bicolor* L.) a better option than other cereals, mainly maize, to grow under stress conditions. Sorghum is a good option for grain production in the second crop season, which presents the lowest rainfall frequency volumes because it is a xerophyte (AMADUCCI et al., 2016) that has high sowing time amplitude and crop implementation flexibility.

Albuquerque et al. (2011) evaluated grain sorghum cultivars under semiarid conditions and found grain yields between 5.500 and 7.000 kg ha^{-1} in a rainy year and lower than 3.000 kg ha^{-1} in a dry year. Silva et al. (2013) and Almeida Filho et al. (2014) evaluated pre-commercial hybrids and found yields of 5.150 kg ha^{-1} and 4.400 kg ha^{-1}, respectively; these results were correlated with the sowing times and high availability and distribution of water in the study regions.

Thus, performance evaluations of sorghum and maize cultivars are needed for grain producing regions to make technical information regarding the use of these crops in production systems available to farmers.

In this context, the objective of this work was to evaluate agronomic and production characteristics of different sorghum and maize hybrids in three sowing times in the second crop season in the central -west region of Paraná.

MATERIAL AND METHODS

The experiments were conducted in the agricultural years of 2014 and 2015, using maize and sorghum crops under rainfed conditions in the municipality of Juranda, state of Paraná, Brazil (24° 23'10"S, 52°49'30"W, and altitude of 570 m). The soil of the area was classified as a Typic Hapludox (Latossolo Vermelho distroférrico; EMBRAPA, 2013). The predominant climate of the region is Cfa, sub-tropical wet, according to the Köppen classification, with mean annual temperature of 22.2 °C and annual rainfall depth of approximately 2.100 mm.

Data of maximum and minimum air temperatures, relative air humidity, solar radiation, rainfall, and wind speed were obtained from a meteorological station (Davis Vantage Pro 2) installed in the study area.

A randomized complete block experimental design was used, in a split-plot factorial arrangement, with sowing times (according to the agroclimatic zoning for the region of Paraná) in the plots, and hybrids in the subplots. The sorghum crop tests were conducted with three blocks, using eight hybrids, four of very-early maturation cycle (ADV-123, ADV-114, 1G100 and 50A10), three of early maturation cycle (1G244, 50A40 and 50A50) and one of normal cycle (1G282) grown in three sowing times (February 20, March 02, and March 03) and (February 09, February 19, and March 01) in the agricultural years of 2014 and 2015, respectively.

The maize crop tests were conducted with four blocks, using four very-early maturation hybrids (DKB-330-Pro, P-3431-HX, Formula-TL, and AG-9010-Pro) grown in three sowing times (February 20, March 02, and March 03) in 2014. The evaluations of the two latest sowing times were not carried out because all plants in the plots had been lodged by wind. In 2015, five maize hybrids were used, four of very-early maturation cycle (DKB-330-Pro, P-3431-HX, Formula-TL, and DKB-275-Pro) and one of early maturation cycle (DKB-290-Pro), in three sowing times (February 09, February 19, and March 01), using four blocks, although the last harvest had been not possible due to the lodging of the plants.

Soil fertilizers were applied at sowing using 210 kg ha^{-1} of the N-P_2O_5-K_20 formulation 08-20-20, and 40 kg ha^{-1} of nitrogen was used as topdressing at the V4 stage for both crops (TEDESCO et al., 2004).

The maize and sorghum experimental plots consisted of six 6-meter rows spaced 0.70 m apart, and the evaluation area consisted of the four central meters of the two central rows. The maize was sown using approximately 4.3 seeds per meter, resulting in a final population of approximately 58.000 plants per hectare. The sorghum was sown using approximately 22 seeds per meter to a final population of approximately 280.000 plants per hectare.

The agronomic performance characterization of the sorghum and maize hybrids were carried out using information collected over the crop cycle. The variables evaluated were: a) number of days from sowing to flowering (DSF), considering the time that 50% of the plants in the plots were releasing pollen as flowering; b) number of spikelets per panicle (NSPP) in the sorghum crop; c) number of rows per ear (NRE) in the maize crop; d) number of grains per row (NGF) in the maize crops; e) leaf area index (LAI), measured by multiplying the leaf area (maximum leaf length multiplied by its width and then by the correction factor 0.75; (FRANCIS RUTGER; PALMER, 1969) by the area occupied per plant (ratio between number of plants and the area used); f) grain yield (kg ha^{-1}), yield of grains obtained by harvesting and threshing of plants in the evaluation area of each plot, the weight of grains was corrected to a moisture of 13% and then transformed into kg ha^{-1}; and g) 1,000-grain weight (1000GW; g).

The data were subjected to tests of normality (Kolmogorov-Smirnov) and homogeneity (Cochran) of errors and then subjected to analysis of variance at 5% probability by the Fisher test. The means were compared using the Scott-Knott grouping test at 10% probability level. The SAS 9.1.3 and SISVAR 5.3 (Build 77) programs was used for the statistical analyses.

RESULTS AND DISCUSSION

Sorghum crop

Regarding the agronomic and yield characterization of the hybrids, the number of spikelets per panicle (NSPP) and 1,000-grain weight (1000GW) of sorghum crops in 2015 did not met the basic assumptions for the analysis of variance and the subsequent Scott-Knott grouping test, even after the transformation of the data.

The sowing times in 2014 presented, in general, high variation between hybrids; the very-early maturation hybrids presented 7% to 11% faster maturation then the others, whereas in 2015, these differences were 2.7 to 5.8%.

The hybrids ADV-123, ADV-114, 1G100, and 50A10 required lower number of days to reach 50% flowering (DSF) in 2014, mainly in the first sowing time, in which hybrids of different maturation cycles (1G244, 1G282, 50A40, and 50A50) presented statistically higher DSF by the Scott-Knott test and within the group of very-early maturation hybrids (Table 1).

Table 1. Number of days from sowing to flowering of sorghum crops grown in three sowing times in 2014 and 2015.

Hybrid	2014			2015		
	February 20	March 02	March 03	February 09	February 19	March 01
ADV-123	62 bB	66 bA	68 bA	59 bB	62 cA	59 dB
ADV-114	57 cC	61 cB	65 cA	60 bA	61 cA	56 eB
1G100	57 cB	60 cB	64 cA	60 bB	63 cA	57 eC
1G244	67 aB	67 bB	75 aA	64 aA	65 bA	63 cA
1G282	66 aB	68 bA	70 aA	64 aA	65 bA	65 bA
50A10	60 bC	65 bB	72 aA	62 aB	65 bA	63 cA
50A40	69 aB	73 aA	74 aA	65 aB	68 aA	67 aA
50A50	66 aB	68 bB	71 aA	63 aB	67 aA	64 cB
CV (%)	3.25			2.07		

Means followed by the same lowercase letter in the columns, or uppercase in the rows, are not different from each other by the Scott-Knott test at 10% probability level.

The hybrids ADV-114 and 1G100 presented lower and statically different DSF than the ADV-123 and 50A10 by the Scott-Knott test, although they belong to the same maturation group. The hybrids ADV-114 and 1G100 presented earlier maturation in the sowing on March 02. The hybrid 50A40 was the most late, and the other treatments were within an intermediate level, despite being from different maturation groups. Only the hybrid 50A10 (very-early maturation cycle), had a late flowering in the third sowing time and was grouped together with longer cycle hybrids.

The sowing on February 09, 2015, presented similar results to the that found for the sowing on

March 12, 2014, except for the hybrid 50A10, the other very-early maturation hybrids were grouped together. These results were repeated for the sowing on February 19 and March 01, however, the hybrid 50A10 was within the intermediate group (Table 1).

The mean DSF of all hybrids, from the first to the last sowing time, was 9.8% and 3.5%, for 2014 and 2015, respectively; thus, the earlier the sowing the lowest the cycle variation between hybrids.

The DSF in 2014 within each sowing time showed that all hybrids presented longer cycle when using the late sowing. The hybrids ADV-114 and 50A10 presented higher sensitivity, both of very-early maturation cycle, which differed in the three sowing times. The hybrids ADV-123, 1G282, and 50A40 did not vary significantly ($p<0.10$) between the second and third sowing time, whereas the other showed difference only between the last and the two first sowing times.

Comparing the hybrids within the sowing times, the sowing on February 19, 2015 presented higher DSF than the last sowing time for three very-early maturation hybrids (ADV-123, ADV-114 and 1G100) and for the early maturation cycle hybrid 50A50; a normal result would be the last sowing time presenting a higher DSF when compared to the two first sowing times.

This result is due to the high rainfall depths and low temperatures at the beginning of the crop cycle as a function of the different sowing times; contrasting with the results found in 2014, which presented rainfall variation and distribution at the beginning of the development of the three most homogeneous sowing times (Figure 1A and 1B).

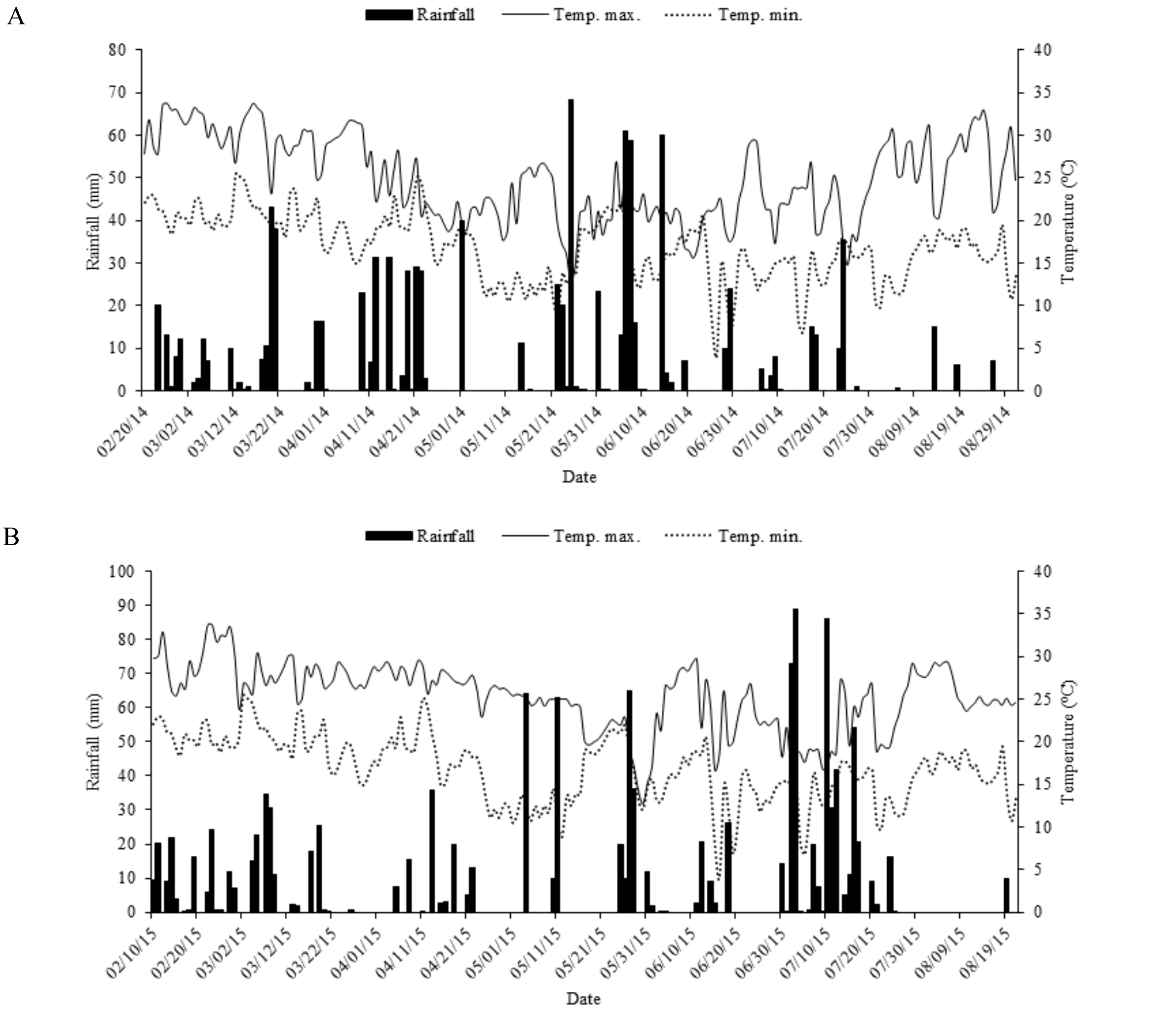

Figure 1. Maximum and minimum temperatures (°C) and daily rainfall (mm) throughout the experiment in 2014 (A) and 2015 (B). Source: Weather station of the experimental area.

Thus, as well as second crop maize, sorghum may be sown in January, focused on minimize losses related to water deficit, mainly in critical periods for the crop and under low temperatures, which affect grain yield and contribute to increases in the time required for the crop to reach the flowering period (LANDAU; SANS; SANTANA, 2010).

The hybrids ADV-123 and 50A40 presented statistically lower number of spikelets per panicle (NSPP) when compared to the other hybrids in all sowing times (Table 2). The hybrid 1G282 had statistically higher NSPP (60 NSPP) in the second sowing time, whereas the other hybrids had 45 to 56 EEP. The hybrid ADV-114 presented the highest NSPP, considering all treatments in the third sowing time, and the highest NSPP for the sowing time February 20, together with other three hybrids, however, numerically higher than the others.

Table 2. Mean number of spikelets per panicle of sorghum plants grown in three sowing times in 2014.

Hybrid	Sowing time		
	February 20	March 02	March 03
ADV-123	48 cA	47 cA	44 cA
ADV-114	63 aA	54 bB	55 aB
1G100	55 bA	56 bA	50 bB
1G244	59 aA	55 bA	51 bB
1G282	59 aA	60 aA	51 bB
50A10	60 aA	55 bB	50 bC
50A40	46 cA	45 cA	45 cA
50A50	54 bA	54 bA	51 bA
CV (%) 4.65			

Means followed by the same lowercase letter in the columns, or uppercase in the rows, are not different from each other by the Scott-Knott test at 10% probability level.

The last sowing time presented the lowest NSPP, except for the hybrids ADV-123 and 50A40, which had the lowest means in all sowing times, and the hybrid 50A50 which had no different NSPP between sowing times. It was not found a correlation between NSPP and the different maturation groups in the evaluation between sorghum hybrids.

The leaf area index (LAI) showed a different dynamic between the years regarding the sowing time (Table 3). In 2014, the LAI decreased, on average, 20% from the first (February 20) to the second (March 02) sowing time, and 16% from the third (March 03) to the second (March 02). In 2015, when the crop was sowed earlier, the LAI increased, on average, 2% from the second (February 19) to the first (February 09) sowing time and decrease 13% from the third (March 01) to the second (February 19) sowing time, with similar results to those found in 2014 between the sowing times March 02 and February 20.

The latest sowing times, such as March 12, 2014, showed higher segregation of means of hybrids, regardless of the maturation cycle, with decreases in LAI as the sowing was delayed, except for the hybrids 1G100, 1G282, and 50A10. The hybrids that composed the group of lowest means for the sowing time February 20, 2014 were those of very-early maturation cycle (ADV-123, ADV-114, 1G100 and 50A10), similar results to that found in the sowing on February 09 and 19, 2015. The difference between the hybrids in 2015 was detected in the two first sowing time, since all treatments in the last sowing time presented no significant variation of means.

The hybrids 1G282, 50A40, and 50A50 stood out with the highest LAI, regardless of the sowing time. Thus, the higher LAI of these hybrids are probably related to their cycle (Table 1), since plants of longer vegetative cycle present higher leaf area development.

The results of 1,000-grain weight (1000GW) vary between sowing times only in two treatments; the hybrids 1G282 and 50A40 presented higher 1000GW in the third sowing time (Table 4). In the second sowing time, very-early maturation hybrids (ADV-123, ADV-114, 1G100, and 50A10) stood out with a higher mean 1000GW than the other hybrids; this result was not found for the sowing on February 20 and March 12, 2014, in which the difference between hybrids were not related to their maturation groups. The mean 1000GW, considering all hybrids and sowing times, was approximately 28 grams.

Table 3. Mean leaf area index of sorghum crops grown in three sowing times in 2014 and 2015.

Hybrid	2014			2015		
	February 20	March 02	March 03	February 09	February 19	March 01
ADV-123	3.35 bA	2.83 aA	1.72 cB	3.35 bA	2.91 bA	2.82 aA
ADV-114	3.64 bA	2.48 aB	1.82 cB	2.09 cA	3.37 bA	2.73 aA
1G100	3.25 bA	3.06 aA	2.04 cA	5.03 aA	3.28 bB	2.88 aB
1G244	3.94 aA	3.16 aA	2.19 cB	3.24 bA	3.42 bA	3.10 aA
1G282	3.96 aA	3.48 aA	2.98 bA	4.60 aA	4.76 aA	3.53 aB
50A10	3.52 bA	3.16 aA	2.67 bA	3.37 bA	3.94 aA	3.30 aA
50A40	4.68 aA	3.46 aB	3.79 aB	4.08 aA	4.52 aA	3.42 aA
50A50	4.17 aA	2.49 aB	2.90 bB	3.79 aA	3.90 aA	4.09 aA
CV (%)		18.81			18.46	

Means followed by the same lowercase letter in the columns, or uppercase in the rows, are not different from each other by the Scott-Knott test at 10% probability level.

Table 4. Mean 1,000-grain weight (g) of sorghum crops grown in three sowing times in 2014.

Hybrid	Sowing times		
	February 20	March 02	March 03
ADV-123	31.30 aA	30.10 aA	28.90 bA
ADV-114	26.10 bA	28.30 aA	27.90 bA
1G100	28.50 bA	29.20 aA	29.20 bA
1G244	28.10 bA	26.30 bA	25.10 cA
1G282	29.60 aA	26.40 bB	31.80 aA
50A10	28.90 bA	28.40 aA	29.80 bA
50A40	27.80 bB	26.90 bB	33.40 aA
50A50	28.00 bA	25.10 bA	26.10 cA
CV (%) 5.84			

Means followed by the same lowercase letter in the columns, or uppercase in the rows, are not different from each other by the Scott-Knott test at 10% probability level.

The results of grain yield showed that all hybrids presented higher means in the first sowing time when compared to the last, in 2014 (Table 5).

The hybrid 1G282 was usually grouped with those that have the best results for the production components evaluated, but had the lowest mean grain yield in the sowing on February 20, March 02, and March 03, presenting 4,643, 4,374, and 1,227 kg ha^{-1}, respectively. However, the high incidence of diseases in the third sowing time in 2014, despite the preventive management, may have caused it to present lower grain yield than the others in this sowing time.

Grossi et al. (2013) found similar problems, with sorghum hybrids presenting grain yields affected by phytopathological factors. Chimonyo, Modi and Mabhaudhy (2016) conducted a field experiment with sorghum and cowpea crops and reported effects of environmental factors on the experimental data, and in this case, rainfall of hail affected the number of leaves and leaf area index.

The low mean grain yield of the hybrid 1G282 in the sowing on March 12, 2014 may have affected the grouping of means of the Scott-Knott test and, thus, the hybrid 1G244 was not grouped with other hybrids that presented high means.

The difference between hybrids of different maturation groups is more evident as the sowing time is delayed, with few or no variation in the means between them in the two first sowing times in

2014; the super early-maturation hybrids had, on average, 14% higher grain yield than the others, even excluding the data of the hybrid 1G282. Whereas in 2015, the means of super early-maturation hybrids were 5%, 10%, and 20% higher in the sowing on February 09, February 19, and March 01, respectively.

Table 5. Mean grain yield (kg ha^{-1}) of sorghum crops grown in three sowing times in 2014 and 2015.

Hybrid	2014			2015		
	February 20	March 02	March 03	February 09	February 19	March 01
ADV-123	6.170 aA	5.430 aA	2.840 aB	7.299 aA	6.701 bA	5.470 aB
ADV-114	6.287 aA	5.033 aB	4.298 aB	7.298 aA	8.252 aA	7.060 aA
1G100	5.553 bA	4.901 aA	2.955 aB	5.733 bA	6.123 bA	5.517 aA
1G244	6.255 aA	5.988 aA	2.297 bB	7.354 aA	6.045 bB	5.705 aB
1G282	4.643 bA	4.374 aA	1.227 bB	6.405 bA	6.744 bA	4.464 bB
50A10	4.921 bA	5.107 aA	3.563 aB	7.314 aA	7.286 aA	6.091 aA
50A40	5.595 bA	4.638 aA	2.815 aB	6.314 bA	5.833 bA	3.095 cB
50A50	7.058 aA	4.874 aB	3.675 aC	6.091 bA	6.706 bA	5.906 aA
CV (%)		17.27			14.39	

Means followed by the same lowercase letter in the columns, or uppercase in the rows, are not different from each other by the Scott-Knott test at 10% probability level.

The comparison between hybrids showed that the hybrids ADV-114 and 50A10 stood out in 2015 as the most productive in all sowing times. The less productive hybrids, regardless of the sowing time, was the 1G282, with 6,405, 6,744, 4,464 kg ha^{-1}, and 50A40, with 6,314, 5,833, 3,095, in February 09, February 19, and March 01, respectively, with the lowest results coinciding with the later sowing times.

Considering the all hybrids within the sowing times, 2014 presented more pronounced decrease in grain yield, with means of 5,810 kg ha^{-1} (February 20), 5,043 kg ha^{-1} (March 02), and 3,206 kg ha^{-1} (March 12), disregarding the data (March 12) of the hybrid 1G282. In 2015, a less pronounced decrease was found for all the hybrids, probably because the first sowing time was 11 days earlier than that in 2014, with a mean grain yield of 6,700 kg ha^{-1} for the sowing on February 09 and 19, and a decrease to 5,413 kg ha^{-1} for the sowing on March 01, although numerically higher than the mean found for the sowing on March 02, 2014 (Table 5).

Considering all data of the sorghum crop, the hybrid ADV-114 was always grouped with the more productive hybrids, regardless of the year and sowing time. This hybrid has a very-early maturation cycle that enables its production in different sowing times, with less time in the field, thus, the plants are less exposed to biotic and abiotic stresses and are faster harvested, which enables a better planning by the farmer. In general, all very-early maturation hybrids present these qualities.

Among the other hybrids, 1G282 stood out negatively, with lower production in all treatments and higher susceptible to diseases than the others. These results contrast with those found by Almeida Filho et al. (2014), who evaluated 25 simple sorghum hybrids and found that the hybrid 1G282 had higher grain yield in all environments. However, these tests were conducted in regions where the mean temperatures during the second crop season are higher than those of the site of the present experiment, which may explain these different results. Thus, the use of cultivars adapted to the production systems and environmental conditions of the region and an adequate crop management are important factors to maximize grain yield (ARAUJO et al., 2014).

The direct or indirect correlation between grain yield and the production components evaluated (NSPP, LAI, and 1000GW) was not confirmed for none of the two study years. Other production components may have affected the grain yield; for example, Tolk, Howell and Miller (2013) found that the number of grains per panicle affected the grain yield of the sorghum hybrids, despite they had equal 1,000-grain weights.

Maize crop

The results of DSF of the maize crop in 2014 showed no significant ($p<0.10$) difference between the hybrids tested, probably because all of them belong to the same maturation group (Table 6). However, the results found for the maize were similar to those of the sorghum hybrids of earlier maturation in the same sowing time (Table 1). In 2015, the DSF was different between hybrids in the first sowing time; the hybrids DKB-290-Pro and DKB-330-Pro had higher DSF, however, the first has an earlier maturation cycle and the second has a very-early maturation cycle.

Table 6. Mean number of days from sowing to flowering of maize plants grown as a second crop in 2014 and 2015.

Hybrid	2014	2015	
	February 20	February 09	February 19
DKB-330-Pro	59 a	65 aA	60 aB
P-3431-HX	57 a	61 bA	58 aA
Formula-TL	60 a	58 bA	61 aA
AG-9010-PRO	55 a	-	-
DKB-290-PRO	-	67 aA	60 aB
DKB-275-PRO	-	57 bA	60 aA
CV (%)	5.47	5.28	

Means followed by the same lowercase letter in the columns, or uppercase in the rows, are not different from each other by the Scott-Knott test at 10% probability level.

Comparing the DSF of sorghum and maize crops in 2014, the four maize hybrids evaluated took, in general, 58 days to reach 50% flowering, whereas the eight sorghum hybrids needed 63 days (Table 6). However, the analysis of the four super early maturation hybrids of same cycle of maize hybrids showed a mean of 59.1 days (Table 1).

In 2015, the mean DSF of very-early maturation maize hybrids were 60 and 59.7 for the first and second sowing times, respectively (Table 6). The very-early maturation sorghum hybrids needed 60 and 63 DSF for flowering in the sowing times February 09 and 19, respectively (Table 1). The visual comparison of the different crops showed that the difference between them is very small; thus, real differences between the total cycle of maize and sorghum crops probably does not exist among hybrids of the same maturation group.

In 2014, the number of rows per ear (NRE) did not meet the basic assumptions for the analysis of variance and Scott-Knott grouping test even after the transformation of the data, and the number of grains per row (NGF) and leaf area index (LAI) presented no significant differences between treatments at 10% probability level by the Scott-Knott test. The results found in 2015 are shown in Table 7.

Table 7. Mean of number of rows per ear (NRE), number of grains per row (NGF), and leaf area index (LAI) of maize crops grown with two sowing times in 2015.

Hybrid	NRE		NGF		LAI	
	February 09	February 19	February 09	February 19	February 09	February 19
DKB-330-Pro	17.58 bA	15.67 bB	34.00 aA	32.92 cA	3.16 bA	3.79 aA
P-3431-HX	19.00 aA	18.00 aA	34.75 aB	37.58 bA	2.76 bA	3.15 aA
Formula-TL	13.50 dA	14.33 cA	35.59 aB	39.92 aA	3.76 aA	2.99 aB
DKB-290-Pro	17.67 bA	17.50 aA	30.33 cB	33.92 cA	3.03 bA	3.63 aA
DKB-275-Pro	15.00 cA	14.50 cA	32.50 bA	32.59 cA	2.06 bA	3.24 aA
CV (%)	5.53		3.83		16.59	

Means followed by the same lowercase letter in the columns, or uppercase in the rows, are not different from each other by the Scott-Knott test at 10% probability level.

The number of rows per ear (NRE) of the cultivar P-3431-HX was higher than that of the other hybrids in the two sowing times in 2015 (Table 7). The hybrid Formula-TL stood out negatively, with the lowest performance regarding NRE. The only hybrid whose NRE varied according to the sowing time was the DKB-330-Pro, which presented the lowest result in the second sowing time.

Despite the hybrid Formula-TL showed the lowest NRE, it presented a high number of grains per row. The inverse occurred for the cultivar DKB-290-Pro, which had good results of NRE, but lower result of NGF than the other treatments (Table 7). The cultivar P-3431-HX stood out with higher results for NRE and NGF in the two sowing times in 2014.

The hybrid Formula-TL stood out with a LAI of 3.76 in the first sowing time (Table 7), which was different within the other hybrids and between the sowing times February 09 and February 19. The other hybrids presented no difference from each other nor between sowing times.

The hybrid P-3431-HX had the best results of NGF and NRE (Table 7), but not good performance regarding 1000GW, which was lower than that of the other hybrids in 2014. Similar results were found in 2015 (Table 8).

Table 8. Mean 1,000-grain weight (g) of maize plants grown as a second crop in 2014 and 2015.

Hybrid	2014	2015	
	February 20	February 09	February 19
DKB-330-Pro	405.6 a	285.2 bA	256.1 bA
P-3431-HX	354.1 b	255.5 bA	236.2 bA
Formula-TL	398.8 a	294.0 bA	302.4 aA
AG-9010-PRO	433.9 a	-	-
DKB-290-PRO	-	318.6 aA	317.8 aA
DKB-275-PRO	-	358.4 aA	319.0 aB
CV (%)	7.17	10.32	

Means followed by the same lowercase letter in the columns, or uppercase in the rows, are not different from each other by the Scott-Knott test at 10% probability level.

The hybrids DKB-290-Pro and DKB-275-Pro stand out with higher mean 1000GW in 2015 in the two sowing times; but the analysis of other variables, such as NGF, showed not similar positive results. DKB 275 was the only hybrid that presented different 1000GW between sowing times, with higher result found in the first sowing time.

Only one sowing time was possible to evaluate in 2014, which showed no difference in grain yield between hybrids, with an overall mean of 6.883 kg ha^{-1}. The individual means are shown in Table 9.

Table 9. Mean grain yield (kg ha^{-1}) of maize plants grown as a second crop in 2014 and 2015.

Hybrid	2014	2015	
	February 20	February 09	February 19
DKB-330-Pro	7.334 a	9.100 aA	7.519 bA
P-3431-HX	6.609 a	9.321 aA	6.758 bB
Formula-TL	6.806 a	9.871 aA	7.044 bB
AG-9010-Pro	6.783 a	-	-
DKB-290-PRO	-	8.125 aA	8.259 aA
DKB-275-PRO	-	9.141 aA	8.886 aA
CV (%)	8.19	13.88	

Means followed by the same lowercase letter in the columns, or uppercase in the rows, are not different from each other by the Scott-Knott test at 10% probability level.

The hybrids presented no differences in grain yield in the sowing on February 09, 2015, and DKB-290-Pro and DKB-275-Pro, as well as for the 1,000-grain weight (Table 8), were the only hybrids whose performance was not affected by the different sowing times.

Considering the hybrid DKB-275-Pro individually, the 1000GW (Table 8) of this hybrid was higher enough to compensate its lower number of grains and provide a high grain yield, higher than those of the other treatments in the second sowing time (Table 9), despite the low number of rows per ear and number of grains per row, components responsible for total quantity of grains per ear. The hybrid DKB-290-Pro showed similar results, and the best results of NRE.

Several studies have shown the direct effect of production components on maize grain yield (FERREIRA et al., 2010; ZUCARELI et al., 2013; ENTRINGER et al., 2014; LU; XUE; GUO, 2017). However, the analyses of the results found in the present study showed a certain compensation between production components, i.e., a hybrid that present low NGF and NRE may present high 1000GW, as in the case of DKB-275-Pro. Moreover, a cultivar that present high NFG and NRE may present a low mean 1000GW, as in the case of the hybrid P-3431-HX.

The hybrid P-3431-HX presented the lowest 1000GW in 2014 and 2015 (Table 8), but its grain yield was only statistically lower than those of the other hybrids in the sowing in 2015.

A factor that should be considered is that the technical recommendation of this material by seed companies describes the use of a higher population than that for the other commercial hybrids. Population is also an important production component for composition of the production capacity of crops; however, all treatments were sown with homogeneous distribution, as described in the Material and Methods section, due to the complexity of evaluating different populations.

The maize grain yield (Table 9) was 16% and 13% higher than those of the sorghum grain yield (Table 5) in the sowing on February 20, 2014 and February 19, 2015, and was well higher (26.2%) in the sowing on February 09, 2015.

The mean decreases in maize production from the first to the second sowing time was approximately 15%, whereas this decrease in the sorghum crop was near zero, showing a possible higher production stability for sorghum crops in different sowing times.

CONCLUSIONS

The agronomic characteristics of the hybrids of both crops tested were affected by the sowing time, which was a determinant factor for grain yield. The best sowing times were the earliest used in each year, in this case, February 20, 2014 and February 09, 2015. The sorghum hybrid that presented the best results was ADV-114, which showed high production potential and stability in different sowing times.

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