Journal of Agricultural Science; Vol. 10, No. 11; 2018
ISSN 1916-9752 E-ISSN 1916-9760
Published by Canadian Center of Science and Education

Sowing Time of Sweet Corn in Summer Season in Northwestern Paraná, Brazil

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Received: June 17, 2018 Accepted: August 10, 2018 Online Published: October 15, 2018

doi:10.5539/jas.v10n11p138 URL: https://doi.org/10.5539/jas.v10n11p138

The research is financed by National Council for Scientific and Technological Development—CNPq, Coordination of Improvement of Higher Education Personnel—CAPES, and Fundação Araucária.

Abstract

The aims of study were to evaluate the effect of sowing time in summer season on agronomic characteristics of sweet corn grown in summer season in Northwest Paraná, Brazil. The experiments were conducted in 2011, and 2012, in both years, the sowing was carried out on ST1: 09/05; ST2: 09/19; ST3: 10/03; ST4: 10/17, and ST5: 10/31. The experimental design was a randomized block design in a 5 × 2 factorial scheme, consisting of sowing time and two corn hybrids, with four replicates. The evaluated variables were plant height, leaf area index and yield of commercial ears, in which the effects of sowing times were studied through regression analysis, and effects of hybrids and agricultural years were studied by F-test. Sowing times promoted reductions in phenology of hybrids, but did not provide variations in degree-days accumulation by hybrids. The maximum leaf area index (3.82) was estimated for 10/04. In year 2011, the maximum plant height (2.17 m) and yield (13.0 Mg ha^{-1}) were estimated for 10/06, and 10/03, respectively. While, in year 2012, the maximum height (2.22 m) and yield (12.85 Mg ha^{-1}) were obtained on 10/09 and 10/11, respectively. The hybrid RB6324 showed greater yield potential, independent of year.

Keywords: *Zea mays* L., climatic factors, physiology, special corn

1. Introduction

Sweet corn is characterized by presence of genes that block the conversion of sugars to starch in endosperm, resulting in accumulation of high sugar content (Okumura et al., 2014), and low starch content (Souza et al., 2013). The main food uses of sweet corn are canned and "*in natura*" consumption and, after harvesting, vegetative part can be used for silage production, destined for animal feed, directed perfectly at family farming (Pereira Filho & Teixeira, 2016).

Although sweet corn has increased interest in Brazil and World, little emphasis has been placed on its management (Souza et al., 2013; Okumura et al., 2014), with farmers being directed to use the recommendations for common maize (Williams II, 2008). However, agronomic practices differ markedly from those recommended for common maize, including stepped planting (Pereira Filho & Teixeira, 2016), shorter time interval for harvesting and reduction of grain filling period (Franco et al., 2016). Thus, the time that sweet corn is exposed to climatic factors is different from corn grain and, considering that *Zea mays* L., is strongly influenced by environmental factors (Tsimba, Edmeades, Millner, & Kemp, 2013a; Marques et al., 2015).

Moreover, in climate change scenarios (Liu, Hubbard, Lin, & Yang, 2013), the negative effects under sweet corn crop are mitigated by changes in sowing time (Waha et al., 2013), selecting periods in which current climatic conditions can be optimized (Silva, Ferreira, Andrade, & Araujo, 2010), reflecting directly on the incidence of pests (Obopile, Hammond, & Thomison, 2013), severity of diseases (Blandino, Reyneri, & Vanara, 2009), in vegetative (Tsimba, Edmeades, Millner, & Kemp, 2013b), and reproductive development (Gaile, 2012). According to Costa, Souza, Lima, and Cardoso (2010) the use of genotypes adapted with a development cycle proportional to new crop seasons, complement the choices promoting success in current climate scenario.

Research that indicates the recommendation of the best sowing season and suitable genotypes (Gaile, 2012; Waha et al., 2013; Tsimba et al., 2013a), promotes the constant increase of maize yields (J. Wang, E. Wang, Yang, Zhang, & Yin, 2012). However, these scientific studies have not included sweet corn (Z. H. Khan, Khalil, M. Y. Khan, Israr, & Basir, 2011).

The knowledge of information contributes to increase the sweet corn yield (Souza et al., 2013, Franco et al., 2016). It is extremely important to have seen the increase in world population and demand for food (Liu et al., 2013), providing options for agricultural diversification and strengthening of family agriculture (Pereira Filho & Teixeira, 2016), as well as climate change. The aims of study were to evaluate the effect of sowing time (ST) in summer season on agronomic characteristics of sweet corn grown in summer season in Northwest Paraná, Brazil.

2. Material and Methods

2.1 Study Site

The experiments were conducted at Experimental Farm of State University of Maringá, located in Maringá city, Paraná State, Brazil (geographic coordinates: 23º20′48″ S and 52º04′17″ W, approximate altitude of 550 m).

The climate of Northwestern Paraná, according to the Köppen classification, is the Cfa type, defined as humid temperate climate with hot summer (Peel, Finlayson, & McMahon, 2007), with average temperature in the coldest month lower than 18 ºC (mesothermic), and the average temperature in the warmest month over 22 ºC. The summers are warm, frosts are infrequent and rainfall tends to concentrate in summer season, but without a specific dry season. Data of temperature, solar radiation, photoperiod, rainfall and supplementary irrigation that occurred during each one of the agricultural years are showed in Figure 1. Data from maximum, average and minimum temperatures were used to determine the thermal amplitude (Figure 1) and accumulated thermal sum.

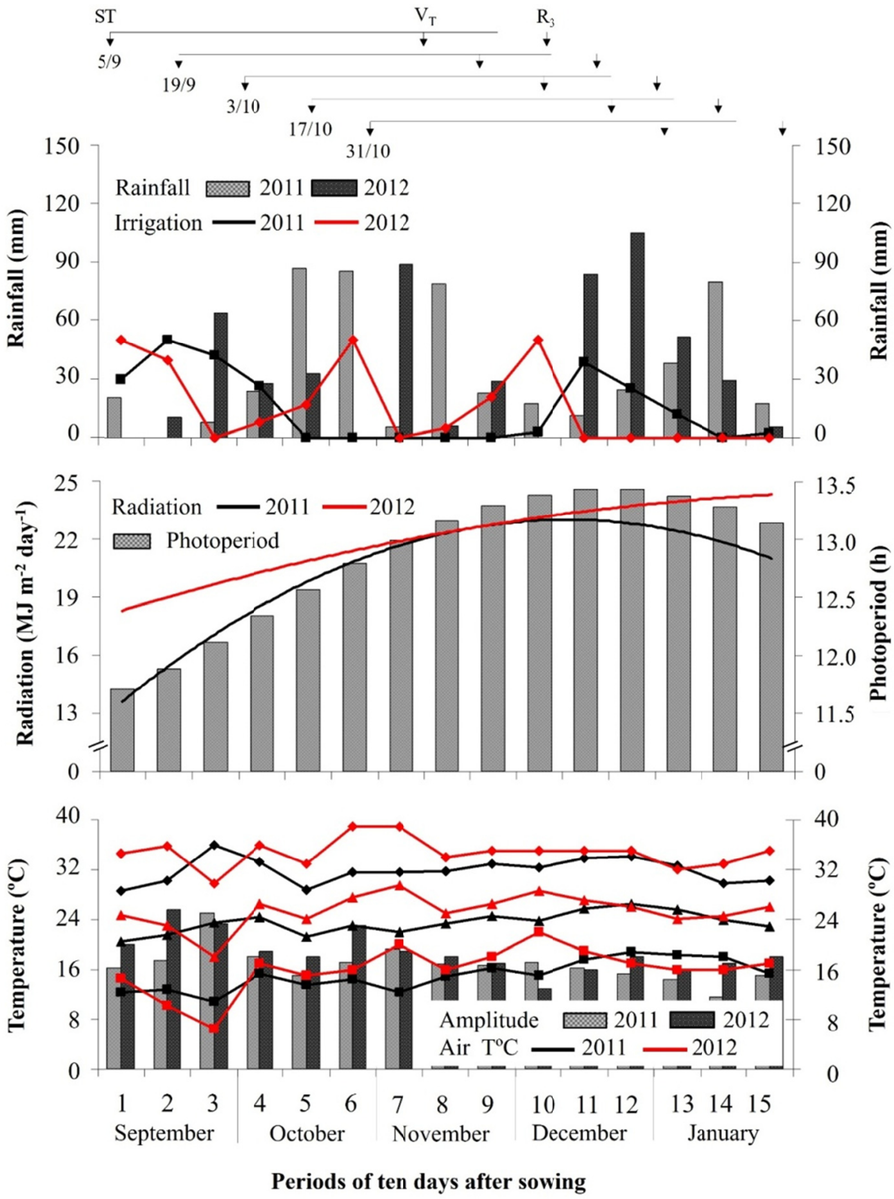

Figure 1. Rainfall, supplemental irrigation, solar radiation, photoperiod, maximum, minimum, average air temperature (Air TºC) and thermal amplitude in the summer season of 2011 and 2012, in Maringá city, Brazil

Note. Phenological stages: V_T = tasseling; R_3 = milky grain (Ritchie et al., 1993).

Sowing times: ST1 (09/05), ST2 (09/19), ST3 (10/03), ST4 (10/17), and ST5 (10/31).

Equivalence of periods of ten days: 1 (09/5-10), 2 (09/11-20), 3 (09/21-30), 4 (10/1-10), 5 (10/11-20), 6 (10/21-31), 7 (11/1-10), 8 (11/11-20), 9 (11/21-31), 10 (12/1-10), 11 (12/11-20), 12 (12/21-31), 13 (01/1-10), 14 (01/11-20), and 15 (01/21-31).

The accumulated thermal sum by sweet corn plants was determined by thermal sum daily units, according to Franco et al. (2016), using the modified expression:

$$ST = \sum_{n=1}^{N} GD\left(\frac{T_{max} + T_{min}}{2}\right) - T_b \tag{1}$$

where, ATS = accumulated thermal sum (°C day^{-1}); ΣTS = thermal sum daily (°C day^{-1}); N = number of days; Tmax = maximum air temperature (°C); Tmin = minimum air temperature (°C); Tb = base air temperature of the corn crop, for which 10 ºC was adopted.

The soil from experimental area was classified as dystroferric Red Nitissol (Embrapa, 2013), clayey texture (clay: 520g kg^{-1}; silt: 140g kg^{-1}; sand: 340g kg^{-1}) and the results of the chemical analyses of the main characteristics of soil material from 0.0 to 0.20m and 0.20 to 0.40m layers are shown in Table 1.

Table 1. Chemical analyses of soil material from experimental plots from layers 0-0.20 and 0.20-0.40 m of depth, in the summer season of 2011 and 2012 agricultural years

Years	pH	***C	*P	*K^+	**Ca^{+2}	**Mg^{+2}	**Al^{+3}	SB	CTC	V
	$CaCl_2$	g dm^{-3}	mg dm^{-3}	------------------------------			$cmol_c$ dm^{-3}	----------------------------		-- % --
Layers 0.00-0.20 m										
2011	5.6	9.21	25.80	0.36	4.20	1.50	0.00	3.17	9.23	65.66
2012	5.1	13.81	22.40	0.29	4.05	1.50	0.00	5.84	9.81	59.53
Layers 0.20-0.40 m										
2011	5.6	9.59	3.90	0.18	4.20	1.54	0.00	5.92	9.09	65.13
2012	5.0	12.28	17.50	0.22	4.02	1.38	0.00	5.62	9.59	58.60

Note. * Mehlich 1; ** KCl 1 mol L^{-1}; *** Walkley-Black.

The installation and conduction of experiments occurred during the rainy season, in summer season of 2011/12, and 2012/13 agricultural years. In both years, sowing was carried out on same dates (ST1: 09/05; ST2: 09/19; ST3: 10/03; ST4: 10/17, and ST5: 10/31), after maize cultivation in 2011 and after oats in 2012.

2.2 Treatments, Experimental Design and Plot

The experiments was conducted in randomized complete block design, in a factorial 5 × 2 in two agricultural years (2011 and 2012), with four replications. The factors studied were: i) Factor A: five sowing time (ST1: 09/05; ST2: 09/19; ST3: 10/03; ST4: 10/17, and ST5: 10/31), and ii) Factor B: two sweet corn simple hybrids (Tropical Plus and RB6324). Each experimental plot was constituted of five rows of plants with 6.0 m in length, spaced by 0.9 m, totaling a total area of 27 m^2 and an experimental area of 13.5 m^2 (Marques et al., 2015).

2.3 Crop Management

The sowing density used was 5 plants m^{-1} in no-tillage system in order to reach a population density of approximately 55.500 plants ha^{-1} (Souza et al., 2013). Management of fertilizing was according to Okumura et al. (2014) and all other cultivation techniques used were those recommended for the corn crop, including irrigation management (Marques et al., 2015).

2.4 Evaluated Characteristics

The phytotechnical evaluations of growth (plant height, and leaf area index) were assessed in five randomly selected plants in each plot at VT (Ritchie, Hanway, & Benson, 1993). Plant height was measured on the stem length from the soil surface to the base of the male inflorescence (Moreira et al., 2018). The leaf area index (LAI) was obtained by measuring the length (L) and the width (W) of all the leaves in each plant. The leaf area (LA) was calculated by the following equation: LA = 0.75 × L × W, later, the LAI was calculated from the LA measures by the equation (Sangoi et al., 2007):

$$LAI = \frac{LA}{S_1 \times S_2} \tag{2}$$

where, S_1 and S_2 refer to the spacing in meter (m) between plants and between rows, respectively.

The sweet corn ears were harvested at R3 (Ritchie et al., 1993), in milky grain (Pereira et al., 2009). At this moment was assessed the yield of dehusked marketable ear (length greater than 15 cm, diameter greater than 3 cm and free from pests), according to Albuquerque, Von Pinho, Borges, Souza Filho, and Fiorini (2008).

2.5 Data Analysis

The experimental data from each one of the agricultural years were assessed using the Shapiro-Wilks and Levene tests ($P \leq 0.01$) to verify the normality and homoscedasticity waste. Later, the data were subjected to an individual analysis of variance, and was verified whether the relationships between the residual mean squares were lower than 7:1. Finally, the data were submitted to analysis of variance with application of F-test ($P \leq 0.05$), and then partitioning as necessary (Barbin, 2013). The sowing time effects were studied by polynomial regression analysis and the effects of the hybrids and years were studied by the F-test ($P \leq 0.05$) of the analysis of variance. The statistical procedures were carried out by SISVAR statistical software (Ferreira, 2011).

3. Results and Discussion

3.1 Climatic Characteristics

The rainfall observed in summer season of agricultural years of 2011 and 2012 were insufficient for water requirement in maize, with values lower than 500 mm (Silva et al., 2010). In 2011, rainfall was mainly concentrated in October and November and accumulated rainfall were 336, 340, 350, 317, and 278 mm, at sowing times: ST1 (249 = 09/05); ST2 (263 = 09/19); ST3 (277 = 10/03); ST4 (291 = 10/17); and ST5 (305 = 10/31), respectively (Figure 1). While, in 2012 occurred regularity of rainfall in December and January, and accumulated rainfall were 260, 286, 242, 380, and 394 mm, at sowing times ST1, ST2, ST3, ST4, and ST5, respectively (Figure 1). Thus, in both years, supplementary irrigation was important to provide the amount of water required for sweet corn (Silva et al., 2010).

Solar radiation was most intense in agricultural year of 2012 (Figure 1). In relation to photoperiod, verified increases until December, followed by decreases (Figure 1). The photoperiod is a factor dependent on day and latitude, so the same is common in every year.

Temperatures showed quadratic behavior, and maximum values were observed in October, November and December (Figure 1), in which the agricultural year of 2012 was warmer and promoted higher thermal amplitudes compared to 2011 (Figure 1).

3.2 Phenological Cycle and Accumulated Thermal Sum

Delays in sowing times promoted reductions in phenological cycle of sweet corn hybrids, RB6324 and Tropical Plus, in both agricultural years (Figure 2). Sowing times did not provide significant variations in degree-days accumulation by RB6324 and Tropical Plus hybrids (Figure 2). Similar result were verified by Williams II (2008), and Franco et al. (2016), studying the effect of sowing time on sweet corn, observed that number of days between emergence and tasseling stage varied with sowing time, and little influence had the thermal time.

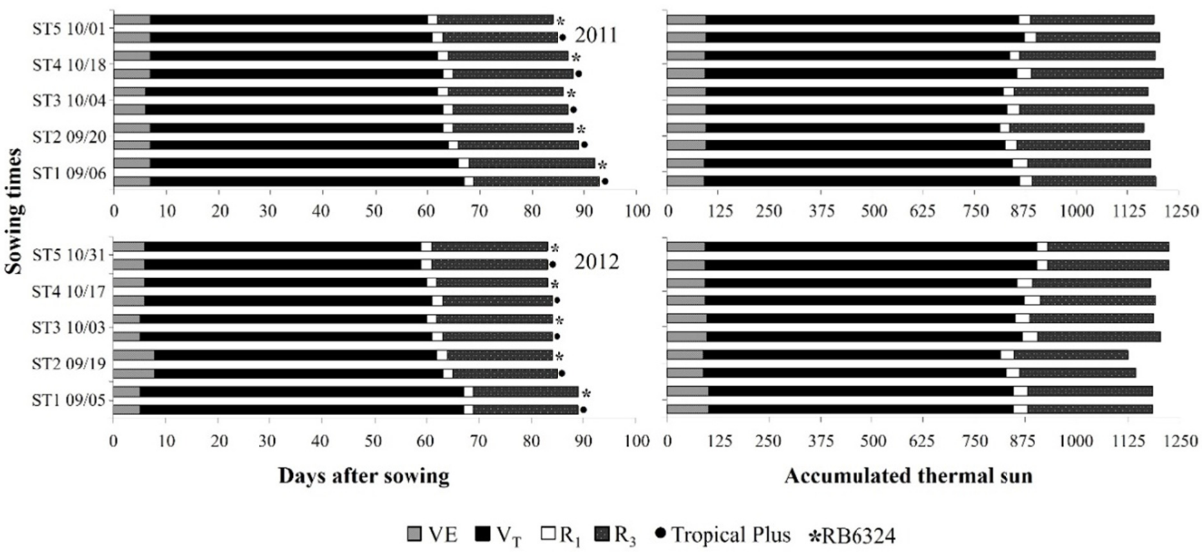

Figure 2. Days after sowing and accumulated thermal sum till emergence (VE), tasseling (V_T), silking (R_1) and milky grain (R_3) for two sweet corn hybrids, in the summer season of 2011 and 2012, in Maringá, Northwest of Paraná State, Brazil

This fact is explained because maize needs an accumulation of degrees-days to complete the stages of development (Tsimba et al., 2013b; Marques et al., 2015). The thermal unit is directly proportional to temperature (Gaile, 2012). Thus, in high temperatures the daily thermal units are larger, justifying the reduction of the cycle, once has completed the accumulation of thermal sum required (Franco et al., 2016).

According to Soler, Sentelhas, and Hoogenboom (2005), the thermal energy describes the development rate with greater accuracy compared to time expressed in days, independent of time and place of cultivation, and being observed in number of days identified between ST2 (09/19) and emergency (VE) in the agricultural year of 2012

(Figure 2), period which the lowest temperatures were recorded (Figure 1). Gaile (2012), studying the effect of sowing time on maize development obtained negative correlations between temperature and number of days until germination.

3.3 Joint Analysis of Variance of Experiments

The analysis of joint variance indicated a significant effect (P < 0.05) for sowing times and agricultural years in evaluated variables. While, hybrid factor was significant only for yield of commercial ears (Table 2).

Table 2. Summary of the variance analysis of sweet corn phenotypic characteristics (plant height-PH, leaf area index-LAI and yield of marketable ear-Yield) in the summer season of 2011 and 2012, in Maringá city, Northwest Region of Paraná State, Brazil

Font of variations	DF	Mean square		
		PH (m)	LAI (m^2 m^{-2})	Yield (Mg ha^{-1})
Times (T)	4	0.207*	0.418*	20.415*
Hybrids (H)	1	0.008^{ns}	0.315^{ns}	6.401*
Years (Y)	1	0.135*	2.285*	5.762*
T × H	4	0.007^{ns}	0.271^{ns}	2.685*
T × Y	4	0.010*	0.094^{ns}	6.438*
H × Y	1	0.003^{ns}	0.005^{ns}	3.172^{ns}
T × H × Y	4	0.003^{ns}	0.010^{ns}	4.333*
Blocks/Years	6	0.004	0.010	1.760
Residue	54	0.004	0.111	0.951
General average		2.07	3.70	11.72
CV (%)		2.93	8.99	8.32

Note. * significant; ^{ns} not significant, in 5% probability level, by F-test.

For the interactions, analysis of variance showed dependence (P < 0.05) between the factors in times x hybrids interaction and in triple interaction for yield, showing that this variable is related to sowing times, hybrids, and years. However, for sowing times x years interaction the analysis showed independence (P > 0.05) among the factors for LAI variable. The analysis did not indicate a significant effect (P > 0.05) on hybrids × years interaction in any studied variable (Table 2).

3.4 Growth and Plant Development Characteristics

Plant height (PH), and leaf area index (LAI) varied with sowing times showing quadratic behavior. In 2011, maximum plant height (2.17m) was estimated for Julian 279 (10/06); for the year 2012 the maximum plant height (2.22 m) was obtained in sowing done on Julian 283 (10/09) in average of hybrids (RB6324, and Tropical Plus). While, maximum LAI (3.82) was estimated for Julian 277 (10/04), in average of hybrids hybrids (RB6324, and Tropical Plus) and years (2011, and 2012) (Figure 3).

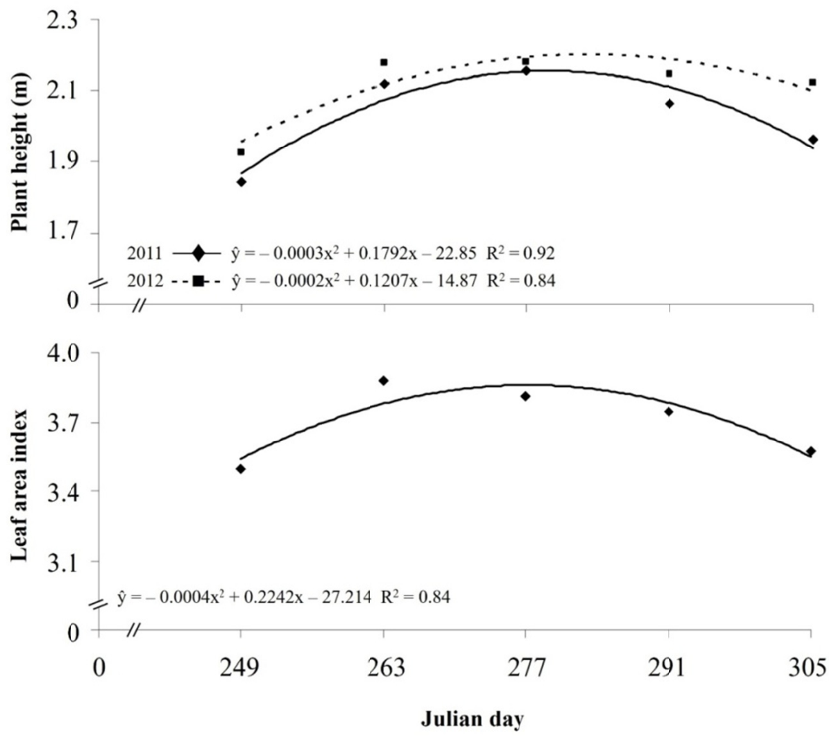

Figure 3. Average plant height and leaf area index of two sweet corn hybrids (Tropical Plus and RB6324) in relation to the sowing time (ST) in the summer season of 2011 and 2012, in Maringá, Northwest of Paraná State, Brazil

Note. ST_1 = 249 (09/05); ST_2 = 263 (09/19); ST_3 = 277 (10/03); ST_4 = 291 (10/17) and ST_5 = 305 (10/31)

The year 2012 promoted favorable climatic conditions for growth and development of sweet corn plants in most of sowing times studied (Table 3). Although corn growth is strongly correlated with genetic trait (Gaile, 2012), greater plant development in 2012 compared to year 2011 (Table 3), probably occurred due to temperature and solar radiation (Figure 1), climatic factors of great influence on corn growth and development (Brachtvogel, Pereira, Cruz, & Bicudo, 2009).

Table 3. Average plant height, and leaf area index of two sweet corn hybrids (Tropical Plus, and RB6324) in two years (2011, and 2012) in five sowing time (ST1: 09/05; ST2: 09/19; ST3: 10/03; ST4: 10/17, and ST5: 10/31), in summer season in Maringá city, Brazil

Years	ST_1	ST_2	ST_3	ST_4	ST_5	LAI
	Plant height (m)					--- m^2 m^{-2} ---
2011	1.84b*	2.12a	2.16a	2.06b	1.96b	3.53b
2012	1.93a	2.18a	2.18a	2.15a	2.12a	3.87a

Note. * Means followed by the same letter in column are not different by F-test ($P \leq 0.05$).

Temperature is main factor that influences the physiological mechanisms of maize (Gaile, 2012). The agricultural year of 2012 showed the highest temperature compared to 2011 (Figure 1), positively influencing the photosynthetic process of sweet corn (Tollenaar, 1989), resulting in a greater accumulation of photoassimilates in leaves (Andrade, Uhart, & Cirilo, 1993).

In year of 2012, verified greater thermal amplitudes compared to 2011 (Figure 1). According to Lozada and Angelocci (1999), corn development shows a linear relationship with thermal amplitude, since this is inversely proportional to increase in cellular respiration, promoting a higher balance of photoassimilates (Edreira & Otegui, 2012).

3.5 Production Component Characteristics

The analysis of triple interaction (times × hybrids × years) for variable yield of dehusked marketable ears allowed to adjust the quadratic polynomial model (Figure 4). In 2011, maximum yields were 13.2 Mg ha^{-1} (RB6324) and 12.8 Mg ha^{-1} (Tropical Plus), both estimated for Julian 276 (10/03). While in 2012, maximum yields obtained by RB6324 and Tropical Plus hybrids were 13.1 Mg ha^{-1}, and 12.6 Mg ha^{-1} estimated for Julian days 282 (10/08), and 288 (10/15), respectively (Figure 4).

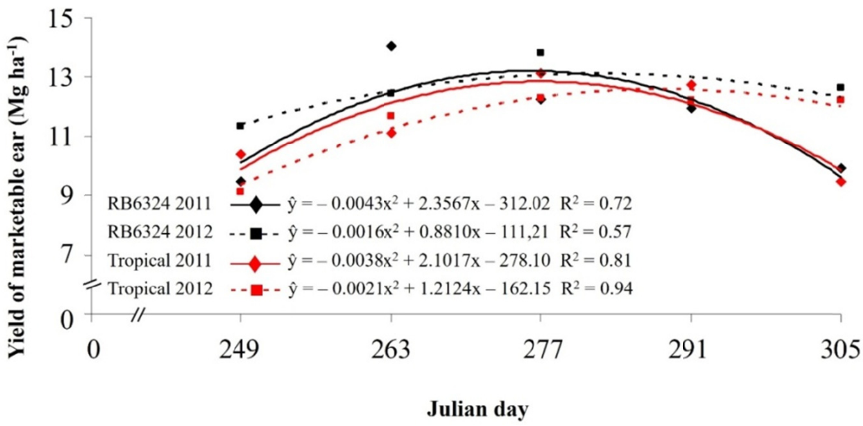

Figure 4. Yield of dehusked marketable ears of two sweet corn hybrids in relation to the sowing time (ST) in the summer season of 2011 and 2012, in Maringá city, Brazil

Note. Sowing times (ST): ST_1 = 09/05; ST_2 = 09/19; ST_3 = 10/03; ST_4 = 10/17 and ST_5 = 10/31.

Other studies founded that anticipating or delaying sowing time negatively influenced sweet corn production (Williams II, 2008; Khan et al., 2011). Corn yield is determined by genetic potential and environment (Córdova & Carreño, 2012), so the results obtained, can be explained by climatic conditions having been restrictive with the delay of sowing time (Figure 1).

Tsimba et al. (2013a) studying the effect of sowing seasons (09/19, 10/12, 11/02 and 11/23) on corn in three sites in New Zealand (37.86º S and 175.32º E at 50 m; 37.98º S and 175.32º E at 84 m; and 40.38º S and 175.58º E at 18 m) obtained quadratic responses for LAI, total biomass and yield, in which the maximum technical efficiency were obtained in sowing conducted at end October and early November, in summer season.

In early sowing time, before spring season (August to September in southern hemisphere), there is lower radiation and temperature in early stages of plant development (Andrade et al., 1993), reducing seeds germination (Williams II, 2008), growth and initial development of sweet corn (Gaile, 2012; Tsimba et al., 2013b), resulting in formation of smaller leaf area per plant and smaller plants (Sangoi, Schmit, & Zanin, 2007), promoting limitation of photoassimilates (Tsimba et al., 2013a). While, sowing performed at end of recommended sowing time the production components are limited because the grain filling stage coincides with a significant deterioration of environmental conditions (Marques et al., 2015; Franco et al., 2016).

The RB6324 hybrid, in general, showed a higher productive potential ($P > 0.05$) for variable yield of dehusked marketable ears, independent of years (Table 4). This result is corroborated by Okumura et al. (2014) studying the same hybrids in summer in three agricultural years.

Table 4. Yield of dehusked marketable ears of two sweet corn hybrids in two years in five sowing time (ST), in summer season in Maringá city, Brazil

Hybrids	2011					2012				
	ST_1	ST_2	ST_3	ST_4	ST_5	ST_1	ST_2	ST_3	ST_4	ST_5
Tropical	10.37a*	11.11b	13.12a	12.75a	9.48a	9.14b	11.69a	12.29b	12.20a	12.20a
RB6324	9.48a	14.05a	12.25a	11.96a	9.92a	11.33a	12.44a	13.80a	12.15a	12.62a
Years	TROPICAL					RB6324				
2011	10.37a	11.11a	13.12a	12.75a	9.48b	9.48b	14.05a	12.25b	11.96a	9.92b
2012	9.14a	11.69a	12.29a	12.20a	12.20a	11.33a	12.44b	13.80a	12.15a	12.62a

Note. * Means followed by the same letter in the column are not different by F test ($P \leq 0.05$).

Sowing times (ST): ST_1 = 09/05; ST_2 = 09/19; ST_3 = 10/03; ST_4 = 10/17 and ST_5 = 10/31.

The year 2012 was better for sweet corn production, independent of hybrids adopted (Table 4). This result can be explained, among other factors discussed, by greater availability of radiation in 2012 compared to 2011 (Figure 1), because solar radiation is one of most influential climatic factors on maize crop (Brachtvogel et al., 2009), promoting excitation of chlorophyll molecules, initiating energy flow necessary for photosynthesis (Taiz & Zeiger, 2013). According to Fageria (1998), solar radiation incident on terrestrial atmosphere is main source of energy for physiological and biochemical processes that occur in plants. For these reasons, maize yield follows a relation directly proportional to radiation, not occurring water restrictions (Bergamaschi et al., 2006).

The climatic conditions observed in 2011 resulted in lower plant development, represented by low plant height (2.03m in 2011, and 2.11m in 2012) and LAI of 3.53 (2011) compared to 3.87 (2012) (Table 3). Although, yield is dependent on photosynthetic production only after flowering (Lee & Tollenaar, 2007), leaf area is main contribution to spike development (Subedi & Ma, 2005), thus, growth and LAI relates directly with yield (Córdova & Carreño, 2012).

In year of 2011, plants showed a smaller canopy capable of potentiating the solar radiation (Subedi & Ma, 2005) factor determining of yield (Tsimba et al., 2013a), promoting lower photoassimilate production and, finally, lower translocation of these to grain filling (Duete, Muraoka, Silva, Trivelin, & Ambrosano, 2008).

4. Conclusions

Sowing times influenced the growth and yield of sweet corn. The RB6324 hybrid showed higher yield of dehusked marketable ears compared to Tropical Plus hybrid. The use of irrigation was essential in all sowing times and years of study.

Acknowledgements

We thank the National Council for Scientific and Technological Development (CNPq/Brazil) for Productivity in Research Scholarship and Fundação Araucária by financial support for this research work. We also appreciate the scholarship from Coordination of Improvement of Higher Education Personnel (CAPES/Brazil).

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