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IRRIGATED MAIZE CROP: GRAIN YIELD IN TWO SOWING SEASONS IN THE MUNICIPALITY OF TERESINA, PIAUÍ

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Abstract – The objective of this work was to evaluate commercial maize hybrids, under conventional sprinkler irrigation, in two sowing seasons (July and August 2017), in the municipality of Teresina, Piauí. A randomized block design was used, with two replications and 39 treatments (commercial maize hybrids). The characteristics evaluated were grain yield, water use efficiency, number of ears and number of grains per area. For the experiment with sowing done in July 2017, the average grain yield was 9.82 Mg ha^{-1} and the water use efficiency was 1.9 kg m^{-3}, which are, respectively, 4.7 % and 15.8 % higher in relation to the experiment with sowing done in August 2017. Regardless of the sowing season, grain yields over 10.0 Mg ha-1 of three hybrids (LG 6418, CD 3880 PW and 2A 401 PW) stand out. The yield components, number of kernels per ear and grain mass per ear, show high values of correlation (over 0.80) with grain yield.

Keywords: *Zea mays*, water use efficiency, air temperature.

MILHO IRRIGADO: PRODUTIVIDADE DE GRÃOS EM DUAS ÉPOCAS DE SEMEADURA NO MUNICÍPIO DE TERESINA, PIAUÍ

Resumo - O presente trabalho teve como objetivo avaliar híbridos comerciais de milho, sob irrigação por aspersão convencional, em duas épocas de semeadura (julho e agosto de 2017) no município de Teresina, Piauí. Foi utilizado o delineamento experimental em blocos ao acaso, com duas repetições e 39 tratamentos (híbridos comerciais de milho). As características avaliadas foram produtividade de grãos, eficiência de uso da água, número de espigas e número de grãos por área. A produtividade de grãos média do ensaio com semeadura em julho/2017 foi de 9,82 Mg ha^{-1} , com eficiência de uso da água de 1,9 kg m^{-3}, respectivamente, superior em 4,7 % e 15,8 % em relação a do ensaio com época de semeadura em agosto/2017. Independente da época de semeadura, produtividades de grãos acima de 10,0 Mg ha^{-1} de três híbridos (LG 6418, CD 3880 PW e 2 A 401 PW) se sobressaem. Os componentes de rendimentos, número de grãos por espiga e massa de grãos por espiga apresentam valores de correlação de alta magnitude (acima de 0,80) com a produtividade de grãos.

Palavras-chave: *Zea mays*, eficiência de uso da água, temperatura do ar.

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Maize crop yield is the result of the cultivar's genetic potential, soil and climate conditions in the cultivation area, as well as crop management. Under no water stress conditions, the factors that most influence maize yield are insolation and air temperature. The crop presents better development when the days are sunny, with higher daytime temperature and milder nighttime temperature (Bergamaschi & Matzenauer, 2014; Sangoi et al., 2010).

Due to the weather variations that occur every year, yield and production present great interannual variability (Berlato et al., 2005). Therefore, the characterization of phenological changes that occur in the maize plant, at different sowing seasons, is important to define the adoption of cultivation practices, targeting the best use of environmental conditions and maximization of grain yield in each season.

Alves et al. (2011) observed that, under optimal conditions of water availability, that is, in irrigated cropping systems, the factors that most influence maize crop yield are the variations of air temperature and incident solar radiation. Since the maize plant highly benefits from solar radiation, it is very sensitive to the lack of light and, because of that, in cloudy days, there is a drop in the photosynthesis rate, which may reduce yield. Moreover, high daytime air temperature shortens the crop cycle, which, associated with high maintenance respiration rates as a result of high nighttime temperature, also reduces yield. That explains the considerable interannual variability in average maize yield, even under irrigated regime (Bergamaschi & Matzenauer, 2014).

Irrigated systems are an alternative to mitigate water stress effects resulting from the irregular rainfall regime. However, due to water shortage periods and the competition for water use, it is necessary to employ management strategies that optimize the use of that resource. Even with no occurrence of water stress, due to the use of irrigation systems, and since incident solar radiation and air temperature affect maize yield, it is important to evaluate which is the most suitable season for cultivation, according to the differences in those climate variables.

In the present study, 39 maize hybrids were evaluated, under irrigation regime, in two sowing seasons, in the municipality of Teresina, Piauí.

Material and Methods

Two experiments, one with sowing done in July and the other with sowing done in August 2017, were conducted in the experimental area (5°05' S, 42°29' W, and 72 m altitude – data obtained through GPS) of Embrapa Mid-North, in the municipality of Teresina, Piauí. It is located in the central-north mesoregion of Piauí state, in soil classified as dystrophic Fluvic Neosol, which presented low activity clay and low base saturation (V<50%), both in most part of C horizon (Santos et al., 2018; Melo et al., 2014). The experiments were conducted under conventional sprinkler irrigation that was managed based on the crop evapotranspiration replacement, which was

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calculated from the reference evapotranspiration estimated with application of Penman-Monteith method and crop coefficients (Souza et al., 2015).

The soil water content was monitored up to the 0.70 m depth with the use of Diviner 2000. In both experiments, irrigation depths of 520 mm and 580 mm were applied in a 100-day cycle, with an average daily consumption of 5.2 mm and 5.8 mm, respectively, in sowing carried out in July and August.

The results of soil fertility analyses, which were conducted in the Soil Fertility Laboratory of Embrapa Mid-North, indicated the following: pH in water (1:2.5) = 6.1; phosphorus (mg dm^{-3}) = 22.1; potassium (mg dm^{-3}) = 119.3; calcium (mmol$_c$ dm^{-3}) = 23.3; and magnesium (mmol$_c$ dm^{-3}) and O.M. (g kg^{-1}) = 26.5. Fertilization was carried out by the time of sowing with 50, 80 and 70 kg of N, P_2O_5 & K_2O ha^{-1}, respectively, and in topdressing with 100 kg of N ha^{-1} by the time of the sixth fully emerged leaf, using the following fertilizers as sources: ammonium sulfate (N), triple superphosphate (P_2O_5) and potassium chloride (K_2O).

A randomized block design was used, with two replications and 39 treatments – maize hybrids (Table 1). Each plot consisted of four rows with 5.0 m length, spaced 0.70 m apart, with spacing of 0.20 m between holes within the rows, keeping one plant per hole after thinning. The two central rows (7.0 m^2) were used as useful area. The number of days and average data for minimum and maximum air temperature and solar radiation (obtained from the agrometeorological station installed 350 meters away from the experimental area) were recorded for the period from sowing to tasseling (50% of the plants with visible tassels), from tasseling to silking (50% of the plants with visible style-stigma), and from silking to physiological maturity, when there is formation of the black layer in grains (Figures 1 & 2). It was assumed that, as from the flowering stage, there is no longer stem and leaf growth, with emergence of kernels and their subsequent filling and loss of moisture.

Figure 1. Maize plant in tasseling stage - Ritchie et al. (1993).

Figure 2. Maize plant in physiological maturity stage - Ritchie et al. (1993).

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Table 1. Characteristics of commercial hybrids used in the experiments. Teresina, PI 2017

	Hybrid	Type	Grain Texture	Company
1	2B 433 PW	TH	SMDENT	DOW AGROSCI SE E BI
2	MG 580 PW	SH	SMFLINT	MORGAN SEMENTES
3	RB 9004 PRO	SH	DENT	RIBER KWS SE S.A.
4	2 B 633 PW	TH	SMFLINT	DOW AGROSCI SE E BI
5	IMPACTO VIP3	SH	FLINT	SYNGENTA SEEDS LTDA
6	LG 6053 PRO2	-	-	LIMAGRAIN BRASIL S.A.
7	2B 512 PW	TH	SMFLINT	DOW AGROSCI SE E BI
8	FEROZ VIP	DH	FLINT	SYNGENTA SEEDS LTDA
9	KWX 76610	-	-	--
10	LG 6030 RR2	SH	SMFLINT	LIMAGRAIN BRASIL S.A.
11	2 B 610 PW	SH	SMDENT	DOW AGROSC SE E BI
12	XB 8010	DH	SMDENT	SEMEALI SE HÍBRIDAS LTDA
13	2 B 587 PW	SH	SMDENT	DOW AGROSC SE E BI
14	RB 9110 PRO	SH	SMDENT	RIBER KWS SE S.A.
15	XB 6012 BT	SH	SMFLINT	SEMEALI SE HÍBRIDAS LTDA
16	90 XB 06 BT	SH	SMFLINT	SEMEALI SE HÍBRIDAS LTDA
17	XB 8030	DH	SMFLINT	SEMEALI SE HÍBRIDAS LTDA
18	RB 9006 PRO	SH	SMFLINT	RIBER KWS SE S.A.
19	RB 9005 PRO	SH	SMDENT	RIBER KWS SE S.A.
20	2 B 810 PW	SH	SMFLINT	DOW AGROSCI SE E BI
21	XB 8018	DH	SMFLINT	SEMEALI SE HÍBRIDAS LTDA
22	MG 600 PW	SH	SMFLINT	MORGAN SEMENTES
23	30 A 91 PW	SHm	SMFLINT	DOW AGROSCI SE E BI
24	13 B 275 PW	SH	SMDENT	DEKALB
25	RB 9077 PRO	TH	FLINT	RIBER KWS SE S.A.
26	LG 6030 PRO2	SH	SMFLINT	LIMAGRAIN BRASIL S.A.
27	RB 9210 PRO	SH	FLINT	RIBER KWS SE S.A.
28	MG 652 PW	SHm	SMFLINT	MORGAN SEMENTES
29	LG 6418	TH	FLINT	LIMAGRAIN BRASIL S.A.
30	60 XB 14	SH	FLINT	SEMEALI SE HÍBRIDAS LTDA
31	20 A 78 PRO	TH	SMDENT	MORGAN SEMENTES
32	30 A 37 PW	SH	SMFLINT	MORGAN SEMENTES
33	CD 3770 PW	SHm	SMFLINT	COODETEC
34	CR 804	-	-	-
35	LG 6310	TH	SMFLINT	LIMAGRAIN BRASIL S.A.
36	CD 3880 PW	-	-	COODETEC
37	2 A 401 PW	SH	SMFLINT	DOW AGROSCI SE E BI
38	RB 9308 PRO	TH	FLINT	RIBER KWS SE S.A.
39	CD 3612 PW	TH	SMDENT	COODETEC

- No information. SMFLINT: Semi-flint and SMDENT: Semi-dent.

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The characteristics assessed were grain yield (GY in Mg ha^{-1}) with 14 % of moisture; number of ears (NE) and number of grains (NG) per area; hundred-grain weight (HGW); grain index (GI) and ear index (EI); grain mass per ear (GME); and water use efficiency (WUE). The WUE was calculated from the ratio between the GY obtained (weight ha^{-1}) and water volume consumed (m³ ha^{-1}). The WUE is expressed in kilogram of maize grains per cubic meter of water used.

For the study of correlation with grain yield, the following were also evaluated: plant height and ear height (cm), hundred-grain weight (g), grain index, ear index and grain mass per ear. Data were submitted to analysis of variance and the means for grain yield and water use efficiency were compared by Scott-Knott test at 5% significance (Zimmerman, 2014).

Results and Discussion

The analysis of variance showed effect (P<0.01) of the hybrid x sowing season interaction on the following characteristics: plant and ear heights, grain mass per ear, number of kernels per ear, grain yield and water use efficiency. That shows that the hybrids present different behavior depending on the sowing season (Table 2).

Higher grain yields and water use efficiency were observed in the sowing done in July 2017, with the average values for that experiment being 9.84 Mg ha^{-1} and 1.9 kg m^{-3}, respectively, which are 4.91 % and 18.8 % higher when compared with the sowing done in August 2017. In the July sowing season, seventeen hybrids presented production above the experiment average (9.84 Mg ha^{-1}) and made better use of the water in the grain production (equivalent or superior to 2.1 kg m^{-3}), especially the hybrids 2 B 512 PW, 2 B 587 PW, CD 3880 PW, LG 6418, and MG 652 PW, with grain mass over 11.0 Mg ha^{-1} (Tables 3 & 4). In the August sowing season, with the general experiment average of 9.38 Mg ha^{-1}, the hybrids LG 6418, CD 3880 PW, CD 3612 PW, and RB 9005 PRO stood out, with grain yields over 11 Mg ha^{-1} and water use efficiency equivalent or superior to 1.9 kg m^{-3}.

Despite the significance of the hybrid x sowing season interaction for grain yield, it was possible to find hybrids with grain yield above the mean verified for the sowing seasons. The grain yield is graphically represented in Figure 3, where the x-axis shows the average grain yield when the sowing was done in July, and the y-axis shows the grain yield obtained in the sowing done in August. The Figure is divided into four quadrants, according to the methodology proposed and adapted by Fageria & Baligar (1993). The hybrids with grain yield above the mean of the experiment planted in August are in the upper left quadrant, while the hybrids with grain yield below the mean are in the lower left quadrant. In both quadrants, the hybrids show grain yield inferior to the mean in relation to the sowing done in July. The hybrids positioned in the upper and lower right quadrants attained higher grain yield in relation to the general mean of the experiment

Table 2. Mean square values for the following characteristics: plant height (PH), ear height (EH), hundred-grain weight (HGW), grain index (GI), ear index (EI), grain mass per ear (GME), number of kernels per ear (NKE), grain yield per hectare (GY), and water use efficiency (WUE) of 39 maize hybrids, under irrigation regime, in two sowing seasons. Teresina, Piauí 2017

S.V.	Mean squares								
	PH	EH	HGW	GI	EI	GME	NKE	GY	WUE
Se	19833.9**	1869.3**	41.03**	0.0000448	0.000984	3278.9**	6.487**	8251733**	2.949**
Hyb	742.0**	366.1**	2.07	0.00142	0.00177*	410.2**	2.527**	3060706**	0.099**
Bl	457.4**	246.7**	12.09**	0.00742**	0.000749	474.8**	4.885**	4065861**	0.123**
Se x hyb	475.9**	291.5**	2.26	0.00123	0.00127	262.6**	1.702**	1325026**	0.042**
Residue	30.5	46.5	2.44	0.00111	0.000914	90.1	0.7705	447331	0.0139
CV(%)	2.84	7.03	4.43	3.93	2.90	6.91	4.45	6.96	6.73

Se= sowing seasons; Hyb= hybrids; **(P<0.01) and *(P<0.05) as per F-test.

Table 3. Mean values for grain yield of 39 commercial maize hybrids, in two sowing seasons, under irrigation regime. Teresina, PI 2017

	Hybrids	Grain yield (Mg ha^{-1})			
		Sowing in July		Sowing in August	
1	2 B 433 PW	10.21	b	9.37	a
2	MG 580 PW	8.49	d	9.23	a
3	RB 9004 PRO	9.60	c	9.24	a
4	2 B 633 PW	9.51	c	9.67	a
5	IMPACTO VIP3	9.55	c	8.17	b
6	LG 6053 PRO2	9.62	c	8.69	b
7	2 B 512 PW	11.05	a	8.49	b
8	FEROZ VIP	9.23	c	7.76	b
9	KWX 76610	9.81	c	8.99	a
10	LG 6030 RR2	9.29	c	9.53	a
11	2 B 610 PW	10.52	b	9.24	a
12	XB 8010	7.61	d	7.63	b
13	2B 587 PW	11.47	a	9.13	a
14	RB 9110 PRO	10.02	c	9.87	a
15	XB 6012 BT	9.33	c	10.59	a
16	90 XB 06 BT	9.69	c	10.11	a
17	XB 8030	7.68	d	7.06	b
18	RB 9006 PRO	10.04	c	6.39	b
19	RB 9005 PRO	9.73	c	11.02	a
20	2B 810 PW	9.80	c	9.83	a
21	XB 8018	9.93	c	9.08	a

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Table 3 (continuation). Mean values for grain yield of 39 commercial maize hybrids, in two sowing seasons, under irrigation regime. Teresina, PI 2017

22	MG 600 PW	10.39	b	9.37	a
23	30 A 91 PW	10.24	b	9.69	a
24	13 B 275 PW	9.65	c	10.16	a
25	RB 9077 PRO	9.35	c	7.70	b
26	LG 6030 PRO2	9.58	c	10.35	a
27	RB 9210 PRO	9.62	c	9.23	a
28	MG 652 PW	11.23	a	9.96	a
29	LG 6418	11.37	a	11.564	a
30	60 XB 14	9.98	c	9.00	a
31	20 A 78 PRO	9.48	c	8.91	a
32	30 A 37 PW	10.75	b	9.68	a
33	CD 3770 PW	9.87	c	10.00	a
34	CR 804	10.16	b	9.71	a
35	LG 6310	9.35	c	6.97	b
36	CD 3880 PW	11.05	a	11.66	a
37	2 A 401 PW	10.58	b	10.98	a
38	RB 9308 PRO	9.35	c	10.35	a
39	CD 3612 PW	9.42	c	11.26	a

Note: average grain yield for sowing in July (9.84 Mg ha^{-1}) and sowing in August (9.38 Mg ha^{-1}). General mean value for grain yield (two seasons): 9.61 Mg ha^{-1}. Means with the same letter in the column are identical at 5% significance level as per Scott-Knott test.

Table 4. Mean values for water use efficiency of 39 commercial maize hybrids, in two sowing seasons, under irrigation regime. Teresina, PI 2017

	Hybrids	Water use efficiency (kg m^{-3})			
		Sowing in July		Sowing in August	
1	2B 433 PW	2.0	b	1.6	a
2	MG 580 PW	1.6	d	1.6	a
3	RB 9004 PRO	1.8	c	1.6	a
4	2B 633 PW	1.8	c	1.7	a
5	IMPACTO VIP3	1.8	c	1.4	b
6	LG 6053 PRO2	1.8	c	1.5	b
7	2B 512 PW	2.1	a	1.5	b
8	FEROZ VIP	1.8	c	1.3	b
9	KWX 76610	1.9	c	1.6	a
10	LG 6030 RR2	1.8	c	1.6	a
11	2B 610 PW	2.0	b	1.6	a

Table 4 (continuation). Mean values for water use efficiency of 39 commercial maize hybrids, in two sowing seasons, under irrigation regime. Teresina, PI 2017.

12	XB 8010	1.5	d	1.3	b
13	2B 587 PW	2.2	a	1.6	a
14	RB 9110 PRO	1.9	c	1.7	a
15	XB 6012 BT	1.8	c	1.8	a
16	90 XB 06 BT	1.9	c	1.7	a
17	XB 8030	1.5	d	1.2	b
18	RB 9006 PRO	1.9	c	1.1	b
19	RB 9005 PRO	1.9	c	1.9	a
20	2B 810 PW	1.9	c	1.7	a
21	XB 8018	1.9	c	1.6	a
22	MG 600 PW	2.0	b	1.6	a
23	30 A 91 PW	2.0	b	1.7	a
24	13 B 275 PW	1.9	c	1.8	a
25	RB 9077 PRO	1.8	c	1.3	b
26	LG 6030 PRO2	1.8	c	1.8	a
27	RB 9210 PRO	1.9	c	1.6	a
28	MG 652 PW	2.2	a	1.7	a
29	LG 6418	2.2	a	2.0	a
30	60 XB 14	1.9	c	1.6	a
31	20 A 78 PRO	1.8	c	1.5	a
32	30 A 37 PW	2.1	b	1.7	a
33	CD 3770 PW	1.9	c	1.7	a
34	CR 804	2.0	b	1.7	a
35	LG 6310	1.8	c	1.2	b
36	CD 3880 PW	2.1	a	2.0	a
37	2 A 401 PW	2.0	b	1.9	a
38	RB 9308 PRO	1.8	c	1.8	a
39	CD 3612 PW	1.8	c	1.9	a

Note: General mean of water use efficiency for sowing in July (1.9 kg m^{-3}) and sowing in August (1.6 kg m^{-3}). Means with the same letter in the column are identical at 5% significance level as per Scott-Knott test.

planted in July. The hybrids located in the upper right quadrant obtained the best results since they reached grain yields above the means for sowing carried out either in July or August.

The sowing season produces changes in the crop cycle and modifies physical and morphological aspects that may affect plant and ear heights, as well as yield components. Number of kernels per ear and grain mass per ear are variables that presented greater values in the July season in relation to the August season, being regarded as the main factors to differentiate the

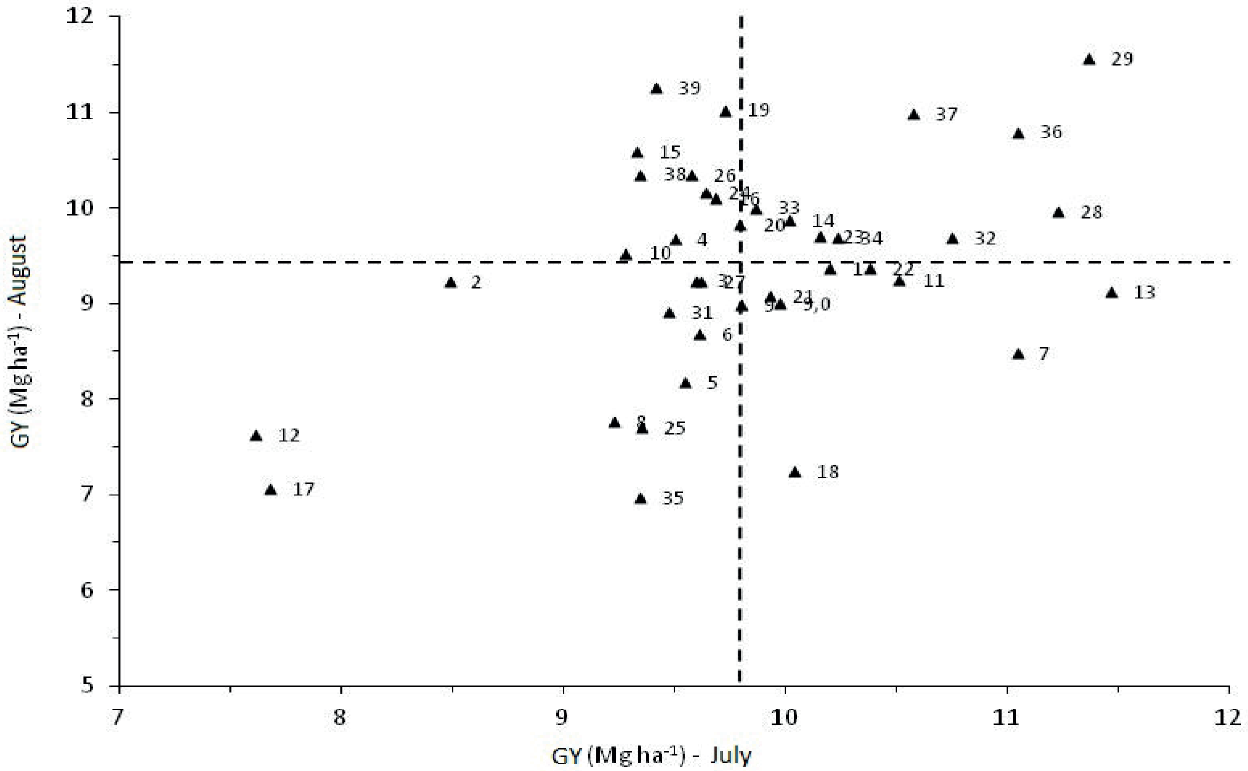

Figure 3. Scatter plot for grain yield of 39 commercial maize hybrids, cultivated under irrigation regime, and evaluated in two sowing seasons: July 2017 (x-axis) and August 2017 (y-axis). The hybrids corresponding to the numbers are listed in Table 3. Teresina, PI 2017

behavior of hybrids in the two seasons (Table 5). This fact is also demonstrated by the correlation between those components and the grain yield per hectare, which presented high values (Table 6) (Nogueira et al., 2012).

The periods (number of days) from sowing to tasseling and from silking to physiological maturity were longer, and the period from tasseling to silking was shorter, when the sowing season occurred in July (Table 7). In those periods, the average climate data relative to air temperature and solar radiation were higher in relation to the sowing season in August (Table 8), certainly favoring the hybrids, which could better express their yield potential. This fact can be demonstrated by the production of 7.67 bags of 60 kg (4.68%) more in relation to the August season (Alves et al., 2011; Sangoi et al., 2010). In irrigated crop systems, the factors that most influence the maize grain yield are the variations of air temperature and incident solar radiation. As it is a plant that highly benefits from solar radiation, it is very sensitive to the lack of light and, therefore, in cloudy days, there is a drop

Table 5. Average data for the following characteristics: plant height (PH - cm), ear height (EH - cm), hundred-grain weight (HGW - g), grain index (GI), ear index (EI), grain mass per ear (GME – g), number of kernels per ear (NKE), grain yield per hectare (GY - Mg ha^{-1}), and water use efficiency (WUE - kg m^{-3}) of 39 commercial maize hybrids, in two sowing seasons, under irrigation regime. Teresina, PI 2017

SE	PH	EH	HGW	GI	EI	GME	NKE	GY	WUE
JULY	206 a	100 a	36 a	0.85 a	1.04 a	142 a	398 a	9.84 a	1.9 a
AUGUST	183 b	94 a	35 a	0.85 a	1.04 a	133 b	383 b	9.38 a	1.6 a

Means with the same letter in the column are identical at 5% significance as per F-test.

Table 6. Pearson's correlation for grain yield, plant height (PH), ear height (EH), hundred-grain weight (HGW), grain index (GI), ear index (EI), grain mass per ear (GME), number of kernels per ear (NKE), and water use efficiency (WUE) of 39 commercial maize hybrids, in two sowing seasons, under irrigation regime. Teresina, PI 2017

PC	Sowing season: July 2017 Grain yield	Sowing season: August 2017 Grain yield
PH	0.07752	0.18389*
EH	0.08235	0.16669*
HGW	- 0.01028	0.00132
GI	0.59970**	0.49363**
EI	0.38278**	0.37316**
GME	0.91331**	0.90094**
NKE	0.86507**	0.83295**
WUE	0.99978**	0.92332**

** and * significant at 1% and 5% significance level, respectively, as per t-test.

in the photosynthesis rate, which may reduce yield. Moreover, high daytime air temperature shortens the crop cycle, which, associated with high maintenance respiration rates as a result of high nighttime temperature, also reduces yield. That is why there is a considerable interannual variability in average maize grain yield, even under irrigated regime (Alves et al., 2011).

Conclusions

Three hybrids (LG 6418, CD 3880 PW, and 2 A 401 PW) stand out when they are sown in July and August.

In the sowing carried out in July, the hybrids produce, on average, 7.67 bags of 60 kg more per hectare in relation to the sowing in August.

Table 7. Average duration (in days) of the periods: from sowing (SO) to tasseling (TA), from tasseling to silking (SI), and from silking to physiological maturity (PM), of 39 maize hybrids, in two sowing seasons, under irrigation regime. Teresina, PI 2017

	Phenological Stages		
Seasons	SO-TA	TA-SI	SI-PM
July	53	3	64
August	49	5	57

Table 8. Average data of maximum and minimum air temperature (°C) and solar radiation (MJ m^{-2}), for the periods (days): from sowing (SO) to tasseling (TA), from tasseling to silking (SI), and from silking to physiological maturity (PM), of 39 commercial maize hybrids, in two sowing seasons, under irrigation regime. Teresina, PI 2017

Seasons	SO - TA			TA - SI			SI - PM		
	Max	Min	Rd	Max	Min	Rd	Max	Min	Rd
July	34.9	21.1	17.2	36.6	22.2	19.4	37.4	23.1	18.5
August	36.8	21.8	18.7	37.7	22.8	18.7	36.7	24.3	17.4

The number of kernels per ear and grain mass per ear are the yield components most correlated with grain yield.

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