GROWING SEASON FOR MAIZE CULTIVARS WITH CONTRASTING MATURITY AT CENTER-SOUTHERN OF BUENOS AIRES PROVINCE, ARGENTINE: A. PREDICTED PHENOLOGY

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ABSTRACT: The objective was to describe variability in predicted phenology for maize cultivars with contrasting maturity across six planting dates. The maize growing season agroclimatology (1971-2010) was based on a simple model of crop development using growing degree-days as estimator. The approach was applied to four locations of the region. Dates of flowering (F) and physiological maturity (M) were predicted for each planting date and for short, medium and long season cultivars. A subperiod (P-F or F-M) was considered as completed when a given accumulation of daily temperatures above the base temperature (8 °C) has been achieved from planting (P), under the assumption of no other limiting conditions. The duration of P-F subperiod was reduced as the planting date was delayed for each cultivar and location, but no significant differences were observed between two consecutives planting dates. Azul had the shortest P-M and F-M subperiods. Balcarce was the only location with significant trend to accelerate the occurrence of flowering stage. No trends were detected for dates of occurrence of physiological maturity stage.
KEY-WORDS: growing degree-days, planting date, flowering, maturity

ESTAÇÃO DE CRESCIMENTO PARA CULTIVARES DE MILHO DE DIFERENTES GRUPOS DE MATURAÇÃO NO CENTRO-SUDESTE DA PROVINCIA DE BUENOS AIRES, ARGENTINA: A. FENOLOGIA

RESUMO: O objetivo foi descrever a variabilidade da fenologia predita para cultivares de milho de constratante maturação ao longo de seis datas de semeadura. O metodo de graus-dia foi aplicado na estimativa de datas de florescimento (F) e maturação (M) para cada data de semeadura e cultivares de curta, media e longa estação para quatro localidades da região. Um subperiodo (P-F ou F-M) foi completado quando foi alcanzada uma determinada soma termica acima da temperature base desde o plantio (P), sob o pressuposto que não existe outra limitação ao desenvolvimento. A duração do subperiodo P-F foi reduzida com o atraso da semeadura para cada cultivar e sitio, mais não foram observadas diferenças significativas entre duas datas consecutivas de semeadura. Azul teve menor duração dos subperiodos P-M e F-M. Balcarce mostrou tendencia a acelerar a ocurrencia do florescimento. Não foram observadas tendencias na data de ocurrencia da maturacão.

PALAVRAS-CHAVE: graus-dia, data de semeadura, florescimento, maturação

INTRODUCTION

As rising on air temperature series has been reported by the scientific community over the world, it is expected effects on length of growing season and crop production. Fernandez Long et al. (2013) over the agricultural area of Argentine indicated a regional warming, mainly due to increases of minimum temperatures. Trends of bioclimatic temperature-based indices were not uniformly distributed. Moreover, some trends have changed in absolute values and also reversed the sign during the more recent period, especially during the spring and summer months. At southern of Buenos Aires province, Irigoyen et al. (2011) have described an increasing trend in accumulated growing degree-days observed either by 3-month periods during maize growing season or the entire season across three planting dates for an intermediate season cultivar. Information about expected variability for agricultural strategies, as selection of planting date or growing season for specific cultivars, is required. Differential responses on crop phenology would be expected since variations in trends of bioclimatic indices. The objective was to describe variability on growing season of maize cultivars with contrasting maturity across six planting dates fairly used in the region.

MATERIAL AND METHODS

Historical series (1971-2010) of daily mean air temperature from locations at southern Buenos Aires province, Azul (-36º 50', 132 m), Tandil (-37º 19', 175 m), Balcarce, (-37º 45', 130 m) and Mar del Plata (-38º 00', 21 m) were used. Growing degree-days (GDD) for maize were computed by subtracting the base temperature (Tb) of 8ºC to daily mean air temperature. Six planting dates from late September (25/09) to mid-November (15/11), moving away by approximately for ten days, were simulated for cultivars with contrasting maturity. A subperiod (P-F or F-M) was considered as completed when a given accumulation of daily temperatures above the base temperature (8 °C) has been achieved as showed in Table 1, under the assumption of no other limiting conditions. Information about recommended cultivars with contrasting maturity was obtained from Capristo *et al.* (2007).

Table 1 - Growing degree-days for planting to flowering (P-F) and flowering to physiological maturity (F-M) subperiods for short (1), medium (2) and long (3) season cultivars

	Growing degree-days (Cd)	
Cultivar	P-F	F-M
1	660	840
2	760	870
3	870	860

Basic descriptive statistics were computed for predicted F or M dates of occurrence. The Shapiro-Wilks test was used to test normality of duration of phenological subperiods. The non-parametrical Kruskal-Wallis test was conducted to evaluate differences among planting dates for each location and cultivar or among locations for each cultivar and planting date. Spearman correlation analysis ($p < 0.05$) was applied to evaluate trends for duration of the phenological subperiods and trends for dates of occurrence of strategic stages.

RESULTS AND DISCUSSION

Over the region, the length of maize growing season ranged from 125 to 160 days for short season cultivar, 137 to 171 for medium season cultivar and 150 to 180 for long season cultivar (Table 2). Differences among planting dates (PD) were observed for the length of growing season (P-M subperiod) with a trend to reducing duration from late September to mid-October planting dates in each location and no differences were observed among late-October and mid-November ones, except for Balcarce, where only the two latest planting date were not different. Azul presented the shortest growing season in each planting date and for each cultivar, while the duration of P-M subperiod were not different among the other locations. However Azul had the more reduced growing season over the region, a maximum value of 232 days was predicted for cultivar 3 on mid-November planting date. A maximum value of 326 days was predicted for the same subperiod and combination of planting date x cultivar at Balcarce. Extended season on La Nina events has been reported for intermediate maturity cultivar (IRIGOYEN et al. 2011). Certainly, frost period can initiate before ending the growing season. The duration of P-F subperiod was reduced as the planting date was delayed for each cultivar and location, but no significant differences were observed between two consecutives planting dates (Table 3). Significant differences were also observed among locations for the durations of P-F and F-M subperiods. The P-F subperiod grouped Tandil to Azul with the shortest duration in most of planting date for cultivars 1 and 2 and only in the latest four planting dates for cultivar 3 (Table 3).

Table 2 - Median values of duration of Planting to Maturity subperiod (P-M) for planting dates (PD) and cultivars

		Duration (days)								
Location	PD	Cultivar 1			Cultivar 2			Cultivar 3		
Azul	25/09	146.0	a	B	156.0	a	B	165.0	a	B
	05/10	140.0	ab	B	151.0	ab	B	159.0	ab	B
	15/10	134.0	bc	B	145.0	bc	B	154.0	bc	B
	25/10	131.0	cd	B	142.0	cd	B	152.0	c	B
	05/11	127.0	d	B	139.0	d	B	150.0	c	B
	15/11	125.0	d	B	137.0	d	B	150.0	c	B
Tandil	25/09	154.0	a	A	166.0	a	A	176.0	a	A
	05/10	149.0	ab	A	162.0	ab	A	172.0	ab	A
	15/10	143.0	bc	A	156.0	bc	A	168.0	b	A
	25/10	140.0	cd	A	153.0	c	A	168.0	b	A
	05/11	137.0	d	A	152.0	c	A	168.0	b	A
	15/11	135.0	d	A	152,0	c	A	174.0	a	A
Balcarce	25/09	160.0	a	A	171.0	a	A	180.0	c	A
	05/10	151,0	ab	A	163.0	ab	A	173.0	a	A
	15/10	146.0	bc	A	158.0	bc	A	168.0	ab	A
	25/10	141.0	c	A	154.0	bc	A	166.0	b	A
	05/11	137.0	cd	A	150.0	c	A	162.0	b	A
	15/11	135.0	d	A	152.0	c	A	165.0	ab	A
Mar del Plata	25/09	158.0	a	A	170.0	a	A	180.0	a	A
	05/10	152.0	ab	A	165.0	ab	A	175.0	ab	A
	15/10	147.0	bc	A	159.0	bc	A	170.0	b	A
	25/10	144.0	cd	A	156.0	c	A	169.0	b	A
	05/11	139.0	d	A	154.0	c	A	168.0	b	A
	15/11	136.0	d	A	153.0	c	A	171.0	b	A

Different minor letters indicate significant differences ($p<0.05$) among planting dates for each combination of location and cultivar and different capital letters indicate differences ($p<0.05$) among locations for each combination of planting date and cultivar.

Table 3 - Median values of duration of Planting to Flowering subperiod (P-F) for planting dates (PD) and cultivars

		Duration (days)								
Location	PD	Cultivar 1			Cultivar 2			Cultivar 3		
Azul	25/09	83.0	a	B	91.0	a	B	99.0	a	B
	05/10	77.0	ab	B	85.0	ab	B	93.0	ab	B
	15/10	73.0	bc	B	78.0	bc	B	86.0	bc	B
	25/10	66.0	cd	B	73.0	cd	B	82.0	cd	B
	05/11	61.0	de	B	69.0	de	B	77.0	de	B
	15/11	57.0	e	B	64.0	e	B	72.0	e	B
Tandil	25/09	88.0	a	AB	97.0	a	AB	104.0	a	A
	05/10	81.0	ab	A	89.0	ab	AB	97.0	ab	A
	15/10	76.0	bc	AB	83.0	bc	AB	91.0	bc	AB
	25/10	69.0	cd	AB	77.0	cd	AB	85.0	cd	AB
	05/11	65.0	de	AB	72.0	de	AB	81.0	de	AB
	15/11	60.0	e	AB	68.0	e	AB	76.0	e	AB
Balcarce	25/09	92.0	a	A	99.0	a	A	108.0	a	A
	05/10	83.0	ab	A	91.0	ab	A	99.0	ab	A
	15/10	77.0	bc	A	84.0	bc	A	92.0	bc	A
	25/10	71.0	cd	A	78.0	cd	A	87.0	cd	A
	05/11	65.0	de	A	75.0	de	A	83.0	de	A
	15/11	61.0	e	A	69.0	e	A	78.0	e	A
Mar del Plata	25/09	91.0	a	A	97.0	a	A	106.0	a	A
	05/10	84.0	ab	A	91.0	ab	A	99.0	ab	A
	15/10	77.0	bc	A	85.0	bc	A	93.0	bc	A
	25/10	71.0	cd	A	79.0	cd	A	88.0	cd	A
	05/11	66.0	de	A	74.0	de	A	83.0	de	A
	15/11	62.0	e	A	70.0	e	A	79.0	e	A

Different minor letters indicate significant differences ($p<0.05$) among planting dates for each combination of location and cultivar and different capital letters indicate differences ($p<0.05$) among locations for each combination of planting date and cultivar.

For F-M subperiod, Azul had also the shortest duration, while Tandil and Balcarce always had the more extended duration (Table 4). Maximum predicted values for duration of F-M subperiod were distanced by about 100 days between Azul and Balcarce. Subperiods at Mar del Plata were similar to Balcarce and Tandil for early planting dates, but were not different from observed at Azul on late ones. The minor difference among cultivars for duration of this subperiod respect to P-F subperiod is associated to thermal requirement as showed in Table 1. No significant trends were detected by Spearman correlation analysis for dates of occurrence of flowering stage of each cultivar at each planting date, except at Balcarce with significant trends to accelerate the occurrence for all cultivars and planting dates. Trends in temperature-based indices not spatially homogeneous have been reported by Fernandez Long et al. (2013). For the other hand, no significant trends were detected for dates of occurrence of physiological maturity stage, whichever cultivar or planting date.

Table 4 - Median values of duration of Flowering to Physiological Maturity subperiod (F-M) for planting dates (PD) and cultivars

		Duration (days)								
Location	PD	Cultivar 1			Cultivar 2			Cultivar 3		
Azul	25/09	63.0	b	B	65.0	b	B	67.0	d	B
	05/10	63.0	b	B	65,0	b	B	68,0	cd	B
	15/10	63.0	b	B	67.0	b	B	69.0	cd	B
	25/10	64.0	b	B	69.0	ab	B	71.0	bc	B
	05/11	66.0	ab	B	71.0	a	B	74.0	ab	B
	15/11	68.0	a	B	73.0	a	B	78.0	a	B
Tandil	25/09	68.0	b	A	72.0	d	A	74.0	d	A
	05/10	67.0	b	A	72.0	cd	A	74.0	cd	A
	15/10	69.0	b	A	74.0	c	A	77.0	c	A
	25/10	71.0	ab	A	76.0	bc	A	81.0	bc	A
	05/11	72.0	a	A	80.0	ab	A	87.0	ab	A
	15/11	74.0	a	A	83.0	a	A	97.0	a	A
Balcarce	25/09	68.0	b	A	72.0	c	A	73.0	c	A
	05/10	69.0	b	A	73.0	bc	A	74.0	c	A
	15/10	69.0	ab	A	73.0	bc	A	76.0	c	A
	25/10	70.0	a	A	74.0	abc	A	81.0	bc	A
	05/11	71.0	a	A	78.0	ab	A	85.0	ab	A
	15/11	72.0	a	A	84.0	a	A	90.0	a	A
Mar del Plata	25/09	69.0	b	A	73.0	c	A	75.0	c	A
	05/10	69.0	b	A	74.0	bc	A	75.0	c	A
	15/10	70.0	ab	A	74.0	bc	A	76.0	c	A
	25/10	71.0	ab	A	77.0	bc	A	78.0	bc	A
	05/11	73.0	ab	A	78.0	ab	A	84.0	ab	A
	15/11	74.0	a	AB	82.0	a	AB	87.0	a	AB

Different minor letters indicate significant differences ($p<0.05$) among planting dates for each combination of location and cultivar and different capital letters indicate differences ($p<0.05$) among locations for each combination of planting date and cultivar.

CONCLUSIONS

The maize growing season is clearly shortest at Azul, whichever the date planting or cultivar. Trend to accelerate the occurrence of flowering was only observed at Balcarce.

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