Seamaíz

XI Congreso Nacional de Maíz

GENÉTICA Y MEJORAMIENTO GENÉTICO VEGETAL

LLENADO Y SECADO DEL GRANO DE HÍBRIDOS COMERCIALES DE MAÍZ EN LA PAMPA ONDULADA: EFECTOS DE LA FECHA DE SIEMBRA

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KERNEL FILLING AND KERNEL DESICCATION OF COMMERCIAL MAIZE HYBRIDS IN THE ROLLING PAMPAS: SOWING DATE EFFECTS

ABSTRACT

Sowing date (Sw) modifies the environmental conditions to which maize crops are exposed during grain filling and after physiological maturity (PM). The objective of this work was to characterize the patterns of kernel filling and kernel desiccation in a set of 4 hybrids when grown at two contrasting environments, an early (ESw: 31-Oct) and a late (LSw: 28-Dec) Sw. Individual kernel weight (KW), kernel filling rate (KFR), total duration of kernel filling (KFD),kernel desiccation rates before (b1) and after (b2) PM, and the breakpoint between these rates (x_1) were computed for each treatment combination. Delayed Sw exposed the crop to reduced mean temperature and solar radiation after flowering. Also caused a 14.6% reduction in final KW ($p<0.01$), which was accompanied by (i) a decrease in KFR of one hybrid ($p<0.05$), and (ii) a shortened KFD in the rest of the hybrids ($p<0.05$).Kernel desiccation rates differed in magnitude (b1>b2), but not across Sw environments. The breakpoint between rates occurred earlier and at higher kernel moisture content (41.3%) in the LSw than in the ESw (32.8%), indicative of a marked source limitation for the former and the inadequacy of constant kernel moisture content for predicting PM across Sw.

Palabras Clave
Zea mays L., Peso individual del grano, Tasa de llenado, Tasa de secado, Fecha de siembra.

Key Words
Zea mays L., Individual kernel weight, Kernel growth rate,Kernel desiccation rate, Sowing date.

INTRODUCTION

Biomass accumulation in maize kernels is characterized by (i) an initial period of slow growth (*lag* phase), when sink potential size is set, (ii) a subsequent period of active biomass accumulation (EGF, *effective grain-filling* phase), when kernel weight increases at the maximum rate, and (iii) a final period of reduced growth rate (*maturation* period), when final kernel weight (KW) is established (Egli, 1998).Maximum KW is reached at physiological maturity (PM) with a kernel moisture content(KMC) of ca. 35% (Sala *et al.*, 2006). KMC at commercial harvest is usually much lower because the trade standard is 14.5%.The rate of kernel drying between PM and final harvest vary depending upon the environment (Schmidt and Hallauer, 1966).

Restrictions to crop growth during the EGF cause equivalent reductions in final KW and consequently in grain yield (Borrás *et al.*, 2004). Such conditions are frequently experienced by late-sown maize crops (Cirilo and Andrade, 1996) and crops grown at high latitudes (Maddonni *et al.*, 1998; Bonelli *et al.*, 2016), due to decreasing levels of incident solar radiation and air temperature. The former has a negative effect on assimilates production (Cirilo and Andrade, 1996), whereas the latter has a negative effect on radiation use efficiency (Andrade *et al.*, 1993) as well as on reserves mobilization (Kiniry and Otegui, 2000).

Once final KW is set at PM, fast kernel drying is a trait usually sought among maize breeders, because it reduces time to harvest and eventual drying costs. These aspects have become relevant in recent years in Argentina, due to the increased proportion of late-sown maize crops, for which kernel drying takes place under less favorable conditions of air temperature (low) and humidity (high).The objective of current research was to characterize the patterns of kernel filling and kernel desiccation of a set of maize hybrids currently used in the Argentine market when grown at two contrasting sowing dates in Pergamino.

MATERIALS & METHODS

Field experiments were performed during 2016-2017 at INTA Pergamino(33° 56'S, 60°33'W)and included two sowing date (Sw) environments, an irrigated early sowing date (ESw: 31-Oct) and a non-irrigated late sowing date (LSw: 28-Dec). In each environment, four F1 hybrids (H) were evaluated at a single stand density of 9 plants m^{-2} in three replicates. Hybrids were released to the market in 2002 (DK 190), 2012 (DK 72-10) and 2016 (DK 70-20 and DK 73-20). Experiments were kept free of weeds, pest and diseases.

Daily weather records (SRi: incident solar radiation; Tm: mean air temperature; RH: relative air humidity) were obtained from an automatic station located at less than 1 km from the experiments. A photothermal quotient (Q; eq.1) was calculated for the postflowering period using a base temperature (Tb) of 0°C.

(1) Q=SR/(Tm-Tb)

At silking date (R1, 50% of plants with at least one silk visible); 12-15 plants were tagged at each plot. Beginning at 20 days after R1 (R1+20), two (ESw) or one (LSw) ears per plot were harvested each 7 (between R1+20 and PM) or 15 days (from PM onwards). Up to the 5th sampling date, husks were removed in a humidified box and 15 kernels removed from the mid-portion of each ear. Kernels were immediately weighed for fresh weight (FW) determination, and subsequently dried at 62 °C up to constant weight for KW assessment.

A bilinear with plateau model was fitted to the evolution of KW (Gambín et al., 2007) for each Sw×H combination, both on a daily (days) and a thermal time basis (TT, in °Cday) from R1, using a base temperature (Tb) of 0°C (Muchow, 1990). Kernel filling rate (KFR, in mg day^{-1} and mg $°Cday^{-1}$) during EGF was obtained from fitted models. Total grain-filling duration (in days and in °Cdays) was computed as the time lag between R1 and the breakpoint of each model. Established parameters were (i) the maximum KFR (b_0), (ii) the maximum KW (KW_{MAX}), and (iii) the breakpoint when KWMAX is reached (X_0).A bilinear model was also fitted to percent KMC evolution from R1 onwards, both in days and in °Cday. The early (b_1) and late (b_2) kernel desiccation rates were estimated (in % day^{-1}and in % °Cday^{-1}) as well as the breakpoint between them (X1).Main and interaction effects on all computed traits and parameters were evaluated by ANOVA, and significant differences among means were estimated by Duncan's test at the 0.05 probability level.

RESULTS

Meteorological conditions during grain filling and from PM onwards differed markedly between Sw environments. Delayed sowing date caused reductions in Tm (-19%, 23.1°C in ESw and 18.8°C in LSw) and SRi (-30%, 20 MJ m^{-2} day^{-1}in ESw and 14 MJ m^{-2} day^{-1}in LSw) from R1 to PM. This trend produced a 14% decrease in Q (0.87 for ESw and 0.74 for LSw). Differences between Sw in Tm (-28%, 23.1°C in ESw and 18.8°C in LSw) and SRi (-40%, 14 MJ m^{-2} day^{-1}in ESw and 9 MJ m^{-2} day^{-1}in LSw) increased from PM to commercial harvest. Contrary, only a slight increase was registered in mean RH during this period (73% in ESw and 75% in LSw). Frost events occurred after PM (12-june onwards).

Delayed sowing date caused a 14.6% reduction ($p<0.05$) in KW_{MAX} (Table 1). A similar Sw effect was registered for KFR when expressed in mg day^{-1} (data not shown), but not on a thermal time basis (Table 1). Hybrids differed in the response to Sw due to the significant reduction in (i) KFR (-18.1%; $p<0.05$) computed for DK 70-20 (Figure 1a), and (ii) KFD (-10.4%; $p<0.001$) computed for the rest of the hybrids (Figure 1b).

For all evaluated treatment combinations, two phases (pre and post PM) were distinguished during kernel desiccation. Estimated rates at each phase differed between Sw environments when expressed on a daily basis (data not shown). The post PM desiccation rate was larger for the ESw (-0.38% day^{-1}) than for the LSw (-0.27% day^{-1}) environment (p<0, 05), with no significant hybrid effect. Two phases were also distinguished during kernel desiccation when expressed on a TT basis (Figure 2). In this case, the rate computed for each phase was neither affected by Sw environments nor by hybrids. There was, however, a significant difference between sowing dates in the occurrence of the breakpoint (X_1) between phases (p<0, 05), which took place earlier for LSw (1003ºCd from R1) than for ESw (1235ºCd from R1). Interestingly, this difference in X_1 corresponded to a higher KMC in the former (41.3%) than in the latter (32.8%). Finally, TT requirement to reach the KMC of 14.5% was estimated to be shorter for the ESw (2158 ºCd) than for the LSw (2315 ºCd).

Sowing date	Hybrid	Silking date	PM date	KW_{MAX}(mg)	KFR (mg ºCd^{-1})	KFD (°Cd)
Early (31-Oct)	DK 190	14-jan	08-mar	276	0,28 AB	1291
	DK 70-20	13-jan	07-mar	264	0,35 C	1169
	DK 72-10	12-jan	02-mar	282	0,29 AB	1273
	DK 73-20	12-jan	06-mar	283	0,28 AB	1303
Late (28-Dic)	DK 190	27-feb	25-apr	227	0,31 BC	1066
	DK 70-20	26-feb	28-apr	233	0,28 AB	1119
	DK 72-10	26-feb	24-apr	252	0,29 AB	1200
	DK 73-20	26-feb	26-apr	231	0,26 A	1177
ANOVA						
Source of Variation		**df**			**Mean Squares**	
Sowing date (Sw)		1		9750,71**	0,00098 ns	84135,04*
Hybrid (H)		3		421,28 ns	0,0019 *	13123,93*
Sw x H		3		214,86 ns	0,0023 *	9121,15 ns
Error		12		202,35 ns	0,00051 ns	3402,46 ns
Total		23				

*** p<0.0001; ** p<0.01; * p<0.05; ns: not significant. Means followed by the same letter do not differ at p<0.05.

Table 1. Top: Silking date, physiological maturity (PM) date, maximum estimated kernel weight (KWMAX), kernel filling rate (KFR), and kernel filling duration (KFD) of four maize hybrids grown in two contrasting sowing date environments. Bottom: ANOVA results.

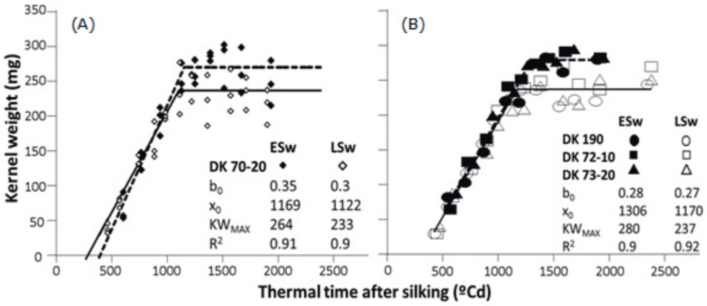

Figure 1. Kernel weight evolution of (A) DK 70-20, and (B) DK 190, DK 72-10 and DK 73-20. Data correspond to early (ESw: 31-Oct, full symbols) and late (LSw: 28-Dec, empty symbols) sowing dates.

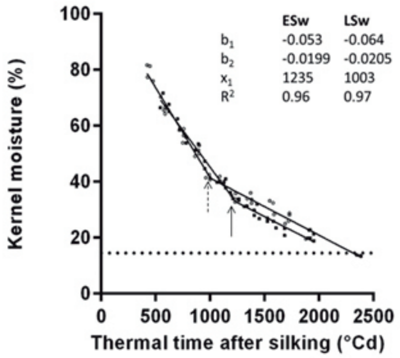

Figure 2. Relative kernel moisture content from R1 onwards of four maize hybrids grown at early (ESw: 31-Oct, full symbols) and late (LSw: 28-Dec; empty symbols) sowing dates. The horizontal dotted line indicates the trade standard for kernel moisture content (14.5%). Arrows indicate the breakpoint (X_1) between pre (b_1) and post (b_2) physiological maturity drying rates, with the solid one for ESw (32.8%) and the dashed one for LSw (41.3%).

DISCUSSION & CONCLUSION

Delayed Sw in the region under study caused a reduction in KW_{MAX}, which can be attributed to the associated decline in photothermal conditions (Borrás *et al.*, 2004; Bonelli *et al.*, 2016). Despite their common commercial source (Dekalb), hybrids differed in the response to this delay of the physiological determinants of KW, but a reduction in grain-filling duration was the prevailing pattern. The described trend was accompanied by an increased KMC at PM of the LSw, similar to that produced by defoliation treatments that caused the early arrest of grain filling (Sala *et al.*, 2006). Consequently, the threshold of 35% KMC seems not a reliable estimate of PM for LSw. Contrary, kernel desiccation rate from PM onwards (b_2) seemed not affected by environmental conditions because it did not differ between Sw, and consequently it can be used to estimate KMC during this period.

In conclusion, detection of described responses was possible due to the extremely late Sw included in the analysis (28-Dic), which produced a marked source limitation during grain filling. Future research should include a broad range of Sw, a necessary step for modeling the effects of the environment on all the parameters of interest for the estimation of KMC.

Financial support: Current research was supported by the National Agency for Science Promotion (PICTs 2015/2671, 2016/1504 and 2016/1578).

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