European Journal of Agronomy 92 (2018) 1–8

Contents lists available at ScienceDirect

European Journal of Agronomy

journal homepage: www.elsevier.com/locate/eja

Research paper

Sowing date and maize grain quality for dry milling

Lucas J. Abdala, Brenda L. Gambin, Lucas Borrás*

Facultad de Ciencias Agrarias, Universidad Nacional de Rosario, Campo Experimental Villarino S/N, Zavalla S2125ZAA, Prov. de Santa Fe, Argentina

ARTICLE INFO

Keywords:
Grain hardness
Sowing date
Maize
Grain type
Dry milling
Grain quality

ABSTRACT

Argentina is the single exporter of non-gmo hard endosperm maize to the European Union, and is internationally known for its grain hardness. This special hard endosperm maize supply chain follows strict regulations to ensure a high quality grain. Specific values for test weight, flotation index, grain vitreousness, and screen retention are demanded by the dry milling industry. Central temperate Argentinean production system is currently changing to later sowings, and there is limited information on the effect of contrasting sowing dates over specific grain quality attributes of interest for the industry. In this study we explored the effects of delaying maize sowing dates from September-October to December on maize dry milling grain quality in the central temperate area. Eighteen commercial genotypes differing in grain hardness were sown during two growing seasons and two sowing dates. Measured traits were grain yield, individual grain weight, dry milling quality (test weight, floaters, vitreousness, 8 mm screen retention), and composition (oil, protein, starch). Grain yield varied significantly among genotypes ($p < 0.001$), and semi-dents showed higher yields when compared to hard endosperm flints (13 110 and 11 463 kg ha^{-1}, respectively). Early and late sown maize yielded 12 737 kg ha^{-1} and 11 003 kg ha^{-1}, respectively. Significant genotype differences were observed for all grain quality and composition attributes. Delaying the sowing date from September-October to December had minimum effects on physical grain quality traits, only evident at some genotypes (significant sowing date x genotype interaction for most traits). Genotype to genotype differences in grain quality and composition were larger than variations between sowing dates. Grain hardness was strongly determined by the genotype, making genotype selection a critical management option for attaining high quality at any sowing date. It is evident that high dry milling quality can be obtained with adequate genotypes also at later sowings.

1. Introduction

Argentinean maize production is around 33 million tons per year (FAO, 2014). Most of the planted area, near 5 million hectares, is occupied with soft endosperm semi-dent gmo (genetically modified organism) genotypes. At the same time Argentina produces 130 000–150 000 ha (average last 10 years) of hard endosperm non-gmo maize for dry milling, also known as flint or plata maize. This production results in a yearly average of 360 thousand metric tons of flint maize exported to the European Union during the last decade (Greco and Martí Ribes, 2016). Argentina is currently the single maize exporter of non-gmo flint maize to the European Union, and special import permits for flint maize are used if the grain quality attains specific standards (European Commission, 1997).

Flint maize is known to present a high proportion of vitreous or hard endosperm, smooth crown, and orange pigmentation. Its physicochemical characteristics make it a preferred raw material for the dry milling industry (Litchfield and Shove, 1990; Rooney and Serna Saldívar, 2003). It is highly demanded because of its high milling yields of large endosperm grits, and the particular quality that it provides to a wide variety of end use products such as corn flakes, snacks, and other textured ingredients (Macke et al., 2016). Their characteristic color and specific cooking functional properties are quality attributes highly desirable by the food industry (Kuiper, 2014).

Hard endosperm maize genotypes are currently yielding in the field 10–20% less than most dent (or semi-dent) genotypes (Tamagno et al., 2015, 2016), and premiums are paid to farmers for covering this yield gap. Flint non-gmo production fields are produced using contracts between farmers and industry, and are subject to strict regulations to ensure a high quality grain (MAGyP, 2015). The physical standards that a grain lot needs to reach for optimum quality are: a minimum test weight (76 kg hL^{-1}), a maximum number of floaters at a standardized solution (25%), and a minimum number of grains with 50% or more of vitreous endosperm (92%). Vitreousness is the proportion of grains having more horny than floury endosperm, and is a key attribute for the milling industry. Screen retention is also contemplated in many

* Corresponding author.
E-mail address: lborras@unr.edu.ar (L. Borrás).

http://dx.doi.org/10.1016/j.eja.2017.09.013
Received 23 July 2017; Received in revised form 21 September 2017; Accepted 27 September 2017
1161-0301/

contracts, and industry demands most grains to be retained in an 8 mm round sieve (ideally > 50%) to achieve optimum milling quality. High test weight, low floaters percentage, high vitreous to floury endosperm ratio, and high screen retention are all attributes related to high dry milling yields (Kirleis and Stroshine, 1990; Cirilo et al., 2011; Blandino et al., 2013). These attributes are especially relevant for recovering a large proportion of large flaking grits after milling.

Maize grain hardness has an important genetic control (Williams et al., 2009; Gerde et al., 2016). However, the crop growing environment can also affect maize final grain quality and composition (Borrás et al., 2002; Fox and Manley, 2009; Cirilo et al., 2011; Tamagno et al., 2016). It is relevant that farmers and cooperatives combine adequate genotypes with specific crop management practices for minimizing the risk of not reaching market quality standards for hard endosperm maize. Genotype selection, stand density, sowing date, and N fertilizer are among cropping options easily applicable by farmers.

The Argentinean maize production system has changed drastically in the last years, especially in relation to variations in sowing date. The sowing date for the central temperate region has moved from late September and early October to December. Late sown maize locates the critical flowering period for yield definition (Andrade et al., 1999) under conditions of less evaporative demand and higher probability of rainfall compared to earlier traditional sowings. However, they are able to complete the crop cycle before the first killing frost. Early sowing dates have been traditionally associated with higher maize yields (Cirilo and Andrade, 1994; Mercau and Otegui, 2014) and lower insect pest incidence, specifically *Diatraea saccharalis* and *Spodoptera frugiperda* (Gil et al., 2010; Mercau and Otegui, 2014). But, under these later sowings farmers are obtaining acceptable yields with higher yield stability, and currently most maize in Argentina is planted under late sowings (PAS, 2015). At present, specific crop management options for late sowing (*e.g.*, stand density, planting date, soil P and N management, genotype selection) are becoming available (Mercau and Otegui, 2014; Gambin et al., 2016). However, information regarding grain quality changes like grain hardness and grain dry milling quality is scarce, especially in relation to variations in traits the industry is interested. Preliminary data showed sowing date not affecting grain hardness (Gerde et al., 2017) in our region. A recent study by Cerrudo et al. (2017) reported decreases in grain quality, referred as grain coarse to fine ratio, for dry milling under late sowings, but tested later sowings in latitudes where crops will normally experience a killing frost before physiological maturity. None of these previous studies described the specific grain quality standards used by the supply chain.

In the present study we explored the consequences of delayed maize sowing dates from September-October to December over maize dry milling grain quality in the central temperate region. Analyzed traits focused on those used for exporting hard endosperm maize from Argentina to the European Union, but the implications are worldwide for any specialty hard endosperm maize produced for dry milling at any temperate environment.

2. Materials and methods

2.1. Crop management

A field experiment was conducted at the Campo Experimental Villarino, Facultad de Ciencias Agrarias, Universidad Nacional de Rosario, in Zavalla, Santa Fe, Argentina (33°1′S, 60°53′W). The experiment was sown during two growing seasons (2014/2015 and 2015/2016, years 1 and 2, respectively) and two sowing dates within each season. Sowing dates were 29 September and 18 December during year 1, and 14 October and 19 of December during year 2.

Field experiments were arranged following a completely randomized design with four replicates. Plots were 4 rows with 6 m long and 0.52 m of inter row spacing. A uniform stand density of 8 plants m^{-2} was used, and plots were always overplanted and thinned at V2-V3 (Abendroth et al., 2011). All measurements were done at the two central rows. Soil samples (0–60 cm) were taken before sowing and analyzed for N-NO_3. At sowing, monoammonium phosphate (MAP, 10–50–0, N–P–K) was applied at a rate of 120 kg ha^{-1} to all plots. The experimental area was fertilized with N using urea (46-0-0, N-P-K) at different rates for reaching 160 kg N ha^{-1} of N from soil sample plus added N. Urea was broadcasted manually over the plots from V4 to V6. Trials were kept free of weeds and pests throughout the growing season. Weeds were controlled by spraying commercially recommended maize herbicides, and also periodically removed by hand whenever necessary. Insect pressure of *D. saccharalis* and *S. frugiperda* were specifically monitored and controlled with recommended products for minimizing any possible effects.

Rainfall from sowing to physiological maturity was 464 and 342 mm (year 1) and 504 and 654 mm (year 2) for early and late sowings, respectively. Average temperatures were 20.9 and 21.9 °C (year 1) and 22.3 and 22.1 °C (year 2) in early and late sowings, respectively. These values are within expected ones based on average historic data for the last 30 years (Table 2). All crops reached physiological maturity before the first killing frost was evident. During both years harvest took place in mid-March and late-May for early and late sowings, respectively.

Eighteen maize hybrids from different seed companies were evaluated (Table 1). At present, farmers are using the same relative maturities for early and late sowings (Mercau and Otegui, 2014; Gambin et al., 2016), and tested hybrids are common commercial genotypes cropped by farmers in the region, representing a range of endosperm hardness. Five hybrids were regular semi-dent grain type, and thirteen were hard endosperm flint grain type. These thirteen flint hybrids are currently used by both local dry milling industry and exporters.

2.2. Grain yield

At commercial maturity, the two central rows of each plot were harvested and used for determining grain yield, average individual grain weight, and all other phenotypic traits. Yield is presented on a 14.5% moisture basis. Individual grain weight was determined by weighing two sets of 100 grains per plot, and average weight per grain calculated.

2.3. Grain quality and composition

Test weight, floaters percentage, and vitreousness were determined according to the methods approved by SENASA (MAGyP, 2015) and the

Table 1
Description of the 18 genotypes tested during two growing seasons and two sowing dates within each season (September-October and December).

Genotype	Grain type	Relative maturity
ACA2002	Flint	128
ACA2002BT	Flint	128
ACA514	Flint	116
ACA530	Flint	131
AX7822TD/TG	Semi-dent	117
AX8010	Flint	118
CyR7325	Flint	124
DK692VT3Pro	Semi-dent	119
DK7210VT3Pro	Semi-dent	122
Mill522	Flint	126
NK940TGPLUS	Flint	126
NK960TD/TG	Semi-dent	128
NT426	Flint	126
NT426BT	Flint	126
NT525	Flint	125
NT525BT	Flint	125
P1780HR	Semi-dent	117
SPS2866	Flint	127