Instituto Nacional de Investigación y Tecnología Agraria y Alimentaria (INIA)
Available online at www.inia.es/sjar

Spanish Journal of Agricultural Research 2008 6(3), 378-384
ISSN: 1695-971-X

Agronomic performance of sweetcorn populations derived from crosses between sweetcorn and field corn

A. Butrón[1], A. Álvarez[2], P. Revilla[1], R. A. Malvar[1], V. M. Rodríguez[1], J. I. Ruiz de Galarreta[3]* and A. Ordás[1]

[1] Misión Biológica de Galicia. Spanish Council for Scientific Research (CSIC). Apdo. 28. 36080 Pontevedra. Spain
[2] Estación Experimental de Aula Dei. Spanish Council for Scientific Research (CSIC). Apdo. 202. 50080 Zaragoza. Spain
[3] NEIKER-Instituto Vasco de Investigación y Desarrollo Agrario. Apdo. 46. 01080 Vitoria. Spain

Abstract

The adaptation of sweetcorn (*Zea mays* L.) to Spanish growing conditions needs to be improved, something that could be achieved by incorporating traits from field corn populations. The aim of the present study was to analyse the performance of sweetcorn populations carrying the genes *sugary1* (*su1*) or *shrunken2* (*sh2*), as well as *sugary enhancer* double mutants (*su1 se1*), produced by crosses between sweetcorn donor populations and the Spanish field corn populations Lazcano, Oroso and Rastrojero. The three field corn populations plus the *su1*, *su1 se1* and *sh2* populations derived from them, as well as the *su1*, *su1 se1*, and *sh2* donor populations used in the crosses with the field corn populations, were evaluated for their agronomic performance. Several hybrids were used as controls. Assessments were made in Zaragoza (NE Spain) and Pontevedra (NW Spain) over two years. The ability of the field corn populations to improve the sweetcorn varieties was not greatly affected by the sweetcorn mutant involved. The field corn populations chosen as donors for improving sweetcorn must depend on the growing conditions in mind. Sweetcorn populations derived Oroso would appear to be the most favourable for northern Spain, while those derived from Rastrojero would appear to be the most suitable for inland Spain, although other field corn populations are still to be examined.

Additional key words: maize, shrunken, sugary, sugary enhancer.

Resumen

Evaluación agronómica de poblaciones dulces de maíz derivadas de cruzamientos entre maíz dulce y maíz grano

La adaptación del maíz dulce (*Zea mays* L.) a las condiciones españolas debe ser mejorada y esto se puede realizar mediante la incorporación de factores de adaptación de las poblaciones locales. El objetivo del presente estudio fue evaluar el resultado de las poblaciones de maíz dulce *sugary1* (*su1*), *sugary enhancer* (*su1 se1*), y *shrunken2* (*sh2*) derivadas de las poblaciones de maíz grano Lazcano, Oroso y Rastrojero. Las tres poblaciones originales junto con las *su1*, *su1 se1* y *sh2* convertidas y las tres poblaciones utilizadas como donantes de los genes *su1*, *su1 se1*, y *sh2,* fueron evaluadas para comportamiento agronómico, utilizando varios híbridos como testigos. Los ensayos se realizaron en dos localidades españolas (Zaragoza y Pontevedra) durante dos años. La capacidad de las poblaciones de maíz grano para mejorar el maíz dulce no se vio en gran medida afectada por el tipo de mutante incorporado. Las poblaciones de maíz grano utilizadas como donantes dependen de las condiciones de crecimiento, siendo Oroso la más favorable para el Norte de España. Las poblaciones de maíz dulce derivadas de Rastrojero parecen ser las más convenientes para la España interior, no obstante pueden explorarse otro tipo de poblaciones de maíz grano.

Palabras clave adicionales: maíz, shrunken, sugary, sugary enhancer.

* Corresponding author: jiruiz@neiker.net
Received: 24-10-07; Accepted: 10-06-08.

Introduction

In some areas of Spain where field corn is not profitable, sweetcorn could be an interesting alternative. However, sweetcorn lacks the necessary adaptations to be able to grow well in some regions of Spain, including the Atlantic coast (Ordás *et al*., 1994).

The northern coast of Spain is characterized by a mild, rainy Atlantic climate with a summer drought, while inland Spain has cold winters, hot summers and almost no rainfall during the maize growing period (making irrigation for summer crops a necessity). The growing conditions in these regions are therefore very different. The adaptation of sweetcorn to the northern Spanish coast needs to be improved since wet, cool spring seasons are associated with poor seedling vigour, small ear size, low yield and non-uniform maturity (Ordás *et al*., 1994). For the specific conditions of northern Spain, Cartea *et al*. (1996a) proposed the use of the field corn population Oroso for improving the yield and yield components of *su1* sweetcorn hybrids. Oroso is also the best potential donor of favourable alleles for sweetcorn survival under cold conditions (Revilla *et al*., 1998). Another promising field corn population for improving the adaptation of sweetcorn to northern Spain is Lazcano; out of 12 flint corn populations it achieved the best yields across different locations in Spain and France (Malvar *et al*., 2005).

Lazcano performs well on both the northern Spanish coast and in the interior (Malvar *et al*., 2005). However, Rastrojero is well adapted to the conditions of Spain's interior and could be a promising source of adaptation traits for sweetcorn in this region; it could also help to improve sweetcorn resistance to corn borers (Malvar *et al*., 1993, 2004). Resistance to corn borers is required in both regions since ear damage by the corn borer, the European corn borer (*Ostrinia nubilalis* Hubner) and the pink stem borer (*Sesamia nonagrioides* Lef.), can greatly reduce the value of the ears (Cordero *et al*., 1998; Velasco *et al*., 1999).

Field corn has been used extensively to improve sweetcorn, and successful sweetcorn populations such as Stowell's Evergreen from Ithaca (New York State, USA), Golden Bantam from New York State (USA), and Spanish Gold from Connecticut (USA), have been developed in temperate areas using this strategy (Tracy, 2001). Many studies have shown the potential of flint and dent temperate corn germplasm for improving sweetcorn resistance to European corn borer (Joyce and Davis, 1995), resistance to corn earworm (Guo *et al*., 2001, 2004), stalk and root quality (Treat and Tracy, 1993), agronomic value, adaptation to cold areas with short growing seasons (Cartea *et al*., 1996a,b; Malvar *et al*., 1997; Revilla *et al*., 1998), yield plus agronomic and quality traits (Tracy, 1990), and for breeding new sweetcorn patterns (Davis *et al*., 1988; Revilla *et al*., 2000; Velasco *et al*., 2002).

The genes commonly used to help sweetcorn crops adapt to temperate areas include *sugary1 (su1)* and *shrunken2 (sh2)*, as well as the *sugary enhancer* double mutation *su1 se1* (Tracy, 2001). Traditional sweetcorn varieties are homozygous for *su1*, and are characterized by a smooth texture, a creamy endosperm, and the rapid decline of grain table quality after harvest. *su1 se1* genotypes produce a high quality, sweet, creamy endosperm, but which is not adequate for post-harvest storage. *sh2* genotypes provide kernels with high sugar levels (supersweet) and an extended shelf life, but are associated with poor germination and field emergence properties. The aim of the present study was to check the performance of new sweetcorn populations derived from sweetcorn donors carrying *su1, sh2* and *su1 se1* and three Spanish field corn populations.

Material and Methods

su1, sh2 and *su1 se1* sweetcorn donor populations were crossed with the field corn populations Lazcano, Oroso, and Rastrojero (Table 1). The product of these crosses were then self-crossed and homozygous *su1, sh2* and *su1 se1* seeds selected, thus obtaining new, homozygous *su1, sh2* and *su1 se1* populations. The original sweetcorn donors were chosen based on their having a flowering period similar to that of the field corn populations used. The field corn population Oroso was crossed with *su1*, *su1 se1* and *sh2* sweetcorn donor populations at the *Mision Biológica de Galicia*-CSIC Centre in Pontevedra. The field corn populations Lazcano and Rastrojero were crossed with *su1*, *su1 se1* and *sh2* sweetcorn donor populations at NEIKER (Vitoria) and the *Estación Experimental de Aula Dei* (Zaragoza) respectively. The three field corn populations plus the new, homozygous *su1, su1 se1*, and *sh2* populations derived from them,

Abbreviations used: CSIC (Consejo Superior de Investigaciones Científicas, Spanish Council for Scientific Research), LSD (least significant difference).

as well as the *su1, su1 se1* and *sh2* sweetcorn donor populations, were assessed for agronomic performance against a number of hybrid controls (Table 1).

Assessments were made in 2003 and 2004 at Pontevedra in northwestern Spain (42° 24'N, 8° 38'W; altitude 220 m; average rainfall 1200 mm), and at Zaragoza (l41° 44'N, 0° 47'W; altitude 220 m; average rainfall 300 mm) in the Spanish interior. The site at Pontevedra has a sandy loam soil, while the soil at Zaragoza is a Xerosol. Fertilizer, herbicide and insecticide were applied according to practices that would facilitate optimum growth at each location. All plants were flood irrigated over the growing seasons: eight irrigations of about 50 mm each at Zaragoza, and one irrigation at Pontevedra, supplementing the low natural rainfall (average 180 mm during the growing seasons in both years at Zaragoza, and 520 mm at Pontevedra). All cultivation operations, fertilization and pest and weed control were carried out according to local practice. Treatments were arranged in a split-plot design with three replicates. The different population types (i.e., those with wild, *su1*, *su1 se1* and *sh2* genotypes) were assigned to different two-row plots [distance between rows 0.80 m, 0.21 m between plants (originally planted as two seeds; one plant later removed as necessary to leave one plant per sowing hole)]. The plots were thinned to 60,000 plants ha^{-1}. Harvesting was manual at both locations.

The traits recorded in 10 plants per replicate were: days to shedding pollen (from sowing to 50% of plants shedding pollen), days to silking (from sowing to 50% of plants silking), plant height (from the ground to the highest node), ear height (from the ground to ear node), stem lodging (percentage of broken stems below the ear), root lodging (percentage of plants leaning more than 45° from the vertical) (Ruiz de Galarreta and Alvarez, 2008), kernel moisture at harvest (g H_2O kg^{-1}) as a percentage of the kernel moisture content (measured using a digital moisture meter), yield (Mg ha^{-1} at 140 g kg^{-1} of H_2O), ear length (cm), ear rows (number of kernel rows per ear), ear health (rated on a 9-point scale taking into account the incidence of fungus and pests; 1 = high incidence, 9 = no damage), and ear shape (percentage of ears with adequate shape).

Analyses of variance (ANOVA) was performed involving the three field corn populations (Lazcano,

Table 1. Type of corn genotype and its origin

Mutant	Genotype	Origin
Wild	Lazcano	Northern Spain
	Oroso	Northwestern Spain
	Rastrojero	Eastern Spain
	(A427 × A556) A632	
su1	Lazcano *su1*	(Lazcano × Golden Early Market) F_2
	Oroso *su1*	(Oroso × Early Evergreen) F_2
	Rastrojero *su1*	(Rastrojero × Stowell's Evergreen) F_2
	Early Evergreen	Early selection of Stowell's Evergreen
	Golden Early Market	Golden Bantam × Early White Market
	Stowell's Evergreen	Menomony soft corn × Northern sugar corn
	I5125 × I453	
su1 se1	Lazcano *su1 se1*	[Lazcano × (IL731a × MIR225)] F_2
	Oroso *su1 se1*	[Oroso × (IL731a × MIR225)] F_2
	Rastrojero *su1 se1*	[Rastrojero × (IL778d × We10T)] F_2
	IL731a × IL779a	
	IL779a × We10T	
sh2	Lazcano *sh2*	(Lazcano × EPS16) F_2
	Oroso *sh2*	(Oroso × EPS18) F_2
	Rastrojero *sh2*	(Rastrojero × EPS18) F_2
	EPS16	Composite of hybrids Marvel and 710A (selection in early sowing)
	EPS18	Composite of hybrids Marvel and 710A (selection in late sowing)
	Marvel	Commercial hybrid

Table 2. Mean values of the mutant types across three populations derived from Oroso, Lazcano and Rastrojero, assessed over two years and at two locations

Genotype	Days to shedding pollen	Days to silking	Plant height (cm)	Ear height (cm)	Stem lodging (%)	Root lodging (%)	Yield (Mg ha^{-1})	Kernel moisture (g kg^{-1})	Ear length (cm)	Ear rows (no.)	Ear health[1]	Ear shape[2]
Wild	68.7 b	71.3	181.6 a	79.9 a	20.3	3.1 c	5.6 a	230 b	16.0	11.8 b	6.9 a	0.81
su1	69.1 b	72.0	170.5 a	65.5 b	26.8	6.8 a	4.3 b	271 a	15.3	12.4 b	6.1 b	0.67
su1 se1	73.4 a	75.8	163.6 ab	64.2 bc	29.0	5.9 ab	4.2 b	291 a	16.0	13.7 a	6.1 b	0.75
sh2	70.6 ab	73.2	148.4 b	56.8 c	21.0	3.9 bc	3.1 c	291 a	16.0	14.0 a	5.3 c	0.70
LSD	3.1	—	22.1	8.3	—	2.4	0.9	31	—	0.7	0.5	—

Within each column, means followed by the same letter do not differ significantly (P > 0.05). [1] Rated on a 9-point scale taking into account the incidence of fungi and pests (1 = high incidence, 9 = no damage). [2] 0 when ear shape is inadequate and 1 when ear shape is adequate.

Oroso, and Rastrojero) and the new *su1, su1 se1* and *sh2* populations derived from them. Each year-location combination was considered a different environment. Environments and replicates were considered random factors, and genotypes (wild, *su1, su1 se1* and *sh2*) and population types (defined by the field corn population present in their pedigrees, i.e., Oroso, Lazcano or Rastrojero) as fixed factors. ANOVA was then performed on the results for each population. Environments and replicates were considered random factors and genotypes fixed factors. Means were compared using the Fisher's protected least significant difference (LSD) method. All analyses were made using the PROC GLM program in the SAS v. 9.1 software package (SAS, 2000).

Results

ANOVA including the three field corn populations, and the new *su1, su1 se1*, and *sh2* sweetcorn populations derived from them, showed significant differences in terms of days to shedding pollen, plant and ear heights, root lodging, yield, kernel moisture, ear rows, and ear health (data not shown). The field corn populations showed a significantly lower kernel moisture content, a greater ear height, greater yield, and healthier ears than any of the new sweetcorn populations (Table 2). In addition, the new *sh2* populations produced significantly lower yields, their member plants were shorter, and they showed poorer ear health than any other corn type. The new *su1* and *su1 se1* populations generally showed intermediate characteristics.

Significant differences were seen among the population types in terms of days to shedding pollen and silking, stem and root lodging, kernel moisture, ear length, and ear rows (Table 3).

Significant differences were seen among *su1* populations in terms of days to shedding pollen and silking, plant and ear heights, stem lodging, kernel moisture, ear length, ear rows, and ear shape (Table 4). Significant differences among *su1 se1* populations were seen in terms of days to shedding pollen, and silking, plant and ear heights, root lodging, ear length, and ear rows. Finally, significant differences were seen among *sh2*

Table 3. Mean values for the three types of populations defined by their background field corn, assessed over two years and at two locations

Population	Days to shedding pollen	Days to silking	Plant height (cm)	Ear height (cm)	Stem lodging (%)	Root lodging (%)	Yield (Mg ha^{-1})	Kernel moisture (g kg^{-1})	Ear length (cm)	Ear rows (no.)	Ear health[1]	Ear shape[2]
Rastrojero	74.9 a	77.4 a	170.0	71.3	19.8 b	3.1 b	4.4	287	16.4 a	11.9 b	6.2	0.80
Oroso	69.5 b	72.4 b	168.5	70.6	27.1 a	7.2 a	4.3	268	16.4 a	13.8 a	6.3	0.81
Lazcano	66.9 c	69.5 c	159.6	58.0	25.9 a	4.4 b	4.2	257	14.8 b	13.2 a	5.8	0.59
LSD	1.7	1.7	—	—	4.5	2.0	—	12	1.0	0.7	—	—

Within each column, means followed by the same letter do not differ significantly (P > 0.05). [1] Rated on a 9-point scale taking into account the incidence of fungi and pests (1 = high incidence, 9 = no damage). [2] 0 when ear shape is inadequate and 1 when ear shape is adequate.

Table 4. Mean values for the variables measured in the different corn varieties, assessed over two years and at two locations

Population	Days to shedding pollen	Days to silking	Plant height (cm)	Ear height (cm)	Stem lodging (%)	Root lodging (%)	Yield (Mg ha^{-1})	Kernel moisture (g kg^{-1})	Ear length (cm)	Ear rows (no.)	Ear health[1]	Ear shape[2]
Field corn												
Rastrojero	73.3 a	75.8 a	162.6 c	72.5	12.7 b	1.9	5.9 b	241 ab	15.6 b	10.4 c	6.9	0.88
Oroso	67.8 ab	70.8 ab	179.3 bc	85.6	22.6 a	4.8	5.2 b	234 ab	16.4 b	11.5 bc	6.8	0.65
Lazcano	65.0 b	67.4 b	202.9 ab	81.6	25.7 a	2.7	5.6 b	216 b	15.9 b	13.4 ab	7.1	0.90
(A427×A556) A632	73.3 a	75.6 a	213.2 a	77.9	20.0 ab	1.7	8.2 a	257 a	18.4 a	15.4 a	7.6	1.00
su1												
Rastrojero *su1*	76.9 a	79.3 a	184.1 a	78.3 a	23.3 d	4.9	4.5	320 a	16.7 a	12.2 c	6.1	0.88 a
Oroso *su1*	70.4 c	73.8 b	188.4 a	74.5 a	31.4 bcd	9.9	4.5	267 bc	16.4 a	14.0 b	6.3	0.86 a
Lazcano *su1*	60.1 d	63.0 c	139.2 bc	43.9 bc	25.9 cd	5.5	4.0	225 de	12.9 c	11.1d	5.9	0.26 c
Early Evergreen	71.3 bc	74.1 b	167.9 ab	64.2 ab	36.4 abc	6.0	4.9	284 bc	15.7 ab	14.2 b	6.4	0.65 abc
Golden Early Market	57.0 e	59.9 d	129.8 c	36.4 c	44.2 a	3.1	2.6	214 e	9.7 d	9.3 e	5.4	0.30 c
Stowell's Evergreen	77.5 a	79.7 a	161.5 ab	59.5 ab	29.4 cd	4.8	3.6	301 ab	14.4 b	14.4 ab	5.8	0.40 bc
I5125×I453	72.3 b	74.8 b	162.6 ab	58.9 ab	42.1 ab	6.5	4.5	253 cd	16.5 a	15.2 a	6.0	0.79 ab
su1 se1												
Rastrojero *su1 se1*	76.2 bc	78.8 bc	182.3 a	75.1 a	27.7	3.3 b	4.1	296	17.4 a	13.0 c	6.2	0.81
Oroso *su1 se1*	71.3 d	73.9 d	163.2 ab	67.6 a	31.3	10.1 a	4.3	285	16.0 b	14.4 b	6.1	0.83
Lazcano *su1 se1*	72.7 cd	74.8 cd	145.2 b	49.8 b	27.8	4.4 b	4.3	291	14.7 c	13.7 bc	5.9	0.61
IL731a×IL779a	78.1 b	80.0 b	148.5 b	50.4 b	22.7	3.0 b	3.3	301	16.7 ab	15.6 a	7.1	0.72
IL779a×We10T	85.4 a	87.5 a	168.6 ab	52.5 b	33.8	3.6 b	3.5	350	17.5 a	13.6 bc	6.1	0.81
sh2												
Rastrojero *sh2*	73.3 a	75.6 a	150.9 a	59.3 a	15.5 c	2.3	3.1	289	15.9	12.1 b	5.6	0.64
Oroso *sh2*	68.5 c	71.3 c	143.3 a	54.8 a	23.1 bc	4.2	3.1	286	16.5	15.3 a	5.9	0.88
Lazcano *sh2*	70.0 b	72.8 b	150.9 a	56.5 a	24.3 bc	5.1	3.0	299	15.6	14.7 a	4.5	0.60
EPS16	69.7 bc	72.4 bc	126.5 c	40.0 b	34.7 a	3.8	3.0	295	15.3	14.6 a	5.2	0.39
EPS18	69.6 bc	72.3 bc	128.8 bc	40.9 b	30.9 ab	4.7	3.1	296	15.3	14.9 a	5.0	0.54
Marvel	69.0 bc	71.3 c	129.3 bc	38.4 b	30.4 ab	3.6	3.3	298	15.0	15.2 a	5.4	0.67

Within each endosperm type and column, means followed by the same letter do not differ significantly ($P > 0.05$). [1] Rated on a 9-point scale taking into account the incidence of fungi and pests (1 = high incidence, 9 = no damage). [2] 0 when ear shape is inadequate and 1 when ear shape is adequate.

genotypes in terms of days to shedding pollen and silking, plant and ear heights, stem lodging, and ear rows (Table 4).

The lack of differences among the different populations with respect to yield could be the consequence, at least in part, of the significant effect of the interaction *environment × genotype*. ANOVA performed separately for each location showed significant differences among genotypes in terms of yield. Among the new *su1, su1 se1*, and *sh2* populations, those derived from Oroso and Rastrojero had the largest yields in Pontevedra and Zaragoza respectively (Table 5). In Pontevedra, Oroso *su1 se1* and *su1* provided significantly larger yield than the hybrid controls, while Oroso *sh2* and the Marvel hybrid produced equal yields. In Zaragoza, the new sweetcorn populations derived from Rastrojero surpassed those derived from Oroso and Lazcano in terms of yield (Table 5), but in general performed less well than the hybrid controls (which are reasonably well adapted to the conditions of the Spanish interior).

Discussion

Backcrossing sweetcorn populations with their corresponding, original field corn populations may improve their adaptation to different regional conditions, although grain quality/yield might be compromised (Tracy, 2001). Further, unfavourable characteristics such as the development of small plants, low yields or

Table 5. Mean yields of the corn varieties at Pontevedra and Zaragoza over the two years of the experiment

Genotype type	Genotype	Yield (Mg ha^{-1})	
		Pontevedra	Zaragoza
su1	Rastrojero *su1*	4.9 b	4.0 b
	Oroso *su1*	6.0 a	3.0 f
	Lazcano *su1*	4.3 b	3.7 c
	Early Evergreen	6.5 a	3.3 e
	Golden Early Market	1.8 c	3.4 d
	Stowell's Evergreen	4.3 b	2.8 g
	I5125 × I453	4.6 b	4.5 a
su1 se1	Rastrojero *su1 se1*	4.5 ab	3.6 b
	Oroso *su1 se1*	5.5 a	3.2 d
	Lazcano *su1 se1*	5.3 a	3.3 c
	IL731a × IL779a	1.8 c	4.0 a
	IL779a × We10T	3.5 b	3.6 b
sh2	Rastrojero *sh2*	2.8 a	3.3 b
	Oroso *sh2*	3.5 a	2.8 e
	Lazcano *sh2*	3.0 a	2.9 d
	EPS16	2.9 a	3.2 c
	EPS18	3.0 a	3.2 c
	Marvel	3.1 a	3.6 a

Within each genotype and column, means followed by the same letter do not differ significantly ($P > 0.05$).

high kernel moisture might arise through such genetic modification. In the future, efforts should be made to improve characteristics such as ear length and ear rows, which are currently far from commercial standards.

Rastrojero and the new sweetcorn populations derived from it flowered significantly later and had fewer ear rows than those derived from Lazcano and Oroso (Table 3). Rastrojero may therefore seem less suitable than the other two field corn populations as a donor of genes for adaptation to the conditions of northern Spain. Earliness is a particular requirement of this area where the growing period is very short. Earliness is not essential in the Spanish interior, but the number of ear rows shown by the new sweetcorn populations derived from Rastrojero needs to be increased if inbred lines are to be competitive. For the fresh corn market, ears should have at least 16 straight rows (Tracy, 2001).

Lazcano *sh2* flowered later, had a higher kernel moisture and fewer ear rows than expected. In the *sh2* background, the different performance of Lazcano compared to the other two field corn populations cannot be explained by mutant sweetcorn *sh2* alleles since all three populations were crossed to similar *sh2* donors.

This study shows that the differences between the new sweetcorn populations derived from Oroso, Lazcano or Rastrojero were stable, and differed from the original field corn populations. The new Lazcano-based populations performed slightly worse than the original Lazcano field corn, while the new Oroso-based populations showed improved performance over the original Oroso population. Revilla *et al.* (unpublished), studying different crosses between field corn and *su1* populations, found that the differences among them were quite stable and barely affected by the genotypes from which they were derived. In other work involving crosses between field corn inbreds belonging to different genetic backgrounds, and *su1* corn inbreds representing the variability of sweetcorn in temperate areas, Revilla *et al.* (2006) showed that the fitness of *su1* depended on the sweet × field corn inbred combination.

With respect to the agronomic traits evaluated in the present work, the new sweetcorn populations derived from Rastrojero, Oroso and Lazcano did not show unfavourable values compared to the hybrid controls, except for ear rows (Table 4). The necessary breeding for table quality should be undertaken jointly with breeding for increasing the ear row number.

The data in Table 5 agreed with those of a previous study in which Oroso was identified as a suitable donor for improving the yield and yield components of *su1* hybrids (Cartea *et al.*, 1996a). Oroso can also supply favourable alleles for improving *su1 se1* and *sh2* varieties. Hopefully, Oroso *su1* will show improved survival under cold conditions compared to *su1* controls; Revilla *et al.* (1998) indicates that Oroso can improve the ability of some *su1* inbreds to germinate and survive under cold conditions. Rastrojero might be able to supply a trait missing in these hybrids: resistance to ear damage by corn borers (Malvar *et al.*, 2004).

In conclusion, the ability of field corn populations to improve sweetcorn was not greatly affected by the sweetcorn donor used. The field corn population chosen as the donor for improving sweetcorn must depend on the growing conditions in mind: Oroso appears to be more suitable for sweetcorn for northern Spain, while populations derived from Rastrojero seem to be more suitable for the Spanish interior. The potential of other field corn populations should be explored.

Acknowledgments

This research was funded by the Spanish Ministry of Education and Science (Project AGL2007-64218-AGR), the *Xunta de Galicia* (PGIDIT04PXI40302PN), and the *Excma. Diputación Provincial de Pontevedra*. V.M. Rodriguez acknowledges a fellowship from the Spanish Ministry of Education and Science.

References

CARTEA M.E., MALVAR R.A., REVILLA P., ORDÁS A., 1996a. Identification of field corn populations to improve sweet corn for Atlantic European conditions. Crop Sci 36, 1506-1512.

CARTEA M.E., MALVAR R.A., REVILLA P., ORDÁS A., 1996b. Improvement of early vigor and adaptation of sweet corn to the European Atlantic coast with open-pollinated field corn populations. Maydica 41, 119-125.

CORDERO A., MALVAR R.A., BUTRÓN A., REVILLA P., VELASCO P., ORDÁS A., 1998. Population dynamics and life-cycle of corn borers in south Atlantic European coast. Maydica 43, 5-12.

DAVIS D.W., BREWBAKER J.L., KAUKIS K., 1988. Registration of NE-HY-13A and NE-HY-13B complementary populations of *sugary* maize germplasm. Crop Sci 28, 381.

GUO B.Z., ZHANG Z.J., LI R.G., WIDSTROM N.W., SNOOK M.E., LYNCH R.E., PLAISTED D., 2001. Restriction fragment length polymorphism markers associated with silk maysin, antibiosis to corn earworm (Lepidoptera: Noctuidae) larvae, in a dent and sweet corn cross. J Econ Entomol 94, 564-571.

GUO B.Z., ZHANG Z.J., BUTRÓN A., WIDSTROM N.W., SNOOK M.E., LYNCH R.E., PLAISTED D., 2004. Lost *P1* allele in *sh2* sweet corn: quantitative effects of *P1* and *a1* genes on concentration of maysin, apimaysin, methoxymaysin, and chlorogenic acid in maize silk. J Econ Entomol 97, 2117-2126.

JOYCE M.S., DAVIS D.W., 1995. Transmittability of ear resistance to European corn borer in sweet corn testcrosses and resistance stability. J Amer Soc Hort Sci 120, 107-111.

MALVAR R.A., CARTEA M.E., REVILLA P., ORDÁS A., ÁLVAREZ A., MANSILLA J.P., 1993. Sources of resistance to pink stem borer and European corn borer in maize. Maydica 38, 313-319.

MALVAR R.A., CARTEA M.E., REVILLA P., ORDÁS A., 1997. Identification of field corn inbreds adapted to Europe to improve agronomic performance of sweet corn inbreds. Crop Sci 37, 1134-1141.

MALVAR R.A., BUTRÓN A., ÁLVAREZ A., ORDÁS B., SOENGAS P., REVILLA P., ORDÁS A., 2004. Evaluation of the European Union maize landrace core collection for resistance to *Sesamia nonagrioides* (Lepidoptera: Noctuidae) and *Ostrinia nubilalis* (Lepidoptera: Crambidae). J Econ Entomol 97, 628-634.

MALVAR R.A., REVILLA P., BUTRÓN A., GOUESNARD B., BOYAT A., SOENGAS P., ÁLVAREZ A., ORDÁS A., 2005. Performance of crosses among French and Spanish maize populations across environments. Crop Sci 45, 1052-1057.

ORDÁS A., REVILLA P., MALVAR R.A., CARTEA M.E., 1994. Development of sweet corn hybrids adapted to the environmental conditions of the northwest of Spain. Maydica 39, 171-175.

REVILLA P., MALVAR R.A., CARTEA M.E., ORDÁS A., 1998. Identifying open-pollinated populations of field corn as sources of cold tolerance for improving sweet corn. Euphytica 101, 239-247.

REVILLA P., VELASCO P., VALES M.I., MALVAR R.A., ORDÁS A., 2000. Cultivar heterosis between sweet and Spanish field corn. J Amer Soc Hort Sci 125, 684-688.

REVILLA P., MALVAR R.A., RODRÍGUEZ V.M., BUTRÓN A., ORDÁS B., ORDÁS A., 2006. Variation of *sugary1* and *shrunken2* frequency in different maize genetic backgrounds. Plant Breed 125, 478-481.

RUIZ DE GALARRETA J.I., ÁLVAREZ A., 2008. Divergent mass selection for different flowering times in a Spanish maize population. Span J Agric Res 6, 56-60.

SAS, 2000. The SAS System. SAS Online Doc. HTML Format Version eight. SAS Institute Inc, Cary, North Carolina.

TRACY W.F., 1990. Potential contributions of field corn germplasm for the improvement of sweet corn. Crop Sci 30, 1041-1045.

TRACY W.F., 2001. Sweet corn. In: Speciality corns (Hallauer A.R., ed), 2nd ed, CRC Press, Boca Raton, Florida. pp. 155-197.

TREAT C.L., TRACY W.F., 1993. Contributions of dent corn germplasm to stalk and root quality in sweet corn. J Amer Soc Hort Sci 118, 885-889.

VELASCO P., MALVAR R.A., REVILLA P., BUTRÓN A., ORDÁS A., 1999. Ear resistance of sweet corn populations to pink stem borer and European corn borer. J Econ Entomol 92,732-739.

VELASCO P., REVILLA P., MALVAR R.A., BUTRÓN A., ORDÁS A., 2002. Resistance to corn borer in crosses between sweet and field corn populations. J Amer Soc Hort Sci 127, 689-692.