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Description of high quality maize single-crosses developed in Argentina

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When completing the process of development, testing and selection of new germplasm specifically designed for commercial use, it is necessary to account with a precise description of the materials. In this sense, the morphological trait descriptors recommended by the IPGRI and UPOV are powerful tools. Accurate morphological descriptions are also indispensable to define the proprietary rights of the new varieties obtained through genetic improvement and facilitate their protection or inscription through utilitarian patents. On November 2007, a three-replicate completely randomized block designed field trial was sown at a density of 71,500 plants/ha in the location of Castelar within the province of Buenos Aires (34º40´00´´S, 58º40´00´´W; 28masl). Twenty-seven high quality single-cross hybrids, generically termed HC, were testcrossed with the dent commercial hybrid ACA 2000 and evaluated through a combination of qualitative and quantitative morphological trait descriptors during the 2007/08 growing season. According to their endosperm characteristics, the materials can be grouped as follows: **I)** *Modified starch (WAXY)*, **II)** *High quality protein (HQP)* and **III)** *Double recessive o2 wx (DR).* Six quantitative morphological traits were used: a) plant height (PH), b) ear insertion height (EIH), c) stem diameter (SD), d) number of total leaves (NL), e) number of leaves above the uppermost ear (NLUE), and f) number of ears per plant (EP). Five qualitative trait descriptors were also considered: g) leaf colour (LC), h) leaf position in relation to the stem (LP), i) sheath pubescence (SP), j) leaf pubescence (LPU) and k) lamina edge curls (LEC). The evaluation was carried out on the basis of individual plants on ten plants per plot. Routine statistical analysis was done according to the classical methodology proposed by Falconer. The information in Table 1 summarizes the evaluation of the quantitative traits of the single-crosses tested in Castelar and reveals their relative behaviour through genotypic means. The maximum PH occurred at silking and the values ranged from 187.6 cm (HC26) to 266.2 cm (HC22). The arrangement of the productive ears in relation to plant height is extremely important, as a lower EIH contributes to a reduction in the tendency to lodging. For that reason, it is preferable that the ears are within the middle third of the PH and this was the case in all the single-crosses tested, as on average, the relationship of EIH/PH was 0.44, ranging from 0.36 to 0.52. Stalk diameter (SD) ranged from 1.4 cm (HC8) to 2.6 cm (HC22), which suggests a satisfactory strength of the stems. On average, the number of total leaves (NL) varied from 11.6 (HC8 and HC16) to 17.6 (HC22), of which 4.4 (HC16) to 7.6 (HC22) were placed above the uppermost ear (NLUE). The data included in Table 1 show that sixteen single-crosses had a PH between the tester (197.0 cm) and the environment mean for the trait (218.4 cm); four hybrids had ears in a lower position than the tester´s EIH (86.6 cm); and fifteen single-crosses showed the same or lower NL than the tester ACA 2000 (13.8). These results permitted us to infer that these single-crosses denote a modern architecture which, according to Sangoi et al. (Field Crops Res. 9(1):39-51, 2002), is expressed through a shorter PH, lower EIH, lower NL and more erect leaves. These features result in less interference between adjoining plants, with a better distribution of the light within the canopy, and so, a greater tolerance to high crop density. The hybrid HC22 obtained by crossing an early inbred derived from an Argentine race of maize from the northwestern region by a strongly inbred *wx o2* line produced the tallest plants with the highest number of total leaves.

Table 1. Average of morphological traits evaluated in single-crosses tested in Castelar during the 2007/08 growing season.

Hybrid	Type	PH	EIH	SD	NL	NLUE	EP
HC5	HQP	208.2	89.0	2.2	15.6	6.6	1.6
HC25	HQP	205.2	91.6	1.9	14.2	6.0	1.4
HC26	HQP	187.6	75.8	1.8	13.8	5.8	1.2
HC27	HQP	202.6	88.0	1.6	14.2	5.2	1.2
HC28	HQP	221.6	89.2	2.0	14.0	5.8	1.0
HC29	HQP	217.0	100.4	1.8	13.0	5.8	1.4
HC30	HQP	200.6	78.2	2.2	13.0	6.0	1.4
HC14	DR	205.6	91.0	1.9	13.2	5.0	1.2
HC15	DR	207.4	96.8	1.6	13.2	5.2	1.2
HC8	DR	219.4	80.2	1.4	11.6	4.6	1.4
HC16	DR	209.6	97.4	1.9	11.6	4.4	2.0
HC17	DR	241.2	111.6	2.2	14.6	6.0	1.8
HC18	DR	248.8	127.0	2.1	14.6	5.2	1.4
HC19	DR	208.0	99.8	2.1	13.0	5.0	1.2
HC20	DR	214.8	101.0	2.3	13.8	4.8	1.6
HC21	DR	253.0	108.0	2.5	15.2	6.8	1.8
HC22	DR	266.2	132.2	2.6	17.6	7.6	2.0
HC23	DR	209.2	99.0	2.4	12.6	4.6	1.8
HC24	DR	205.8	80.2	2.3	15.0	7.6	1.4
HC1	WAXY	210.6	97.6	2.0	12.8	5.2	1.2
HC31	WAXY	214.8	97.2	1.9	12.8	4.8	1.4
HC32	WAXY	220.4	103.4	1.7	14.0	5.0	1.2
HC33	WAXY	224.4	108.2	2.1	13.6	5.0	1.4
HC34	WAXY	208.0	90.5	1.7	14.0	6.0	1.6
HC35	WAXY	224.0	103.6	2.3	14.2	5.6	1.6
HC36	WAXY	245.0	114.8	2.5	13.0	5.0	1.8
HC37	WAXY	218.2	107.2	2.2	13.2	5.2	1.6
ACA2000	TESTER	197.0	86.6	2.1	13.8	5.8	1.4
Environment avg.		218.9	98.4	2.0	13.8	5.5	1.5
s.d.		19.1	13.4	0.3	1.2	0.8	0.3
CV%		8.7	13.6	14.8	8.7	14.7	17.9
Min.		187.6	75.8	1.4	11.6	4.4	1.0
Max.		266.2	132.2	2.6	17.6	7.6	2.0
LSD 0,01		3.3	10.1	0.2	0.4	0.2	0.2

Although prolificity relies on the genotype, the quality of the environmental conditions around flowering determine the ultimate number of ears per plant. Prolificity is a very important trait for yield determination, as usually only one or two productive ears per plant occur and then individual plant production is slightly elastic (Pedrol et al., IDIA XXI 6(4):141-146, 2004). Most of the commercial hybrids grown in Argentina have 1.0 to 1.5 ears per plant, whilst eleven out of all the single-crosses tested bear more than 1.5 productive ears per plant. Since maize yield decreases when it is grown at high densities due to a marked increase in the number of individuals that undergo ear and kernel abortion, the high prolificity level found in these materials will result in better tolerance to high crop densities.

Significant differences were found for PH (*Student´s t= 2.78*; *p≤ 0.05*) and EIH (*Student´s t= 2.43*; *p≤ 0.05*) among HQP and DR hybrids. Significant differences were also detected for NLUE (*Student´s t= 2.65*; *p≤ 0.05*) among HQP and DR genotypes, and very significant differences for EIH (*Student´s t= 3.27*; *p≤ 0.01*) among HQP and Waxy materials. No significant differences were found among the different groups of single-crosses for the rest of the morphological traits studied. The ANOVA shows highly significant differences among single-crosses for all the parametric variables measured (Table 2).

Table 2. ANOVA results (mid-squares) for the morphological traits considered in single-crosses evaluated during 2007/08 in Castelar.

Variation source	PH	EIH	SD	NL	NLUE	EP
Hybrid	708.2**	469.9**	0.18**	3.19**	1.21**	0.13**
Replicate	2.16 ns	9.88 ns	0.0006 ns	0.04 ns	0.0001 ns	0.0001 ns

Tables 3, 4 and 5 summarize all of the information collected in relation to the qualitative traits considered in each single-cross. 59.3% of the single-crosses evaluated have their leaves arranged in normal position in relation to the stems, similar to the dent tester ACA 2000. 77.8% of the materials showed abundant sheath pubescence, and in 52.9% of the single-crosses abundant leaf pubescence was observed.

Table 3. Qualitative traits evaluated in HQP single-crosses during 2007/08.

Hybrid	LC	LP	SP	LPU	LEC
3146	dark green	semierect	abundant	abundant	weak
3150a	dark green	semierect	medium	medium	weak
3237	middle green	normal	abundant	medium	weak
3332´´´	middle green	semierect	abundant	medium	weak
3368´´	dark green	semierect	abundant	abundant	weak
3396	dark green	normal	abundant	abundant	weak
3446a	middle green	normal	medium	medium	weak
ACA2000	middle green	normal	medium	medium	strong

Table 4. Qualitative traits evaluated in DR single-crosses during 2007/08.

Hybrid	LC	LP	SP	LPU	LEC
HC14	dark green	normal	abundant	light	weak
HC15	dark green	semierect	abundant	abundant	weak
HC8	dark green	semierect	abundant	light	weak
HC16	dark green	normal	abundant	abundant	strong
HC17	dark green	erect	abundant	abundant	weak
HC18	dark green	normal	abundant	abundant	strong
HC19	middle green	normal	abundant	abundant	weak
HC20	dark green	normal	abundant	abundant	weak
HC21	dark green	semierect	abundant	abundant	strong
HC22	dark green	normal	abundant	abundant	strong
HC23	dark green	normal	abundant	abundant	strong
HC24	dark green	normal	abundant	abundant	weak
ACA2000	verde med	normal	medium	medium	strong

Table 5. Qualitative traits evaluated in waxy single-crosses during 2007/08.

Hybrid	LC	LP	SP	LPU	LEC
HC1	dark green	normal	abundant	light	strong
HC31	dark green	semierect	light	medium	weak
HC32	dark green	normal	abundant	abundant	strong
HC33	dark green	normal	abundant	abundant	weak
HC34	dark green	normal	light	light	weak
HC35	dark green	normal	abundant	abundant	weak
HC36	dark green	semierect	light	light	strong
HC37	dark green	semierect	medium	medium	strong
ACA2000	middle green	normal	medium	medium	strong

Days and heat unit requirements to flowering of quality maize single-crosses developed in Argentina

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It is well known that the number of days necessary to complete each phenological phase varies among environments according to changes in relative humidity, air and soil temperature, solar radiation and photoperiod. Most of the disparities in the number of days to flowering and maturity may be explained on the basis of the diverse temperatures recorded among years and locations. The influence of temperature on the length of the different stages of maize development was first mentioned by Lebenhauer in 1914. As temperature is the main factor responsible for the interannual variations observed in the length of growth stages and development, several authors created models to calculate the thermal-time (TT) through linear, exponential or more complex equations.

In November 2007, a three-replicate completely randomized block designed field trial was sown at a density of 71,500 plants/ha at Castelar, in the province of Buenos Aires (34º40´00´´S, 58º40´00´´W; 28masl). Twenty-seven high quality single-crosses, generically named HC, were testcrossed with the dent commercial hybrid ACA 2000 and evaluated last summer (2007/08) for number of days to tasseling (DT), days to silking (DS) and thermal-time, measured as growing-degree days to tasseling (GDDT) and silking (GDDS). The linear method proposed by Gilmore and Rogers in 1958, also known as *modified residual method 10/30*, was used because of its high precision and predictive reliance. This method is based on the amount of energy represented by the sum of degrees centigrade that a plant needs to complete a determined phenological phase and likewise the complete cycle. According to their endosperm characteristics, the materials can be grouped as follows: **I)** *Modified starch (WAXY)*, **II)** *High quality protein (HQP)* and **III)** *Double recessive-o2wx (DR).* The necessary calculations were performed on the basis of information provided by the Climatology Institute of INTA Castelar obtained through field measurements recorded by an automatic station placed in the location.

Because of the poor correlation between the number of days to flowering and plant growth and development it is not possible to get acceptable results when the genotypes are simply classified by their evolutive cycle, although this may be useful as a guideline. Anyway, a well-fitted classification must be based on the proper measurement of the components of the physical environment that promote variations in the number of days necessary to reach a particular phase.

Table 1 summarizes the information obtained for cycle length to flowering evaluated in the single-cross hybrids tested. The average values show that 96.3% of the genotypes evaluated reached silking (R_1; Ritchie & Hanway´s scale, 1993) at 63 days or less from emergence (V_E), with a thermal requirement of ≤733.2 GDD, calculated according to Gilmore & Rogers. These single-crosses showed a shorter evolutive cycle than the tester ACA 2000, and considering their heat unit requirements to silking, belong to FAO classes 100, 200 and 300-400 (Derieux and Bonhomme, Maydica 35:41-46, 1990). They could be subjectively rated as *ultraprecocious* or *precocious.* The DR hybrids HC15 and HC8 reached silking in 55 days and 631.5 GDD, so they could be classified as FAO 100, or *ultraprecocious.* Silking also occurs at 56-57 days from emergence (650.1-670.1 GDD) in the single-crosses HC14, HC18, HC23, HC24, HC26, HC27, HC31 and HC34, which can also be included in the same class FAO 100.

59.3% of the genotypes reached R_1 between 58 and 70 days from emergence, with a 687.8 to 827.8 GDD, so they correspond to classes FAO 200, FAO 300-400, FAO 500 and FAO 600 and can be classiied as *precocious* or *full-season* in relation to their evolutive cycle length. The longest evolutive cycle was observed in the hybrid HC22 (70 days; 771.3 GDD), which was obtained by crossing an early inbred derived from an Argentine maize race