Yield evaluation of high quality single-crosses in Argentina

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Maize yield is closely related to the number of kernels produced per unit area, which is determined during flowering, and thus a decrease in the aboveground plant growth rate at this phase, promoted for example by shading or diminution of the incident radiation, incites important yield losses. Consequently, the growth rate of the crop at flowering (associated with radiation, temperature, water and nutrient supply) is a reference of the crop capacity to yield kernels. Whilst the number of fertile ears per plant is defined at flowering, the final number of kernels per ear is determined after silking and is associated with the physiological condition of the crop during flowering. If environment or growing conditions are good, a greater number of kernels per unit area can be developed. On the other hand, the morphogenetic processes that end in the determination of kernel rows per ear and spikelets per row are quite insensitive to environment and crop management variations. The number of kernel rows is primarily determined by the plant genotype. So, the number of kernels per unit area relies on the number of kernels per ear, the number of ears per plant and the number of plants per unit area (crop density). Likewise, the average kernel weight results from the combined effect of two coinciding factors: length of filling period and filling rate.

In November 2007, a completely randomized block designed field trial with three replicates 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). On the basis of their endosperm characteristics, the hybrids may be grouped as: **I)** *Modified starch (WAXY)*, **II)** *High quality protein (HQP)* and **III)** *Double recessive-o2 wx (DR).* Twenty-seven high quality single-cross hybrids, generically named HC, were testcrossed with the dent commercial hybrid ACA 2000 and evaluated during the summer of 2007/08 according to ear and yield traits. The traits evaluated were *ear length* (EL), *ear diameter* (ED), *number of kernel rows* (KR), *kernel number per row* (KNR), *average ear weight* EW), *average kernel weight per ear* (KWE) and *cob percentage* (%C). Yield estimation was performed as follows: ears from each plot were hand-harvested and only ten representative ears were selected and weighed. After shelling, moisture percentage was recorded using a portable humidimeter (Protimeter model Grainmaster 900) and kernel weight per ear was measured and averaged to obtain KWE. The **minimum potential yield** (MINPY) was calculated as KWE x 71,500 ears/ha, assuming that only one ear is borne by each plant. The **maximum potential yield** (MAXPY) was estimated using the following equation: KWE x crop density x ears per plant (prolificacy).

The average values for ear and yield traits of each quality single-cross hybrid are summarized in Table 1. 29.6% of the materials tested yielded long ears (20 to 25 cm) similar to the tester ACA 2000, and 70.4% yielded middle sized ears (15 to 19.9 cm). The average EW was 185.2 g, including 18.0% cob. The DR hybrid HC17 yielded significantly heavier ears than the tester before and after shelling. 55.6% of the genotypes evaluated showed a higher KWE than the environmental average. Significant differences (*Student´s t*) among the different groups of single-cross hybrids (HQP, DR and waxy) were not found for any of the descriptors considered (see Table 2). The ANOVA detected very significant differences among hybrids for all ear and yield traits measured (see Table 3).

Table 1. Average values for ear and yield traits measured in single-crosses in Castelar during 2007/08.

Hybrid	Type	EL	ED	KR	KNR	EW	KWE	%C
HC5	HQP	19.4	4.1	14.0	41.3	157.0	122.2	22.4
HC25	HQP	17.3	4.2	12.0	43.5	137.5	113.5	17.4
HC26	HQP	18.1	4.1	14.0	35.2	151.0	123.2	18.5
HC27	HQP	19.6	4.0	14.0	39.8	195.4	158.6	18.8
HC28	HQP	18.7	4.3	15.3	40.8	187.5	156.7	16.3
HC29	HQP	21.0	4.3	16.0	37.5	230.5	196.0	15.0
HC30	HQP	20.0	4.4	18.0	49.0	212.0	164.0	22.6
HC14	DR	21.5	4.5	18.0	42.0	231.0	187.5	18.8
HC15	DR	18.0	4.2	15.0	34.0	145.0	119.0	17.9
HC8	DR	20.8	4.3	15.6	42.8	192.4	152.2	20.4
HC16	DR	20.5	4.2	13.0	43.0	191.5	152.5	20.2
HC17	DR	20,5	3.9	13.7	46.5	169.8	146.5	13.9
HC18	DR	17.7	4.4	16.4	36.2	184.4	155.0	16.4
HC19	DR	19.0	4.3	16.0	39.5	190.5	159.3	16.1
HC20	DR	17.7	4.2	16.7	38.0	173.7	149.3	14.1
HC21	DR	19.1	4.1	16.0	41.1	193.1	156.1	19.1
HC22	DR	19.8	4.2	16.0	40.3	212.7	173.3	18.3
HC23	DR	16.5	3.9	13.5	36.3	135.5	111.0	18.2
HC24	DR	17.8	4.2	15.7	37.8	161.7	134.5	17.1
HC1	WAXY	18.9	4.5	16.8	39.0	192.2	161.4	15.9
HC31	WAXY	20.2	4.0	14.4	40.6	190.6	152.8	20.1
HC32	WAXY	18.6	4.3	15.0	34.0	167.0	140.5	15.6
HC33	WAXY	17.0	4.3	17.2	37.6	162.0	132.8	17.4
HC34	WAXY	17.5	4.2	17.3	34.0	153.0	126.0	17.6
HC35	WAXY	17.7	4.3	16.5	35.2	160.7	133.1	16.9
HC36	WAXY	18.6	4.5	17.0	38.3	189.0	160.3	15.2
HC37	WAXY	21.6	4.3	16.5	43.8	217.3	166.0	23.2
ACA2000	TESTER	20.6	4.8	16.8	42.0	261.8	227.6	13.1
Environment avg.		19.1	4.3	15.7	39.6	185.2	151.7	18.0
s.d.		1.6	0.2	1.6	3.9	35.8	30.3	2.6
CV%		8.6	5.4	9.9	9.8	19.3	20.0	14.2
Min.		14.9	3.9	12.0	30.5	133.5	100.5	13.1
Max.		21.6	4.9	18.5	49.0	301.8	246.8	23.2
LSD 0.01		1.1	0.3	0.8	2.6	11.3	6.6	0.9

Table 2. Significance t test (Student´s) for ear traits among the different groups of hybrids.

Contrast	EL	ED	KR	KNR	EW	KWE	%C
QPM vs DR	1.08 ns	0.00 ns	0.39 ns	0.52 ns	1.00 ns	1.07 ns	0.81 ns
QPM vs Wx	0.26 ns	1.25 ns	1.30 ns	0.82 ns	0.32 ns	0.45 ns	0.91 ns
DR vs Wx	0.88 ns	1.05 ns	1.37 ns	1.94 ns	0.87 ns	0.93 ns	0.29 ns

ns= non significant differences

Table 3. ANOVA results for ear and yield traits in single-cross hybrids tested in 2007/08.

Variation source	EL	ED	KR	KNR	EW	KWE	%C
Hybrid	4.98**	0.08**	4.71**	26.91**	2411.39**	1758.15**	12.03**
Replicate	0.08 ns	0.05 ns	0.06 ns	0.05 ns	0.01 ns	1.70 ns	0.0006 ns

ns= non significant; **= significant at 0,01%.

The MINPY and MAXPY of all single-cross combinations tested at Castelar are included in Table 4. The tester ACA 2000, also used in previous years and field trials, expressed a MINPY of 16,273 kg/ha and a MAXPY of 22,782 kg/ha. The general average of the trial was 10,848 kg/ha for MINPY and 15,955 kg/ha for MAXPY. It was observed that the methodology used to estimate the MAXPY produced an overestimation of around 47.1 % in relation to MINPY. In fact, when the plant bears more than one ear, the second one does not have the same size or weight as the older and this promotes the deviation observed. Fifteen genotypes expressed a higher MINPY than the environmental average registered for the trait. It must be remarked that 50% of the DR hybrids, as well as 57.1% of the HQP single-crosses and 62.5% of the waxy genotypes, exceeded the environmental average for MINPY. Considering only MINPY, the hybrid with the lowest yield was HC23, which yielded 51.2% less than the tester and a significant

26.8% less than the trial's combined average. The most common statistics for the MINPY and MAXPY of each group of single-cross hybrids are shown in Table 5. No significant differences (*Student´s t*) could be detected between HQP, DR and waxy hybrids for MINPY and MAXPY (see Table 6).

Table 4. Average yield for single-cross hybrids evaluated at Castelar (2007/2008).

Hybrid	Type	MINPY	MAXPY
HC5	HQP	8,737	13,979
HC25	HQP	8,115	11,361
HC26	HQP	8,809	10,571
HC27	HQP	11,340	13,608
HC28	HQP	11,204	11,204
HC29	HQP	14,014	19,620
HC30	HQP	11,726	16,416
HC14	DR	13,406	16,087
HC15	DR	8,509	10,211
HC8	DR	8,801	12,321
HC16	DR	10,904	21,808
HC17	DR	10,475	18,855
HC18	DR	11,083	15,516
HC19	DR	11,390	13,668
HC20	DR	10,675	17,080
HC21	DR	11,162	20,092
HC22	DR	12,391	24,782
HC23	DR	7,937	14,287
HC24	DR	9,617	13,464
HC1	WAXY	11,540	13,848
HC31	WAXY	10,925	15,295
HC32	WAXY	10,046	12,055
HC33	WAXY	9,495	13,293
HC34	WAXY	9,009	14,414
HC35	WAXY	12,820	20,512
HC36	WAXY	11,461	20,630
HC37	WAXY	11,869	18,990
ACA2000	TESTER	16,273	22,782
Environment avg.		10,848	15,955
s.d.		1,900.5	3,959.5
CV%		17.5	24.8
Min.		7,937	10,211
Max.		16,273	24,782
LSD 0,01		1,593.3	263.9

Table 5. Usual statistics for potential yield of the hybrids tested during 2007/08.

	HQP		DR		WAXY	
Statistic	MINPY	MAXPY	MINPY	MAXPY	MINPY	MAXPY
Average	10,123.6	13,705.3	11,079.2	16,968,7	10,895.6	16,129.7
s.d.	2,141.4	3,673.7	2,212.0	4,132.0	1,288.9	3,404.5
variance	4,585,615.8	13,496,303.9	4,893,031.7	1,707,325.8	1,661,339.0	11,590,372.6
CV%	21.2	26.8	20.0	24.4	11.8	21.1
min	7,186.0	8,623,2	7,937.0	10,210.8	9,009,0	12,055.2
max	14,014.0	19,619.6	17,646.0	24,782.0	12,820.0	20,629.8

Table 6. Significance t test (Student´s) for potential yield among different groups of hybrids.

Contrast	MINPY	MAXPY
QPM vs DR	0.107 ns	2.06 ns
QPM vs Wx	0.93 ns	1.45 ns
DR vs Wx	0.27 ns	0.55 ns

In Argentina, although the nationwide average maize yield is about 5,861 kg/ha, it is not uncommon to obtain 13,000 kg/ha without irrigation. The high yields recorded are due to the incorporation of biotechnology tools during recent years, as well as the use of new crop management practices, that together favour maximum expression of the genetic potential. The quality single-crosses tested at Castelar during 2007/08 exceeded the average national yield by about 85%, when considering the MINPY combined average.

Chemical composition of inbreds and single-crosses developed in Argentina

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The physiochemical constitution of the maize kernel not only defines its nutritional value but also its ability to be used in transformation industries. Kernel quality depends on external factors influenced by the environment, weather, soils, temperature, and rainfall, as well as the management technology used during crop growth and development aimed at obtaining economically sustainable yields. Inherent characteristics of the kernel, such as the genetic background, undoubtedly influence chemical quality and may be modified to improve chemical constitution and so achieve new germplasm with excellent attributes in relation to industrial uses and nutritional value.

Last summer (2007/08), at Castelar, in the province of Buenos Aires (34º40´00´´S, 58º40´00´´W; 28masl), a complete randomized block design field trial with three replicates, which included twenty-seven single-cross hybrids and a tester (ACA2000), was sown at a density of 71,500 plants/ha. Based on their endosperm attributes, the materials, generically named HC, can be grouped as: **I)** *Modified starch (WAXY)*, **II)** *High quality protein (HQP)* and **III)** *Double recessive-o2 wx (DR)*. The materials were evaluated using chemical descriptors, which are better than the morphological ones, in the sense that they are not significantly influenced by the environment. Thus, it is feasible to compare descriptions taken in different locations and years if properly standardized methods are used. The kernels of thirteen inbreds kept in a cold room were also analyzed. The chemical composition of the hybrids and inbreds was determined using an infrared spectrophotometer model Foss Infratec 1241 Grain Analyzer to quantify protein content (%P), starch content (%S), oil content (%O) and kernel density (KD) through a non-destructive assay. Two 60 g samples of each genotype were analyzed and the results were averaged to obtain the final values. In addition, the oil content of the inbreds was also determined through Soxhlet (AOAC, 2000). The simple correlation coefficient (*Pearson*) among the different chemical components was estimated.

Table 1 summarizes all the information relative to the chemical composition of each single-cross hybrid determined via NIRT. Maize is one of the main energy sources of animal dietary rations. On average, oil content is relatively low and usually ranges from 3% to 5%. Bromatological analysis of the maize most commonly produced worldwide indicates that oil content is around 3.0% to 3.5%. According to data published by ILSI (Source = *ILSI Crop Composition Database version 2.0; www.cropcomposition.org*) maize oil content throughout the world varies from 1.74% to 5.56%. If only maize produced in Argentina is considered, the oil content is about 2.68% to 5.56%. According to the previous data, a maize kernel with ≥ 5.6% oil could be considered a high oil content genotype (HOC). Around 40.7% of the HC single-crosses tested at Castelar showed 5.6% to 6.3% oil content. Four hybrids equaled, or even slightly exceeded, the tester´s average oil content.

In general, maize protein content varies greatly depending on the genotype, production environment, sampling and calculation factors used to convert N into protein. According to ILSI, average protein content of maize kernels produced in Argentina is about