Development and evaluation of promising popcorn hybrids developed from local and exotic germplasm

ABSTRACT

Popcorn is considered as one of the oldest forms of field corn and mainly used as a snacke food. In the time being, no local popcorn registered hybrids are available in Egypt and all country needs are imported hybrids. Therefore, there is a dire need to develop local popcorn hybrids. Using local and exotic germplasm, eighty-six promising yellow F_1- hybrids were developed at Nubaria research station (30^0 54' N, 29^0 30' E) maize program, Field Crops Research Institute, ARC, Egypt. These hybrids were split into two groups (A and B); each one along with two exotic hybrid checks were evaluated under irrigation in 2019 at two environmentally different locations, one in north of Egypt and the other one in south of Egypt. Purpose of this investigation was to evaluate these promising hybrids for grain yield, number of days to mid-silk, plant height, resistance to late wilt disease and two quality traits i.e. popping volume and percentage of unpopped kernels. Randomized complete block design with 4 replications was used. All technical recommendations for maize production were applied. Highly significant differences were found among tested hybrids for all studied traits except number of wilted plants in trial A. Seven hybrids were selected, 5 from trial A and two from trial B. Hybrids # 11, 12, 17, 20 and 28 from trial A and 15, 33 from trial B. Results revealed that germplasm of Serbian origin was more beneficial to the national popcorn breeding program than other germplasm sources since most selected hybrids were of Serbian origin. Further evaluation of selected hybrids across multiple different locations is necessary before submission of selected hybrids to Variety Registration Committee.

Key words: Popcorn, popping volume, percentage of unpopped kernels, exotic germplasm.

INTRODUCTION

Popcorn (*Zea mays* L. *everta*) is a worldwide nutritious snack food. It is considered as a special type of flint maize that puffs up when heated. Evolution studies showed that ruins of popcorn ears were found in many caves in Mexico and other Latin American countries dating back to more than 5600 years (**Kusche, 1977**). Primitive types of popcorn were grown by native Indians in south, central and North America. Its cultivation and consumption is increasing in Egypt and worldwide. Egypt imports more than 20,000 tons of popcorn annually mainly from Argentine and Brazil, all of yellow seed (**Ministry of Commerce, Egypt, 2018**). Therefore,

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Egypt started an intensive popcorn breeding program for more than ten years to develop local popcorn hybrids having good yield potential as well as good quality attributes. It was necessary from the beginning to make use of available local germplasm in addition to exotic germplasm taking into account that local germplasm has the privilege of adaptability to local growing environment and resistance to the main prevailing maize diseases. Although yield is a very important trait in selecting popcorn germplasm, quality traits such as popping volume, flavor of popped flakes, color, and percentage of unpopped kernels in addition to disease free kernels are considered very important selection criteria (**Alexander, 1988; Sweely *et al*, 2013; Erdal *et al*, 2018; Khalifa, 2019**). Among popcorn quality attributes, popping volume is considered the most important one. It is affected, to a large extent, by kernel moisture which affects the rate and extent of vapor pressure built up in kernel starch granules (**Hoseney *et al*, 1983**). Many studies were conducted to determine optimal kernel moisture content for induction of maximum popping volume; most of them stated that, in general, optimal kernel moisture ranges from 13-14.5%. In addition, lower or higher kernel moisture content can result in lower popping volume (**Khalifa, 2019**). It was found also that seed size, type of cultivar and degree of kernel damage caused during seed processing have an effect on popping volume and percentage of unpopped kernels (**Sprague, 1988**). Studies revealed also that popping volume was significantly higher in hybrid cultivars compared to open pollinated ones; in addition, hybrid cultivars always have percentages of unpopped kernels lower than open pollinated ones (**Sakin *et al*, 2005**). High percentage of unpopped kernels is considered defective attribute because the unpopped kernels do not contribute to popping volume (**Sing *et al*, 1997**). Regarding yield potentiality of popcorn cultivars, it was found that, not only the genetic constitution of a cultivar that affects yield but also all agronomic practices that are applied to the crop from planting to harvest (**Babic and Pajic, 1992**). There is always a controversy issue between farmers from one side and consumers from the other side, since farmers prefer cultivars with high yield while consumers like cultivars that produce high popping volume and good flavor.

The main objectives of the present study were to evaluate 86 F_1 popcorn hybrids for, 1) yield potentiality under different growing environments; 2) assessment of hybrids for two important popcorn quality traits i.e.; popping volume and percentage of unpopped kernels and 3) resistance to late wilt (stalk rot) disease.

MATERIALS AND METHODS

Due to lake of Egyptian popcorn hybrids in the local market and the large amounts of popcorn that are imported annually, a comprehensive popcorn breeding program was established at Nubaria agriculture research station, National Maize Program, Field Crops Research Institute, ARC, Egypt, for more than 10 years. Due to insufficient local genetic variability for popcorn, it was necessary to involve exotic germplasm in the ongoing breeding program. Argentinean, Brazilian and Serbian popcorn germplasm in addition to local germplasm were used to establish popcorn breeding program which aims to develop inbred lines with satisfactory grain yield and good quality traits; these inbreds can be further used for constitution of new popcorn hybrids. As a result of this breeding program, many yellow inbred lines with different genetic background were developed. Out of them, 36 inbreds (13 local, 18 Serbian, 4 Brazilian and one Argentinean) were used to generate 86 F_1-hybrids. These hybrids were split into two groups; each one was evaluated in a separate trial in 2019 at two environmentally different locations. Trial "A" which involved 37 yellow F_1–hybrids all of Serbian background was conducted at Nubaria (30^0 54' N, 29^0 3o' E, north of Egypt) and Mallawy (27^0 69' N, 30^0 82' E, south of Egypt) agricultural research stations. Trial "B" involved 49 yellow F1- hybrids was conducted at Nubaria and Sids (28^0 91' N, 30^0 95' E, south of Egypt) agricultural research stations. Two exotic commercial hybrid checks were used in both trials. Purpose of these trials was to assess grain yield expressed in t/ha^{-1} at 15.5% kernel moisture, number of days from planting to mid-silking (d), plant height (cm), number of plants infected with late wilt disease (wilted plants) and two quality traits i.e. popping volume and percentage of unpopped kernels. Popping traits were measured on a representative kernel sample from each hybrid. Popping volume was determined by placing 30 g of kernels in hot air popping equipment then popping volume was measured. Percentage of unpopped kernels was measured by dividing on the number of unpopped kernels after popping completion of each sample by total number of kernels in each sample expressed as percentage. Numbers of days to 50% silking and plant height were measured at the proper time of plant growth. Number of wilted plants plot^{-1} was scored at 35 days from mid-silking of each hybrid. Grain yield was harvested on plot basis (kg plot^{-1}) and then converted to ton/hectare (t/ha^{-1}) with grain moisture of 15.5%.Randomized complete block design with 4 replications was used. Plot size was one row of 6 m long, rows were 80 cm apart and hills were spaced 25 cm along rows. All technical recommendations for maize production were applied. Data analyses for separate locations and combined over locations were performed according to **Steel and Torrie (1980**) while testing homogeneity of error mean squares was achieved according to the method described by **Snedecor and Cochran (1967)**.

RESULTS AND DISCUSION

Analysis of variance

Combined analyses of variance over the two testing locations for trials A and B are shown in Tables 1 and 2. Results showed that differences among tested hybrids for all agronomic and quality traits in addition to disease resistance were highly significant except late wilt resistance in trial A indicating a wide genetic diversity among these promising hybrids since they were derived from different genetic backgrounds (local, Serbian, Brazilian and Argentinean). Differences among locations in both trials were highly significant for all studied traits except for days to 50% silking in trial A and plant height in trial B indicating the presence of clear variation between each of the two locations in climatic conditions. Interaction of hybrids x locations was highly significant in both trials for all studied traits except for number of wilted plants in trial A and plant height in trial B indicating that hybrids differed in their order of performance in each of the two locations.

Days to 50% silking

Differences among hybrids in number of days to 50% silking were highly significant in both trials (Tables 1and 2) indicating genetic variability among tested hybrids as they were developed from different genetic sources. Number of days to mid-silking ranged from 51-61 days in trial A with an average of 58.9 days (Table 3) and from 56-63 days in trial B with an average of 59.2 days (Table 4).The two hybrid checks were nearly in the same flowering range of tested hybrids.

Plant height

Differences in plant height among tested hybrids in both trials were highly significant as shown in Tables 1 and 2. Plant height of hybrids in trial A ranged from 197-231 cm with an average of 212.1cm (Table 3). In trial B, plant height ranged from 150-254 cm with an average of 195.8 cm (Table 4). It was obvious that average plant height of hybrids developed from Serbian germplasm (trial A) were taller than those developed from other germplasm sources in trial B. In addition, plant height of both checks, specially check 2, was shorter with smaller ears compared to the tested hybrids which resulted in low yield.

Number of wilted plants

Differences among tested hybrids for resistance to late wilt disease (wilted plants) were highly significant only in trial B (Table 2). Since late wilt pathogen does not normally survive in alkaline calcarious soils of Nubaria research station, decision on level of late wilt resistance of tested hybrids was based on disease scores taken at Mallawy research station (clay soils) in trial A and disease scores at Sids research station (clay soils) in trial B. Number of wilted plants plot^{-1} in trial A (Table 3) ranged from 0-10 plants with an average of 2.4 plants plot^{-1}, while in trial B it ranged from 0-22 plants plot^{-1} with an average of 5.1 plants plot^{-1} (Table. 4). Hybrids with 0-1 plant plot^{-1} are considered late wilt resistant while that having 3-4 plants plot^{-1} is considered moderately resistant. Both checks showed resistance to late wilt. Disease free kernels are considered an important quality trait (**Erdal *et al*, 2018; Khalifa, 2019**).

Grain yield

Highly significant differences among tested hybrids for grain yield were obtained (Tables 1 and 2). Grain yield in trial A ranged from 3.15 – 6.18 t ha^{-1} with an average of 4.21 t ha^{-1} while in trial B, the range was from 1.98 – 5.81 t ha^{-1} with an average of 4.23 t ha^{-1}. Average grain yield of hybrids involved in both trials was 36.4% higher than yield performance of the best check (3.11 t ha^{-1}). In trial A, hybrid 11 (NPC1006AxNPC1017A) produced the highest grain yield (6.18 t ha^{-1}) while in trial B, hybrid 13 (NPC1019A x Loc 5-3) was the highest producing hybrid (5.81 t ha^{-1}). Both top producing hybrids in trial A and B had 98% and 102% more grain yield than the highest check in each trial, respectively. Nonadaptability of exotic hybrid checks may be the reason for weak yield performance. **Sakin *et al* (2005)** evaluated 14 single and three-way crosses and reported average grain yield of 3.07- 5.52 t ha^{-1}.**OZ and Kapar** (**2011**) evaluated 18 popcorn hybrids and obtained grain yield ranged from 3.53 - 5.39 t ha^{-1}. In a study by **Erdal *et al*, 2018**, 119 F1 popcorn hybrids were tested; they reported grain yield ranged from 2.27- 6.33 t ha^{-1}. **Mosa *et al*, 2019** evaluated 39 promising popcorn hybrids and reported grain yield ranged from 3.9 – 5.8 t ha^{-1}. **Olakojo *et al* (2019)** evaluated 18 popcorn inbred lines and recorded grain yield ranged from 1.0 - 2.61 t ha^{-1}. **Broccoli and Burak** (**2004**) evaluated 14 popcorn hybrids and stated that the relationship between grain yield and expansion (popping) volume was negative.

Table1(Trial A): Mean squares for days to 50% silking, plant height, grain yield and late wilt disease for 39 popcorn hybrids evaluated across Nubaria and Mallawy research stations in 2019.

SOV	d f	50% silking	Plant height	Grain yield	Late wilt
Locations (loc)	1	5.65	7173.13**	310.74**	453.12**
Replications/loc.	6	2.38*	504.08	65.30**	69.21**
Entries (Ent)	38	7.91**	1007.27**	42.63**	9.83
Loc×Ent	38	6.80**	953.22**	12.68**	9.83
Error	228	1.15	136.64**	2.95	6.90

*, ** significant at 0.05 and 0.01 probability levels, respectively.

Table2 (Trial B): Mean squares for days to 50% silking, plant height, grain yield and late wilt disease For 51 popcorn hybrids evaluated across Nubaria and Sids research stations in 2019.

SOV	d f	50% silking	Plant height	Grain yield	Late wilt
Locations (loc)	1	66.727**	8.82	34.64**	2500.24**
Replications/loc.	6	2.691	438.56*	14.60**	43.70
Entries (Ent)	50	22.197**	4365.85**	35.34**	47.88**
Loc×Ent	50	10.513**	395.45	18.12**	47.86**
Error	300	1.510	187.64	2.69	23.55

*, ** significant at 0.05 and 0.01 probability levels, respectively.

QUALITY TRAITS

Two popcorn quality traits were taken into consideration in the present study, popping volume and percentage of unpopped kernels. To evaluate hybrids involved in this study for both traits, a representative sample of 30 g from each hybrid was taken for measuring of both traits.

Popping volume

Among popcorn quality attributes, popping volume is considered the most important criteria for popcorn evaluation (**Hoseney *et al*, 1983).** Differences among tested hybrids for popping volume were highly significant (Tables 1 and 2). Mean performance for both trials is presented in Tables 3 and 4. In trial A, popping volume ranged from 270-1100 c^3 30 g^{-1} with an average of 756 c^3 30 g^{-1} while in trial B, range was from 480-1170 c^3 30 g^{-1} with an average of 747 c^3 30 g^{-1}. Highest popping volume in trial A (1100 c^3 30 g^{-1}) was obtained from hybrid 28 (NBC1009A x NBC1017A) while in trial B, hybrid 22 (NBC1019A x Br. 13-1) produced the highest popping volume (1170 c^3 30 g^{-1}). The best check hybrid for popping volume in both trials was check 2 (930 c^3 30 g^{-1}). Seven hybrids exceeded the best check hybrid in trial A and 2 hybrids in trial B. In the present study, hybrids with popping volume of 750 c^3 30 g^{-1} or more were selcted conditioning that they meet requirements for other desirable popcorn traits. **Sakin *et al* (2005)** evaluated 14 singe and three- way crosses and reported a range of 34.7- 46.5 c^3 g^{-1} (1041-1392

c^3 30 g^{-1}), they found also that single crosses gave higher values than three-way crosses. **OZ and Kapar (2011)** evaluate 18 popcorn hybrids and reported significant differences among tested hybrids; in addition, they indicated that genetically diversified genotypes normally give variable popping volume values. **Junior *et al* (2013)** reported popping volume average of 31ml g^{-1} (930 c^3 30 g^{-1}), while **Oliveira (2019)** in a study to evaluate different popcorn genotypes stated popping expansion ranged from 11.8 - 56.0 ml g^{-1} (354 - 1680 c^3 30 g^{-1}). **Mosa *et al* (2019)** evaluated 39 hybrids and reported popping volume ranged from 20.7-35.5 ml g^{-1} (621 – 1065 c^3 30 g^{-1}). **Olakojo *et al* (2019)** evaluated 18 popcorn inbred lines; they reported a range of 73.3 - 3080 cm^3/ sample which is considered very wide range for popping volume.

Percentage of unpopped kernels

Percentage of unpopped kernels is considered another important popcorn quality trait. Unpopped kernels are considered defective attribute because they do not contribute to popping volume (**Sing *et al*, 1997).** Differences among tested hybrids for this trait were highly significant (tables 1, 2). Mean performance values of this trait for both trials are presented in Tables 3 and 4. In trial A, range for unpopped kernels was from 0- 31.4% with an average of 14.9% while for trial B, range was from 5.6 - 50.5% with an average of 19.6%. Percentage of unpopped kernels was 25% for check 2. In trial A, 30 hybrids out of 37 had better values than best check while in trial B, 33 hybrids out of 49 had better values than the same check. Obtained values for this trait are relatively high. This may be due to low kernel moisture content at testing (10–12%) or/and damage occurred to kernels during seed processing. Genetic constitution of hybrids may be also another reason. **Allred-Coyle (2000), Oz and Kapar (2011) and Khalifa (2019**) stated that popping properties including popping volume and unpopped kernels are affected by kernel moisture content and popping method. **Song *et al* (1991)** stated that differences among genotypes and kernel size affect percentage of unpopped kernels. **Sakin *et al* (2005)** reported unpopped kernels ranged from 3.3-6.3% while **Oz and Kapar** scored values ranged from 1.31-11.9%. **Mosa *et al* (2019)** evaluated 39 hybrids and reported unpopped kernels ranged from 2.53-8.13%. For present study, hybrids with values of about 20% or less were considered satisfactory and were selected conditioning that they meet requirements of other popcorn favorable traits.

CONCLUSION

Certain levels for important popcorn traits were set as criteria in selection of favorable hybrids in this investigation as follow: grain yield, a minimum of 4.3 t ha^{-1}; number of wilted plants, a maximum of 4 plants $plot^{-1}$; popping volume; a minimum of 750 c^3 30 g^{-1} and percentage of unpopped kernels, a maximum of about 20%. Based on these criteria and other field observations, 7 hybrids were selected, 5 from trial A and 2 from trial B.

Trial A: Hybrids # 11(NPC1006xNPC1017A), 12 (NPC1007AxNPC1017A), 17 (NPC1009BxNPC1017A), 20 (NPC1010xNPC1017A) and 28 (NPC1015AxNPC1020B), all developed from Serbian germplasm.

Trial B: Hybrids #15 (NPC1019Ax Loc. 6-2) and 33 (NPC1020BxArg.8-1). Parents of these two hybrids were developed from local, Argentinean and Serbian germplasm.

Results showed that Serbian germplasm was more useful for the Egyptian popcorn breeding program. Selected hybrids should undergo further testing across more different locations before submission to Variety Registration Committee. Also, since percentage of unpopped kernels of most tested hybrids was relatively high, more efforts should be directed towards improving germplasm material for popping trait and as a result percentage of unpopped kernels will be reduced. Also, caution during seed processing and selection of appropriate popping method is recommended.

Table 3 (Trial A): Mean performance of 39 popcorn hybrids for six traits evaluated across two locations in 2019.

No.	Pedigree	50% silking (d)	Plant height (cm)	Wilted plants (no)	Grain yield (t ha^{-1})	Popping volume (c^{3} 30 g^{-1})	Unpopped kernels (%)
1	NPC 1001A × NPC 1019A	53	200	2	3.81	680	7.1
2	NPC 1001C × NPC 1017A	59	221	1	4.94	760	6.9
3	NPC 1001C × NPC 1019A	59	204	3	3.63	960	23.8
4	NPC 1002 × NPC 1019A	58	205	10	3.81	810	20.1
5	NPC 1002 × NPC 1020B	60	207	4	3.35	820	12.4
6	NPC 1002 × NPC 1021A	59	210	4	3.71	820	13.2
7	NPC 1004A × NPC 1017A	59	224	3	5.10	770	6.0
8	NPC 1004A × NPC 1019A	58	205	2	4.25	660	17.1
9	NPC 1004A × NPC 1020B	59	208	2	3.76	570	17.6
10	NPC 1005A × NPC 1017A	58	225	2	5.03	270	26.2
11	NPC 1006A × NPC 1017A	59	237	1	6.18	800	4.4
12	NPC 1007A × NPC 1017A	59	226	1	5.24	400	20.1
13	NPC 1007A × NPC 1019A	58	203	0	4.23	700	31.4
14	NPC 1007A × NPC 1021B	58	201	4	3.92	700	25.8

15	NPC 1007B × NPC 1017A	58	222	0	4.21	1000	16.0
16	NPC 1009A × NPC 1017A	61	221	0	4.83	750	26.7
17	NPC 1009B × NPC 1017A	58	215	0	5.12	1000	4.9
18	NPC 1009B × NPC 1019A	59	208	1	4.17	490	27.0
19	NPC 1009B × NPC 1020B	59	213	2	3.44	530	10.7
20	NPC 1010 × NPC 1017A	58	230	4	5.21	830	20.4
21	NPC 1010 × NPC 1019A	58	204	4	3.62	800	22.6
22	NPC 1011 × NPC 1019A	57	207	6	3.15	900	1.9
23	NPC 1012 × NPC 1017A	51	221	6	5.24	930	15.1
24	NPC 1013 × NPC 1017A	60	231	1	4.73	750	21.7
25	NPC 1009A × NPC 1019A	58	211	0	4.25	780	18.9
26	NPC 1009A × NPC 1020B	60	200	3	3.45	660	4.4
27	NPC 1009A × NPC 1017A	61	230	6	4.83	860	19.8
28	NPC 1009A × NPC 1017A	60	223	1	5.16	1100	19.5
29	NPC 1009A × NPC 1019A	59	208	4	3.63	950	0
30	NPC 1009A × NPC 1015A	59	213	0	3.81	1000	30.8
31	NPC 1009A × NPC 1020B	58	206	0	3.54	900	26.4
32	NPC 1009A × NPC 1020B	58	209	4	3.83	1000	7.4
33	NPC 1009A × NPC 1017A	58	212	0	4.49	640	12.9
34	NPC 1009A × NPC 1021A	59	215	2	4.37	560	14.5
35	NPC 1009A × NPC 1020B	58	201	3	3.52	780	21.6
36	NPC 1009A × NPC 1015A	58	197	2	5.09	550	15.8
37	NPC 1009A × NPC 1019A	59	206	2	4.26	500	6.6
38	Check – 1	61	191	1	2.95	900	28.6
39	Check – 2	60	104	0	3.11	930	25.0
	CV %	2.38	5.51	18.30	13.50	–	–
	LSD (0.05)	1.96	11.52	0.59	1.69	–	–

Table 4 (Trial B): Mean performance of 51 popcorn hybrids for six traits evaluated across two locations in 2019.

No.	Pedigree	50% silking (d)	Plant height (cm)	Wilted plants (no)	Grain yield (t ha^{-1})	Popping volume (c^3 30 g^{-1})	Unpopped kernels (%)
1	Nb1017A×Loc.5-2	60	214	1	3.89	800	12.4
2	Loc.5-2×NPC1017A	60	222	3	4.17	730	38.8
3	NPC1017A Loc.6-1	63	254	1	4.63	480	6.8
4	Loc.6-1×NPC1017A	60	238	11	5.55	700	23.3
5	NPC1017A Loc.6-2	63	239	7	5.19	480	28.1
6	Loc.6-2×NPC1017A	63	234	6	3.59	600	13.7
7	NPC1017A× Loc.7-3	59	225	2	4.47	790	26.7
8	Loc.7-3×NPC1017A	61	238	1	4.06	700	12.7
9	NPC1019A Loc.1-1	57	192	3	4.65	800	31.9
10	NPC1019A× Loc.1-2	58	184	9	4.34	1000	18.1
11	NPC1019A×Loc.2-1	56	179	12	4.19	700	13.1

No.	Pedigree	50% silking (d)	Plant height (cm)	Wilted plants (no)	Grain yield (t ha^{-1})	Popping volume (c^3 30 g^{-1})	Unpopped kernels (%)
12	NPC1019A× Loc.5-1	57	193	5	5.08	820	25.7
13	NPC1019A× Loc.5-3	58	198	7	5.82	800	26.5
14	Loc.5-3×NPC1019A	60	189	3	4.64	750	33.3
15	NPC1019A× Loc.6-2	60	208	2	5.07	770	11.3
16	NPC1019A× Loc.7-3	60	201	3	3.77	680	30.0
17	Loc.7-3×NPC1019A	60	191	8	5.05	860	24.4
18	NPC1019A× Loc.7-4	57	201	1	4.51	650	5.6
19	Loc.7-4×NPC1019A	57	201	5	4.42	550	22.6
20	NPC1019A×Br.12-2	59	184	3	4.97	840	28.0
21	Br.12-2×NPC1019A	58	182	2	4.37	900	31.2
22	NPC1019A×Br.13-1	58	189	22	4.15	1170	10.1
23	NPC1019A×Br.13-2	60	198	0	4.47	900	25.8
24	NPC1020B× Loc.1-2	57	164	11	4.29	550	14.6
25	NPC1020B× Loc.2-1	57	173	12	4.40	800	7.9
26	NPC1020B× Loc.3-1	58	190	2	3.94	705	17.1
27	NPC1020B× Loc.3-2	59	183	0	3.88	710	25.0
28	NPC1020B× Loc.6-1	61	214	5	4.64	750	24.1
29	NPC1020B× Loc.7-1	59	193	4	4.07	710	19.2
30	Loc.7-1×NPC1020B	58	194	5	4.37	670	18.2
31	NPC1020B× Loc.7-3	60	194	0	4.22	750	10.1
32	NPC1020B×Br.12-1	60	174	0	3.73	900	26.3
33	NPC1020B×Arg.8-1	59	183	0	4.57	830	17.1
34	NPC1021A× Loc.1-1	57	174	15	4.77	740	9.2
35	NPC1021A× Loc.1-2	59	177	14	3.72	600	20.5
36	NPC1021C× Loc.7-4	59	193	9	5.00	640	10.8
37	Loc.7-4×NPC1021C	59	198	4	3.75	900	9.1
38	NPC1021C×Br.13-2	59	191	4	3.43	930	21.1
39	Loc.5-1×NPC1017A	60	222	1	4.62	740	35.0
40	Loc.5-2×NPC1019A	60	193	2	3.36	700	9.8
41	Loc.5-3×NPC1017A	63	216	2	4.24	840	10.1
42	Loc.5-3×NPC1021A	59	182	9	4.60	850	17.7
43	Loc.7-1×NPC1017A	60	208	4	4.40	700	14.8
44	Loc.7-3×NPC1021A	60	204	2	4.40	710	35.1
45	Loc.7-4×NPC1017A	60	219	4	4.59	700	9.9
46	Br.12-2×NPC1021A	59	176	1	4.10	820	34.6
47	Br.13-1×NPC1017A	59	209	16	4.39	600	7.6
48	Br.31-1×NPC1020B	61	150	6	1.98	860	50.5
49	Br.13-1×NPC2021A	58	172	2	3.61	870	40.2

No.	Pedigree	50% silking (d)	Plant height (cm)	Wilted plants (no)	Grain yield (t ha^{-1})	Popping volume (c^3 30 g^{-1})	Unpopped kernels (%)
50	Check – 1	62	143	0	2.77	900	28.6
51	Check – 2	61	146	0	2.23	930	25.0
	CV %	2.07	7.00	4.80	12.88	–	–
	LSD (0.05)	1.21	13.48	4.72	1.62	–	–

Table 5: Selected hybrids from trial A and trial B

Hybrid No.	Trial	Pedigree	Popping volume (c^3 30 g^{-1})	Unpopped kernels (%)	Grain yield (t ha^{-1})	Wilted plants/plot (no)
11	**A**	**NPC1006×NPC1017A#**	**800**	**4.4**	**6.17**	**1**
12	**A**	**NPC1007A×NPC1017A#**	**900**	**20.1**	**5.23**	**1**
17	**A**	**NPC1009B×NPC1017A#**	**1000**	**4.9**	**5.13**	**0**
20	**A**	**NPC1015A×NPC1020B#**	**830**	**2o.4**	**5.20**	**4**
28	**A**	**NPC1015AxNPC1020B#**	**1100**	**19.5**	**5.16**	**1**
15	**B**	**NPC1019AxLoc. 6-2***	**770**	**11.3**	**5.07**	**2**
33	**B**	**NPC1020B×Arg. 8-1****	**830**	**17.1**	**4.57**	**0**

#: Serbian germplasm
*Loc.: local germplasm

******: Argentinean germplasm

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