SYNTHETIC POPULATIONS – SOURCES OF PRECOCITY IN MAIZE BREEDING

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***Abstract**: In the maize breeding the local landraces could presented a special interest, evenly like useful gene sources for adapting capacity and for physiological and agronomical traits and for valuable quality. The exploration of these resources can be possible only through complexes studies and measures which will determine the biodiversity keeping and the sustainable use of this. The creation of maize hybrids which, among other features, to be early it is a big concern of breeder teams. In northern and pre-montane areas, due to thermal lowered resources, precocity is indispensable to achieving maturity. The objectives of this research were: -to explore the phenotypic variability existing for early maturity in a large range of maize local and synthetic populations; -to identify genotypes that could be interesting in heritability of short growing season. It was noticed some maize local populations which can be used like initial genetic material for breeding of precocity, such as: Avram Iancu, Bereni, Corbu 189-84, Cerbal, Dumbravita, Desesti, Mara1, Mara2, Eremitu, Giulesti, Satu Lung, Satu Mare, Tarna Mare, Vlaha, and synthetic populations Tu Syn. 6, Tu Syn Mara1, Tu Syn Gutin, Tu SRR 2I(5D), Myn Syn AS-G. The determination of the genetic value of seven synthetic consisted in their crossing with four testers (inbred lines): two flint inbred lines (TD 233 and CO 255) and two dent inbred lines (TC 184 and TC 209). The test crosses and their parental forms were evaluated in four environmental conditions: two years 2009 and 2010 and two locations Turda and Targu-Mures respectively, for both per se and test cross performances. The highest values of additive effects for grain dry matter content were recorded at: Tu Syn Mara ($\hat{g}_n$ = +1.80), Tu SRR 5D (2I) (1) ($\hat{g}_n$ = +0.62) and Tu Syn 1 ($\hat{g}_n$ = +0.45). Therefore, Tu Syn Mara, Tu SRR 5D (2I)(1) and Tu Syn 1 produced hybrids with the most early maturity.*

***Key words:** maize germplasm, precocity,* GCA, *general combining ability; SCA, specific combining ability*

INTRODUCION

The maturity ratings of maize (*Zea mays* L.) varieties usually grown in Transilvania (central and north-western Romania) rang from FAO 100 to 400. Late material normally shows too much moisture at normal harvesting time and then presents problems with storage. This severely limits the scope of the germplasm that can be used in a breeding program located in this area. Selection for early flowering and low moisture at harvest adapts later material to areas that require earlier maize (GIESBRECHT, 1960; ORDAS, 1988; HAWBAKER et al., 1996; GONZALEZ et al., 1997; TROYER, 2001; TALLER and BERNARDO, 2004; SHRANG et al., 2006)

Choosing reliable maize varieties that are early maturing is essential for maize growers in the areas with limited heat treatment, but that doesn't mean losing out on yield. These genotypes, in effect, require a shorter growing season than later maturing ones.

Flint x dent maize hybrids are commonly planted in the early corn growing regions of Europe (northern and the Atlantic Coast of Europe). Evaluation of the early maize germplasm is important for the development of new commercial hybrids adapted to cooler summer regions (REVILLA et al., 1999; GONZALEZ et al., 2000).

Local populations to improve maize may be of particular interest, especially as gene sources for resilience and some agronomic properties (MURARIU et al., 2010). The most valuable populations have undergone extensive works of inbreding and selection for the creation of inbred lines, hybrids that provide it with a better language capacity to adapt in comparison with foreign hybrids. Partial results confirmed expectations (SARCA, 2004).

Local populations of maize are distinguished by a great capacity of adaptability and physiological properties specific to certain areas, and a production capacity and outstanding quality. Each population bears the imprint of the environment in which it was formed (TROYER, 2001). Romanian local populations are very different, as are the environmental conditions in our country. Local populations are the result of a long process of evolution, under the action of factors that determine evolution, possessing assets particularly valuable that the inbred lines can transfer these traits of hybrids, which highlight the poignancy of appropriating adaptability (CRISTEA, 1978). Development of such hybrids is fully possible, whereas in local populations of corn in our country there are genetic factors responsible for the manifestation of these assets. For efficient use of local germoplasm, it must be inventoried and stored valuable genes. Characterizing maize genetic resources and understanding the structure of the diversity they encompass should lead to enhanced utilization for the improvement of this crop. Vegetative traits can be included as descriptors for describing and characterizing maize germplasm (ORTIZ et al., 2008; ORTIZ et al., 2009).

The obtaining of maize hybrids which, among other features, to be early too, represents an important concern of the maize breeders. Early maize must grow faster and mature sooner under cooler conditions than later maize, to produce mature kernel in a shorter season. Early maize grows faster, particularly in the spring when the weather is cool. European northern flint varieties, as sources of early germplasm, grow extremely fast in seedling and in juvenile plant stages, flowers sooner and reaches physiological maturity sooner than later maize (HAS, 2001). Maturity zones are based on accumulated GDUs during the frost-free period: GDU = [Max temp ($\leq 30^0$C) + Min temp ($\geq 10^0$C)]/2 - 10^0C.

In northern and premontane areas, due to limited thermal resources, precocity is indispensable to achieving maturity (CRISTEA et al., 1986, 1986a; CABULEA, 1987). In southern areas, precocity is used to mitigate the moisture stress of late drought by sowing earlier and early use of earlier hybrids (CIOCAZANU et al., 1998; BAGIU, 1999).

Some of sources of early germplasm might be local and synthetic populations breeding by recurrent selection (CRISTEA et al, 1978; GULEA, 2011; HAS et al., 2011).

The inheritance of maturity in maize is governed quantitatively. In general, the genes act in an additive manner, as if many genes with small and equal effects were involved; heterosis affects flowering time about 10% (TROYER, 1994, 2001).

Knowledge about germplasm diversity and genetic relationships among breeding materials could be an invaluable aid in maize improvement strategies, maize germplasm could be easily managed, using recurrent selection method (LAVERGE et al., 1991; MOHAMMADI and PRASANNA, 2003; TALLER and BERNARDO, 2004).

Turda - Romania maize genotypes have great phenotypic and genetic variability, consisting of local populations, varieties, synthetics. Genotype germplasm sources range from very early to late and from dent to flint grain characteristics (HAS et al., 2006).

The objectives of this research were:

- -to explore the phenotypic variability existing for early maturity in a large range of maize local and synthetic populations;
- -to identify genotypes that could be interesting in heritability of short growing season.

MATERIALS AND METHODS

Maize samples

I. Phenotypic variability

Maize samples used in this study consisted of 264 accessions from "TURDA" germplasm collection, among which there were 208 local populations (landraces), collected in different Romanian regions (Transylvania and Moldavia); 56 synthetics/composites among which 30 synthetics created at ARDS Turda and 26 synthetics acquired from different countries (Spain, Italy, Germany, University of Minnesota, University of Pennsylvania).

All local populations (landraces) and synthetics are currently used in the framework of breeding and genetic program at the Agricultural Research Station, Turda – Romania (ARS Turda). The studied genotypes differed by germplasm source, grain type, maturity classification (very early, early, intermediate and late) and grain appearance and colour.

Experimental designs**.** These genotypes were grown at the Agricultural Research and Development Station Turda – Romania (Transylvania region), in 2009. Each group of genotypes was grown in separate but adjacent trials. Experimental plots were 2-rows, 5 m - long, with 0.7 m spacing between two rows without replications. Plant densities averaged 60 000 plants/hectare in each trial.

I.Statistical analysis of *per se* variability. All stages of growing season were performed in duplicate, and the mean value was analyzed statistically. Analyses of variance (ANOVA) using a one-factor model without replications were done for each trait and for each group of genotypes (CEAPOIU, 1968).

Standard deviation:

$$s = \sqrt{\frac{\sum(x-\overline{x})^2}{n-1}} = \sqrt{s^2}$$

Coefficient of variation (CV %):

$$CV\% = \frac{s}{\overline{x}} * 100$$

II. Genotypic variability

Seven early maturing maize synthetic populations derived from three different breeding programs were chosen for this study:

1) *per se* selection (Tu Syn 3 (per se) (1)),

2) recurrent selection (Tu Syn Mara, Tu Syn 1, Tu Syn 8),

3) recurrent reciprocal selection (Tu SRR 2I(5D) (1), Tu SRR 5D(2I) (1), Tu SRR 5DR (6I) (4)) were used in this study. These synthetic populations were well suited for the objectives of research as they had proven to be with high and low moisture content at normal harvesting time. They are genetically broad based populations improved for agronomic traits. These synthetic populations are under continuous genetic improvement for agronomic traits: grain yield capacity, early maturity, resistance to root and stalk lodging.

Experimental designs. II-1-2) Seeds from the crosses (7 synthetic populations x 4 inbred lines-testers) were produced in a factorial mating design. Synthetics were crossed with four testers (inbred lines): two flint inbred lines (TD 233 and CO 255) and two dent inbred lines (TC 184 and TC 209). The test crosses and their parental forms were evaluated in four environmental conditions: two years 2009 and 2010 and two locations Turda and Targu-Mures respectively, for both *per se* and test cross performances. Complete block designs were used with 3 replications for *per se* and testcross trials respectively. Plant densities averaged 60 000 plants/ha in each experiment. Plots were 2-rows, 5m-long, with 0.7 m spacing between two rows.

II) Statistical analysis of genotypic variation. Analysis of variance in testcross was performed for all traits within and among environments. Analysis of GARDNER and EBERHART

(1966) was used to partition genetic and environmental effects. Genotypes were considered as fixed effects while environments and replication (locations) within each environment were considered as random effects. The genotypes variance was decomposed orthogonal and non-orthogonal for: test cross hybrids, check hybrids and comparisons between the two groups.

There were calculated values for the general combining ability (GCA) and specific combining ability (SCA) following the procedure describes by GRIFFING (1956) Model II, for factorial analysis:

$$\hat{g}_m \text{ or } \hat{g}_n = \frac{X_{m.}}{m} - \frac{X_{..}}{m.n}$$ (CABULEA, 1975)

ĝm or ĝn = general combining effects of "m" and „n" parent
n = synthetic populations - parental forms used as father
m = inbred lines-tester used as mother

RESULTS AND DISCUSSIONS

Description of *per se* variability. In all trials, coefficients of variability, both for local populations and for synthetics, were over 5% for most stags of vegetation period (table 1); they were higher for early vigour (15.1 to 15.3%) and stage of silking – physiological maturity (8.9% for local populations to 10.9% for synthetics). Although, there is little variation in the stage of sowing – physiological maturity (4.2% for synthetics to 4.4% for local populations) in the germplasm studied here.

Table 1.

Means values, range of variation, and coefficients of variation (CV) for **stages of vegetation period** in „TURDA" germplasm

Traits		Stages of vegetation period: sowing – flowering	sowing – silking	sowing – physiological maturity	silking – physiological maturity	Early vigor
Germplasm		$\sum^0$ C				Note
Local populations (count = 208)	Minimum	438.7	438.7	883.7	362.8	4
	Mean	519.8	526.7	1012.2	485.5	6.8
	Maximum	672.0	691.4	1172.1	600.9	9
	Range	233.3	252.7	288.4	238.1	5
	Variance	1382.2	1428.3	1996.6	1846.9	1.1
	Standard Deviation	37.18	37.79	44.7	43.0	1.0
	Standard Error	2.6	2.62	3.1	3.0	0.1
	ConfidenceLevel (95%)	5.1	5.2	6.1	5.9	0.1
	CV (%)	**7.2**	**7.2**	**4.4**	**8.9**	**15.2**
Turda Synthetics (count = 56)	Minimum	430.7	438.7	850.1	276.8	5
	Mean	536.9	549.1	1020.6	467.9	7.8
	Maximum	619.4	664.9	1085.8	573.8	9
	Range	188.7	226.2	235.7	235.7	4
	Variance	1294.5	1536.0	1845.3	2619.8	1.4
	Standard Deviation	36.0	39.2	43.0	51.2	1.2
	Standard Error	4.8	5.2	5.7	6.8	0.2
	Confidence Level (95%)	9.6	10.5	11.5	13.7	0.3
	CV (%)	**6.7**	**7.1**	**4.2**	**10.9**	**15.4**

- Coefficient variability (CV %)

In the same Table 1 it was also evident that local populations showed variability for maturity ranging between 233.3 $\sum^0$ C in case of stages of sowing – flowering and 288.8 $\sum^0$ C for stage of sowing – physiological maturity. The range of variation observed for synthetics was larger than in local populations, ranging between 188.7 $\sum^0$C (sowing – silking) and 235.7$\sum^0$C (sowing – physiological maturity). Among local populations some interesting forms with earlier silking, most of them being collected from Maramures areas, were identified: Tulghes (438.7$\sum^0$C), Tarna Mare, Cerbal and Lancram (449.6 $\sum^0$C), Corbu B189-84, Giulesti, Desesti, Lunca, Miercurea, Mara-1 and Ungheni 1 (460.1$\sum^0$C). In the studied germplasm were local populations which have been noted by longer period between sowing-silking and shorter maturity between silking - physiological maturity: Rosu de Beriu, Eremitu, Campeni, Mara 2, Stanceni (table 2).

Table 2

Per se values of some stages of vegetation period of local populations, as maize maturity rating equivalents

I. Local populations noted by shorter period between sowing-silking

No.	Local populations	Stages of vegetation period: sowing – flowering ($\sum^0$C)	sowing – silking ($\sum^0$C)	sowing – physiological maturity ($\sum^0$C)	silking – physiological maturity ($\sum^0$C)
1	Atid	460.1	500.7	110.2	509.5
2	Aschileul Mare	460.1	500.7	110.2	509.5
3	Bereni	460.1	470.5	914.9	444.4
4	Borsa	460.1	500.7	110.2	509.5
5	Corbu B189-84	460.1	460.1	940.5	480.4
6	Cerbal	449.6	449.6	914.9	465.3
7	Cerbal Aries	449.6	449.6	930.2	480.6
8	Desesti	449.6	460.1	917.9	457.8
9	Desesti 2	460.1	470.5	899.3	428.8
10	Giulesti	460.1	460.1	1061	600.9
11	Hateg	460.1	460.1	132.3	572.2
12	Lunca	449.6	460.1	982.7	522.6
13	Lancram	449.6	449.6	124.3	574.7
14	Miercurea	460.1	460.1	110.2	550.1
15	Mara 1	449.6	460.1	949.9	489.8
16	Pascani	460.1	460.1	995.8	535.7
17	Tulghes B160-84	449.6	438.7	124.3	585.6
18	Tulghes B179-84	438.7	438.7	970.2	531.5
19	Zetea(B 147-84)	449.6	449.6	982.7	533.1
20	Zetea(B145-84)	449.6	449.6	982.7	533.1
Mean/208 populations		**519.7**	**526.6**	**1012.0**	**485.4**

II. Local populations noted by shorter period between silking - physiological maturity

No.	Local populations	Stages of vegetation period: sowing – flowering ($\sum^0$C)	sowing – silking ($\sum^0$C)	sowing – physiological maturity ($\sum^0$C)	silking – physiological maturity ($\sum^0$C)
1	Apoldu de Sus	500.7	512	930.2	418.2
2	Rosu de Beriu	587.1	587.1	949.9	362.8
3	Berind(CN3-84)	538.9	573.3	982.7	409.4
4	Cisteiul de Mures	531.1	547.4	970.2	422.8
5	Campeni	531.1	547.4	949.9	402.5
6	Eremitu	500.7	500.7	899.3	398.6
7	Erina	522.3	538.9	949.9	411
8	Mihaiesti CN 42	522.3	522.3	949.9	427.6
9	Mara 2	481.6	531.1	940.5	409.4
10	Rosu de Suatu	538.9	538.9	949.9	411
11	Seini	522.3	538.9	949.9	411
12	Stanceni	609.7	609.7	1010.2	400.5
13	Selimbar	619.4	619.4	1042	422.6
14	Sinca Noua	599.4	629.4	1042	412.6
Mean/208 populations		**519.7**	**526.6**	**1012.0**	**485.4**

II. The genetic value of the synthetic populations

II.1. *Per se* values of some stages of vegetation period of parental forms – synthetic populations, as maize maturity rating equivalents

The synthetic populations used as parental forms Tu Syn Mara and Tu SRR 5DR (6I) (4) were chosen for this study mainly because of the large difference in maturity between them. This difference in maturity is reflected in the comparative sum of the degrees of temperature ($\sum^0$ C) which were for the period from sowing to silk emergence 526.5 → 627.4 $\sum^0$ C, sowing to pollen shedding 509.3→588.0 $\sum^0$ C and sowing to physiological maturity 1091.0 → 1158.6 $\sum^0$ C respectively (table 3). The difference in sum of the degrees of temperature ($\sum^0$ C) to silking was 100.9^0 C and 67.6^0 C for physiological maturity respectively. The difference in maturity between the parents is therefore very similar when measured by these two characters. The data from the parents also indicated that, on the average, silking occurred later (+38.5^0 C) than pollen shedding. The difference in percentage of grain dry matter at harvest between the parental forms indicated that the high values for dry matter content in grain at harvest were obtained from synthetic populations Tu Syn Mara, Tu SRR 5D (2I) (1), Tu Syn 1, Tu SRR 2I (5D) (1). Lowest values for the percentage of dry matter were obtained from synthetics Tu Syn 3 (per se) (1) (very significant lower than the average synthetic) comparable to those recorded for some of the check hybrids (table 3). Therefore, Tu Syn Mara is the most early of the parent forms.

Table 3.

Per se values of some stages of vegetation period of parental forms – synthetic populations, as maize maturity rating equivalents

No.	Traits Genotype	Grain dry matter at harvest	Stages of vegetation period:				
			sowing – flowering	sowing-silking	sowing – physiological maturity	silking – physiological maturity	Early vigor
		%	$\sum^0$ C				Note
1.	Tu Syn Mara	82.2	509.3	526.5	1091.0	564.5	6
2.	Tu Syn 1	80.7	510.5	569.6	1134.8	565.2	6-7
3.	Tu Syn 8	80.1	557.5	598.9	1106.1	507.2	6
4.	Tu SRR 2I(5D) (1)	80.1	540.7	575.3	1107.1	531.2	6-7
5.	Tu SRR 5D (2I) (1)	80.8	555.6	587.0	1131.5	544.5	6
6.	Tu Syn 3 (per se) (1)	77.9	563.6	627.4	1158.6	531.2	6-7
7.	Tu SRR 5DR (6I) (4)	78.8	588.0	610.3	1128.0	518.0	5-6
Mean of check hybrids		78.0	-	-	-	-	-
Mean		80.1	546.5	585.0	1122.4	537.5	-

II. 2. Genetic values of the seven synthetic populations for maturity

The determination of the genetic value of those seven synthetic consisted in their crossing with four testers (inbred lines): two flint inbred lines (TD 233 and CO 255) and two dent inbred lines (TC 184 and TC 209). The test crosses and their parental forms were evaluated in four environmental conditions: two years 2009 and 2010 and two locations Turda and Targu-Mures respectively, for both *per se* and test cross performances. Testcross hybrids were compared with four commercial hybrids: Turda Mold 188, Turda 165, Turda SU 181 and Turda 201. The expression of grain dry matter content was significantly ($P < 0.05$) different for all crosses in each environment (table 4). The interaction term of environment x genotype was significant.

Table 4.

Analysis of variance of the grain dry matter content of testcross hybrids "tester x synthetic population" (2 experimental years, 2 locations) compared with the check (commercial) hybrids

Source of variation	df	Mean squares	F test	Significance
Years (Y)	1	2500,02	1366,13	**
Locations (L)	1	59,38	32,43	**
(L x Y)	1	3,42	1,88	
Genotypes (G)	31	39,21	21,46	**
(G x Y)	31	7,74	4,24	**
(G x L)	31	3,07	1,68	*
(G x Lx Y)	31	3,95	2,17	**
Error	248	1,83		

An analysis of variance on the plot means indicated significant differences between years, locations and between genotypes. The error mean squares were low, indicating the existence of good experimental conditions.

The hybrids realized with Tu Syn Mara, Tu SRR 5 D (2I) (1) and Tu Syn 1 were with the highest dry-matter content (81.3%, 80.1% and 79.9% compared to average of check hybrids); the difference in the first situation is very significant statistically (table 5).

Table 5

General combining ability for kernels dry matter content (%) of the synthetic populations ($\hat{g}_n$) and tester inbred lines ($\hat{g}_m$)

Tester - inbreds / Synthetics	TC 184 cmsC	TC 209	CO 255	TD 233	Mean - synthetics	$\hat{g}_n$
	%					
Tu Syn Mara	80.74	81.50	82.93	79.97	81.29	**1.80**
Tu Syn 1	78.96	79.52	81.42	79.85	79.94	**0.45**
Tu Syn 8	78.72	78.43	81.82	77.15	79.03	-0.46
Tu SRR 2I(5D) (1)	77.85	78.40	80.70	78.37	78.83	-0.66
Tu SRR 5D(2I) (1)	80.28	80.08	82.75	77.33	80.11	**0.62**
Tu Syn 3 (per se) (1)	77.83	77.64	80.22	75.09	77.69	-1.79
Tu SRR 5DR (6I) (4)	78.90	79.64	81.49	78.10	79.53	0.04
Mean - tester	79.04	79.32	81.62	77.98	**79.49**	
$\hat{g}_m$	-0.45	-0.17	2.13	-1.51		

LSD (0.05) comparisons genotypes = 1, 09 %

The highest values of additive effects for grain dry matter content were recorded at: Tu Syn Mara ($\hat{g}_n$ = +1,80), Tu SRR 5D (2I)(1) ($\hat{g}_n$ = +0,62) and Tu Syn 1 ($\hat{g}_n$ = +0,45). Therefore, Tu Syn Mara, Tu SRR 5D (2I)(1) and Tu Syn 1 produced hybrids with the most early maturity. The most late hybrids were those produced by the synthetic populations Tu Syn 3(per se) (1) ($\hat{g}_n$ = -1,79), Tu SRR 5D (2I)(1) ($\hat{g}_n$ =-0,66) and Tu Syn 8 ($\hat{g}_n$ = - 0,46) (table 5).

Table 6.

Specific combining ability effects ($\hat{s}_{ij}$) for kernels dry matter content of the synthetic populations and tester inbred lines

Genotype	TC 184 cmsC	TC 209	CO 255	TD 233
Tu Syn Mara	-0.10	0.39	-0.49	0.19
Tu Syn 1	-0.53	-0.24	-0.65	**1.42**
Tu Syn 8	0.14	-0.43	**0.66**	-0.37
Tu SRR 2I(5D) (1)	-0.54	-0.25	-0.26	**1.05**
Tu SRR 5D(2I) (1)	**0.62**	0.14	0.51	-1.27
Tu Syn 3 (per se) (1)	0.58	0.12	0.40	-1.10
Tu SRR 5DR (6I) (4)	-0.18	0.28	-0.18	0.08

LSD (0.05) comparisons genotypes = 1,09 %

Generally, absolute values for non-additive effects were lower than the absolute values of the highest additive effects ($\hat{g}_m$ and $\hat{g}_n$). SCA was positive for:

- TD 233 x Tu Syn 1 - $\hat{s}_{m \times n}$ = +1, 42;
- TD 233 x Tu Syn 2I (5D)(1) - $\hat{s}_{m \times n}$ = +1,05;
- CO 255 x Tu Syn 8 - $\hat{s}_{m \times n}$ = +0,66;
- TC 184 cms C x Tu SRR 5D (2I)(1) - $\hat{s}_{m \times n}$ = +0,62.

CONCLUSIONS

1. The local populations and synthetics studied may be used as sources of initial material for precocity in maize breeding programmes.

2. There is variability between genotypes for maturity; coefficients of variability were over 5% for most stages of vegetation period.

3. Most of the local populations with a short vegetation period were collected in the area of Maramures.

4. The synthetic populations studied for their genetic values in heritabity of precocity were well suited for the objectives of research.

5. The highest values of additive effects for grain dry matter content were recorded at: Tu Syn Mara ($\hat{g}_n$ = +1, 80), Tu SRR 5D (2I) (1) ($\hat{g}_n$ = +0, 62) and Tu Syn 1 ($\hat{g}_n$ = +0, 45).

6. Tu Syn Mara, Tu SRR 5D (2I) (1) and Tu Syn 1 produced hybrids with the most early maturity.

7. Nonaditive gene effects have brought the contribution in the determinism of dry matter content in grain at normal harvesting time, but their role was, however, lower within framework of this experimental system, in comparison with the additive effects.

8. The process of improvement of synthetic population may continue as there is still enough genetic variability.

9. All local populations (landraces) and synthetics are currently used in the framework of breeding and genetic program at the Agricultural Research Station, Turda – Romania (ARS Turda).

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