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Evaluation of New Maize Genotypes for Seed Yield Potential and Stability

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ABSTRACT

The yield analysis of new maize hybrids at multiple locations could provide information on the their stability. The aims of the study were to identify the effect of genotype, environment, year and their interactions on yields of some new Romanian maize hybrids and to compare maize hybrids that have high and stable yields in diverse environments in Romania based on three method: parameters of regression, drought susceptybility index and coefficient of variation. We evaluated the stability of 17 maize hybrid in six different location from Romania. Maize hybrids with high yield potential and early maturity traits derived from a diallel cross were carried out in a randomized complete block design as a single factor with three replicates. The effects of environment, genotype, year and its interaction on yield were highly significant (P<0.01).

Eight hybrids (Oituz, HSF 1191-14, HSF 3425-16, HSF 1034-17, HSF 1033-17, HSF 4075-17, HSF 3877-17 and HSF 7395-18) had yields that were higher than the average yield of all genotypes in all environments and were considered stable on the basis of two stability parameters, i.e., parameters of regression and coefficient of variation. Three of these hybrids are considered unstable on basis on drought susceptybility index. Thus, these three hybrids (Oituz, HSF 3877-17 and HSF 1033-17) could be targeted for these specific locations with low water stress. The drought susceptybility index highlight the maize hybrid HSF 1191-14 as the promising for high yield and instead presented the best drought tolerance in all years.

Keywords: maize hybrids, yield, stability.

INTRODUCTION

It is estimated that by 2050, due to the growth of the global population, the demand for maize will be almost double compared to the current one, (Ray et al., 2013). Unfortunately, between 15-20% of maize grain production is lost each year due to drought and such losses may continue and even intensify as droughts become more frequent and severe due to climate change (Petcu et al., 2018). Irrigation is not an option for a large number of farmers and there is limited potential for any expansion of irrigation in developing countries and even water shortages are predicted (Ingrao et al., 2023). Thus, the use of maize hybrids represents an important contribution of genetics to the improvement of plants for applied purposes (Cosmin et al., 1987) and improving tolerance to drought and heat offers a stability of the yield, thus being a viable and more practical solution to stabilize production (Petcu et al., 2018).

Romania, the country with the largest area of cultivated corn in Europe, does not have the higher level of yields. One of the main factors being large variations in climatic factors during the vegetation period, but also from one year to another and the lack of irrigation systems. Thus, the adaptation of maize hybrids to variations in environmental conditions represents a major contribution to increasing production and its stability, through the superior exploitation of natural resources and the reduction of damage caused by stress factors (Mureșan et al., 1967; Horhocea et al., 2020).

Production capacity and its stability being so, the main objectives of breeding programs. Increasing productivity and its stability is only possible by creating genotypes adapted to variations in environmental conditions (Mandache, 2013). The basic condition for the cultivation promotion of new maize hybrids is a good adaptation to environmental conditions, reflected by superior productions from a quantitative and qualitative point of

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view. Early-maturing varieties are expected to solve the water availability problem encountered in dryland/or unirrigated areas where in rainfall, the main water source, is limited and the rainy season is short and unevenly distributed in time and space (Amzeri et al., 2020). In this context, breeding programs from NARDI Fundulea was focus in last time on creating new early-maturing and high-yielding varieties.

The production capacity is a complex attribute, for its achievement the genetic system of the plant is acting in its entirety in interaction with the environment, throughout the vegetation period and the stability of production is achieved through genetic homeostasis and tolerance to abiotic factors (drought, heat, low temperatures) and to biotic factors (diseases and pests) (Sarca, 2004). The yield stability of new variety candidates can be analyzed by using various methods. The indexes proposed by Brukner and Frohberg (1987), coefficient of variation and drought susceptibility index are interesting options, because they inform jointly about the adaptability and stability of hybrids, and are ease application and interpretation. The aims of the study were to identify the effect of genotype, environment, year and their interactions on yields of some new 15 Romanian maize hybrids and to compare maize hybrids that have high and stable yields in diverse environments in Romania based on different method.

MATERIAL AND METHODS

Fifteen hybrid maize hybrids with high yield potential and early-maturing traits derived from a diallel cross and create by National Agricultural Research and Development Institute Fundulea - Romania were used in this study.

This research was conducted during 2020-2022 at unirrigated in six location from Romania different from the pedoclimatic point of view: Fundulea, Brăila, Șimnic, Valu lui Traian, Lovrin and Livada (Table 1).

Table 1. Description of the six research location

Location	Geographic position		Average annual rainfall (mm)	Temperature (°C)	Soyl type
	Longitude	Latitude			
Fundulea	24°10'	44°30'	584.3	10.9	Cambic chernoziom
Brăila	27°55'	45°12'	442.0	10.9	Vertic chernoziom
Şimnic	23°48'	44°19'	565.1	11.2	Reddish-brown
Valu lui Traian	28°30'	44°10'	434.8	11.4	Typical vertic chernoziom
Lovrin	20°44'	45°75'	521.0	10.9	*Phreatic-moist* chernoziom
Livada	25°07'	47°52'	752.1	9.9	Luvic brown

The experiments were carried out according to the method of completely randomized blocks, in three repetitions, in plots of four rows with a length of 4.8 m and the distance between the rows of 0.7 m, the total area of the plot being 13.44 m^2. To reduce the intergenotypic competition, the two central rows were harvested, the harvestable surface of the plot being 6.72 m^2. The plant density used in the six experimental locations was 65.000 plants/ha.

The stability of maize hybrids was determined used three methods. The first is based on the regression parameters proposed by Brukner şi Frohberg (1987), the second on the index of drought susceptibility after Ficher and Maurer (1978) and the last one on the coefficients of variation.

Brukner and Frohberg, (1987) using the method of regression analysis suggested that a variety:

- it is adapted to unfavorable environmental conditions when b<1 (subunit regression slope) and a (regression constant, intercept) have positive values;
- adapted to favorable environmental conditions when b>1 (overunit regression slope);
- widely adapted to different environmental conditions when b>1 and a has large values.

The drought susceptibility index (DSI) was calculated based on the formula proposed by Ficher and Maurer [1978, taken from Petcu et al. (2018)]:

$$DSI = (1-ys/ym)/(1-YS/YM)$$

where ys = hybrid production under stress conditions (HWS locations); ym = hybrid production under optimal conditions (LWS locations), YS = average production of all hybrids tested under stress conditions and YM is the average production of all hybrids tested under optimal conditions.

The classification of locations with high water stress conditions (HWS) and low water stress conditions (LWS) took into account the level of maize yield (Table 2).

Table 2. The classification of locations with high water stress conditions and low water stress condition

Location	2020	2021	2022
Fundulea	HWS	LWS	HWS
Brăila	LWS	LWS	LWS
Şimnic	HWS	HWS	HWS
Valu lui Traian	LWS	HWS	LWS
Lovrin	HWS	LWS	HWS
Livada	LWS	LWS	LWS
HWS	Mean of yield/location < 6-7 to/ha		
LWS	Mean of yield/location > 8 to/ha		

RESULTS AND DISCUSSION

During the three years of experimentation (2020-2022), the climatic conditions were different from year to year, influencing the yields obtained in the maize hybrids in the 6 test locations.

Figures 1 and 2 show the amount of precipitation and average monthly temperatures in the maize vegetation period (April-August) recorded in the period 2020-2022, in the 6 locations of testing.

From a pluviometric point of view, it can be observed that in 2020 the precipitation during the vegetation period a of maize were below the multiannual average in five locations, with the exception of Livada where they exceeded normal area. In 2021, the amount of monthly precipitation during the maize vegetation period exceeded the multi-annual in 3 locations: Brăila, Valu lui Traian and Livada (Figure 1).

In the year 2022, the amount of monthly precipitation during the maize vegetation period did not exceed the average of multiannual average in any location (Figure 1).

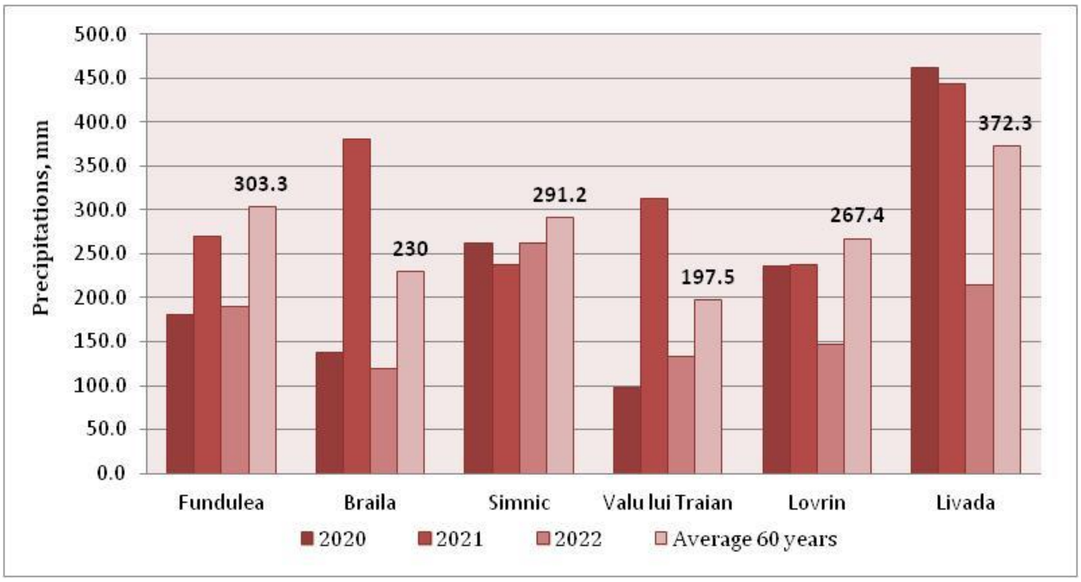

Figure 1. The sum of the annual rainfall recorded in the period 2020-2022 in the six locations

Regarding the average temperature, it is observed that in all the years of experimentation the temperatures recorded during the maize vegetation period exceeded the multiannual average.

The highest average temperatures were recorded at Fundulea and Brăila in the years 2020 and 2021 and in all locations in 2022 (heat stress) (Figure 2).

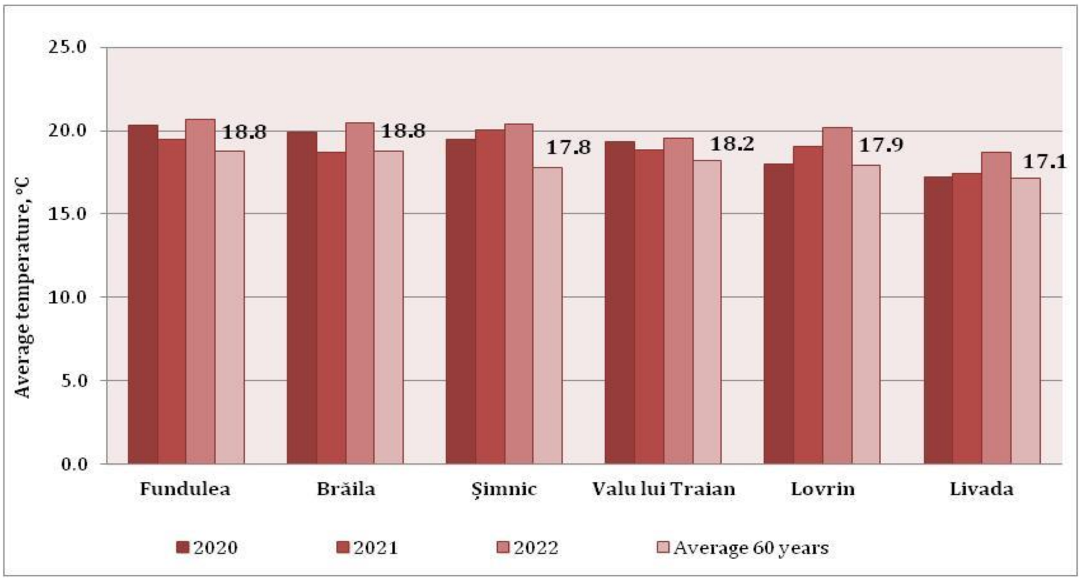

Figure 2. Average monthly temperatures during the maize growing season (April-August) recorded in the period 2020-2022, in the six locations

The results of the variance analysis of the yield per hectare of 15 maize hybrids showed that the effect of hybrid, year, environment and their interaction was statistically significant at the level of <0.01 (Table 3). The contributions of hybrids, year, environment to the yield were 1.09%, 10.62%, and 75.23%, respectively. The hybrid × environment interactions highlight that the genotypes tested showed variation in different environments.

Table 3. Variance analysis for the yield of maize genotypes, tested in the period 2020-2022

Source of variance	DF	SS	MS	F	% Variance explained
Hybrids (H)	14	104.924	7.495	58.55***	1.09
Year (Y)	2	146.426	73.213	572.05***	10.62
H x Y	28	26.1	0.932	7.28***	0.14
Environment (location) (E)	5	2592.646	518.529	4051.57***	75.23
H x E	70	77.301	1.104	8.62***	0.16
Y x E	10	867.671	86.767	677.96***	12.59
H x Y x E	140	155.359	1.11	8.67***	0.16
Eroare	538	68.854	0.128		0.02
Total	809	4040.209			

**** significant at the level of <0.01; DF = degrees of freedom; SS = Sum of squares; MS = mean squares.*

As a result of the fluctuations of the environmental factors, a great variability of production was observed from one year to another (Table 4). Average yield ranged from 5.83 to 11.50 t/ha. The lowest yiel were obtained in 2021 at Șimnic and in 2022 at Lovrin (a year characterized both by severe drought but also by the phenomenon of heat, especially during the period of intense growth - flowering and the period of grain filling) (Table 4). The maximum production was achieved at Livada in 2020, in conditions where the drought was not as intense as in the other test points, obtaining an yield of 12.95 t/ha even in non-irrigated conditions. By year, the highest average yield was obtained in 2021, and the lowest in 2022, because in most of the test localities the temperatures during the flowering-silking period were higher. The HSF 7395-18 and HSF 1370-17 hybrids achieved lower yields than the average of all hybrids, and the HSF 1191-14 and HSF 7375-18 hybrids achieved higher yields.

Table 4. The variation of average yields of several maize hybrids in 18 contrasting environmental conditions

Location	2020	2021	2022	Average
Fundulea	5.80	9.89	7.47	7.72
Brăila	8.89	10.68	8.82	9.46
Șimnic	6.64	5.21	5.63	5.83
Valu lui Traian	9.75	7.43	8.63	8.60
Lovrin	7.00	8.62	5.57	7.06
Livada	12.95	11.01	10.54	11.50
Average	**8.50**	**8.81**	**7.78**	**8.36**

The biggest difference between the minimum and maximum yield of the same hybrid, in the three years of experimentation, was recorded in the hybrids HSF 1034-17 and HSF 3877-17 (over 1.4 t/ha).

Relative large differences of yield in contrasting environmental conditions (over 1 t/ha) were also recorded in other seven maize hybrids (Table 5).

In the Brukner and Frohberg method, the slope and intercept of regression are used to dermine genotype adaptability. Thus, according to this method, a hybrid is considered well adapted to unfavourable environmental conditions, if the value of the parameter b (slope) is <1 and parameter a (intercept) has positive values.

There are eight hybrids (green color in the table) that show adaptation to unfavorable environmental conditions, but their production in optimal conditions is lower than the average of all hybrids. The rest of the hybrids are adapted to favorable environmental conditions (b>1, a with small, negative values), in unfavorable conditions their production is lower than the average of all hybrids (Table 6).

Table 5. The yield of semi-early maize hybrids in 18 environmental conditions

No.	Hybrid	2020	2021	2022	Average	Maxim	Minim	Amplitude
1	Oituz	8.31	8.63	7.74	8.23	8.63	7.74	0.90
2	HSF 1191-14	8.82	9.39	8.39	8.87	9.39	8.39	1.00
3	HSF 1128-14	8.22	9.40	7.91	8.51	9.40	7.91	1.49
4	HSF 3425-16	8.84	8.90	8.08	8.61	8.90	8.08	0.82
5	HSF 1034-17	8.37	8.76	7.95	8.36	8.76	7.95	0.81
6	HSF 3407-16	8.72	9.02	7.81	8.52	9.02	7.81	1.21
7	HSF 1033-17	8.68	9.02	8.19	8.63	9.02	8.19	0.84
8	HSF 7375-18	8.67	8.81	7.72	8.40	8.81	7.72	1.09
9	HSF 4075-17	8.81	8.83	8.38	8.68	8.83	8.38	0.45
10	HSF 1032-17	8.37	8.58	7.47	8.14	8.58	7.47	1.11
11	HSF 1142-17	8.03	8.68	7.48	8.07	8.68	7.48	1.20
12	HSF 3877-17	8.86	8.82	8.07	8.59	8.86	8.07	0.79
13	HSF 7395-18	8.71	8.96	8.24	8.64	8.96	8.24	0.72
14	HSF 1370-17	8.11	8.18	6.49	7.59	8.18	6.49	1.69
15	HSF 1214-17	7.90	8.07	6.91	7.63	8.07	6.91	1.16
16	**Average**	**8.50**	**8.80**	**7.79**	8.36	8.80	7.79	1.02

Table 6. Parameters of the production response of the 15 hybrids to the variation of environmental conditions (Experiences carried out during 2020-2022 in six locations)

No.	Hybrid	Intercept (a)	Slope (b)
1	**Oituz**	**0.96**	**0.87**
2	**HSF 1191-14**	**1.15**	0.92
3	HSF 1128-14	-2.25	1.29
4	**HSF 3425-16**	**1.43**	**0.86**
5	**HSF 1034-17**	**2.01**	**0.76**
6	HSF 3407-16	-1.63	1.21
7	**HSF 1033-17**	**1.92**	**0.80**
8	HSF 7375-18	-0.99	1.12
9	**HSF 4075-17**	**4.74**	**0.47**
10	HSF 1032-17	-1.28	1.13
11	HSF 1142-17	-1.22	1,11
12	**HSF 3877-17**	**1.89**	**0.80**
13	**HSF 7395-18**	**2.81**	**0.70**
14	HSF 1370-17	-7.24	1.77
15	HSF 1214-17	-2.28	1.19

The DSI values for the year 2020 were from 0.79 (HSF 1191-14) up to 1.13 (Oituz). For the year 2021 the DSI values varied between 0.69 (HSF 1370-17) and 1.36 (HSF 1034-17) and for the year 2022 the DSI values varied between 0.74 (HSF 1033-17) and 1.20 (HSF 1214-17) (Table 7). Subunit values of the DSI index mean a good drought tolerance. Regarding the stability of the hybrids, the differences compared to the average of the hybrids and the coefficient of variation were determined. Analyzing the significance of the differences compared to the average yield of the hybrids, the hybrid HSF 1191-14 achieved a 6% increase in yield, and the hybrids HSF 1032-17, HSF 1370-17, HSF 1214-17, HSF 1142-17 and Oituz were lower in yield than the average of the hybrids (Table 8). Classifying the hybrids according to the production performance obtained in the three locations during 2020-2022, the first places are HSF 1191-14, HSF 4075-17 and HSF 7395-18 and from the point of view of the coefficient of variation, the hybrids HSF 4075-17, HSF 7395-18 and HSF 1034-17 have the lowest coefficients of variation, so they show better production stability (2.92-4.83), on the last places are the hybrids HSF 1128-14 and HSF 1370-17 (9.22-12.59) (Table 8).

As can be seen, two of the hybrids (HSF 4075-17 and HSF 7395-18) show both good yields and stability.

Table 7. Drought sensitivity index for hybrids in the FAO 300-400 group

No.	Hybrid	DSI			Average
		2020	2021	2022	
1	Oituz	1.13	0.84	1.04	1.09
2	HSF 1191-14	0.79	0.77	0.93	0.90
3	HSF 1128-14	1.01	0.96	0.95	0.97
4	HSF 3425-16	0.97	1.04	0.87	0.90
5	HSF 1033-17	1.00	1.14	0.74	0.84
6	HSF 1034-17	0.99	1.36	0.94	0.98
7	HSF 3407-16	1.12	0.91	0.95	1.12
8	HSF 7375-18	1.05	1.28	1.16	1.04
9	HSF 4075-17	0.91	1.01	0.95	0.93
10	HSF 1032-17	0.96	1.01	1.08	1.00
11	HSF 1142-17	1.02	0.89	0.94	1.02
12	HSF 3877-17	1.09	0.81	1.12	1.05
13	HSF 7395-18	0.96	1.04	0.95	0.96
14	HSF 1370-17	1.05	0.69	1.18	1.16
15	HSF 1214-17	0.95	1.04	1.20	1.04

Table 8. Average yield of hybrids in the 18 test conditions and coefficients of variation

No.	Hybrid	Yield (average)	Difference from average of hybrids		Coefficient of variation (s%)
			Kg/ha	Procents	
1	Oituz	8.23	0.13	98.39	5.51
2	*HSF 1191-14*	8.87	-0.51	106.09	5.67
3	HSF 1128-14	8.51	-0.15	101.77	9.22
4	*HSF 3425-16*	8.61	-0.25	102.95	5.34
5	*HSF 1034-17*	8.36	0.00	100.02	4.83
6	HSF 3407-16	8.52	-0.16	101.88	7.43
7	*HSF 1033-17*	8.63	-0.27	103.23	4.87
8	HSF 7375-18	8.40	-0.04	100.45	7.07
`9	**HSF 4075-17**	**8.68**	**-0.32**	**103.79**	**2.92**
10	HSF 1032-17	8.14	0.22	97.34	7.26
11	HSF 1142-17	8.07	0.29	96.48	7.43
12	*HSF 3877-17*	8.59	-0.23	102.70	5.16
13	**HSF 7395-18**	**8.64**	**-0.28**	**103.31**	**4.20**
14	HSF 1370-17	7.59	0.77	90.83	12.59
15	HSF 1214-17	7.63	0.73	91.28	8.20

Analyses of parameters of regression and the coefficients of variation can effectively describe genotype response in diverse environments, but these approaches only explain linear components and ignores diversity if a component is nonlinear (Widyastuti et al., 2013). Drought susceptibility index can also be used to visualize the characteristics of tested genotypes for checking whether they are stable in all locations or only at a certain location (Gauch et al., 2008).

According to analyzing the regression parameters (Brukner şi Frohberg method) and coeficient of variation characterized eight maize hibrids (Oituz, HSF 1191-14, HSF 3425-16, HSF 1034-17, HSF 1033-17, HSF 4075-17, HSF 3877-17 and HSF 7395-18) as stable (Table 9).

According to DSY analsis results indicated that Oituz, HSF 3877-17 and HSF 1033-17 were unstable, whereas Brukner şi Frohberg and cofficient of variation analysis indicated that these hybrids were stable. Oituz, HSF 3877-17 and HSF 1033-17 had high yield rates of 8.23, 8.59 and 8.63 tons ha^{-1}, respectively, but showed a low adaptation to drought.

Table 9. The stability of semi-early maize hybrids according to the studied methods

No.	Hibridul	Brukner and Frohberg	DSI	Coefficient of variation
1	Oituz	Stable	Unstable	Stable
2	HSF 1191-14	Stable	Stable	Stable
3	HSF 1128-14	Unstable	Stable	Unstable
4	HSF 3425-16	Stable	Stable	Stable
5	HSF 1034-17	Stable	Stable	Stable
6	HSF 3407-16	Unstable	Stable	Unstable
7	HSF 1033-17	Stable	Unstable	Stable
8	HSF 7375-18	Unstable	Unstable	Unstable
9	HSF 4075-17	Stable	Stable	Stable
10	HSF 1032-17	Unstable	Unstable	Unstable
11	HSF 1142-17	Unstable	Unstable	Unstable
12	HSF 3877-17	Stable	Unstable	Stable
13	HSF 7395-18	Stable	Stable	Stable
14	HSF 1370-17	Unstable	Unstable	Unstable
15	HSF 1214-17	Unstable	Unstable	Unstable

CONCLUSIONS

The effects of environment, genotype, and its interaction on yield were highly significant (P<0.01). The hybrids: HSF 1191-14, HSF 4075-17 and HSF 7395-18 stood out for high productions in all years and locations.

The maize hybrids Oituz, HSF 1191-14, HSF 3425-16, HSF 1034-17, HSF 1033-17, HSF 4075-17, HSF 3877-17 and HSF 7395-18 showed good production stability with low coefficients of variation and value of the parameter b (slope of regression) smaller than 1 and value of a (intercept) with positive values.

The HSF 1191-14 maize hybrid stood out with good drought tolerance in all years.

The hybrids Oituz, HSF 3877-17 and HSF 1033-17 had high yield rates (above average of all hybrids in six locations and three years), but narrow adaptation to drought.

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