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Agronomic evaluation of temperate maize populations in tropical zone

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ABSTRACT

Three temperate maize populations, DEA, FS14 and BUGARD which may be useful for the improvement of tropical maize populations through introgression, were evaluated agronomically during two consecutive years in two tropical agroecological zones (north and south of Benin). The traits studied were: earliness (days to silking and maturity, number of leaves), plant and ear heights, reaction to diseases, husk cover, grain yield and its components, and harvest index. All the populations were early maturing, susceptible to rust, tropical blight and maize streak and showed intermediate or poor husk cover. Their grain yields were low but FS14 and DEA yielded significantly higher than BUGARD in savanna zone. FS14 and DEA harvest indexes were high and significantly greater than that, very low, of BUGARD. FS14 and DEA can be used in tropical breeding programs, through introgression, to improve tropical maize populations for traits such as earliness, reduced plant and ear heights, and harvest index.

1. INTRODUCTION

Maize *(Zea mays* L.) is a cereal crop widely grown throughout the world in a range of agroecological environments [1]. It is of worldwide importance as food, feed, and source of diverse industrially important products [2]. In 2012, more than 176 million hectares were cultivated in the world for a production of about 875 million tons [3]. Production may not be able to meet out the demands without strong technological and policy interventions [4]. National and international maize improvement programs in tropical zone work to increase maize production through the improvement of tropical maize varieties. But, they seldom use temperate germplasm although it possesses genetic variability and traits complementary to those of tropical maize [5]. Few authors including [6, 7, 8, 9, 10, 11, 12] tried to improve tropical maize populations with temperate material. The low use of temperate material in tropical zone may be mainly due to its misbehavior in the tropics. Temperate germplasm is generally non adapted to tropical zone and susceptible to pests and diseases of the zone [13, 7, 5, 14, 15]. Nevertheless, precise figures related to temperate maize characteristics in tropical zone are scarce. Moreover, the characteristics can vary with material and location. Their knowledge will help breeders to choose judiciously the temperate material to utilize in their programs of introgression of temperate germplasm to improve tropical maize populations. This work was undertaken to evaluate agronomically in tropical zone three temperate maize populations which may be useful for the improvement of tropical maize populations. The traits studied were: earliness (days to silking and maturity, number of leaves), plant and ear heights, reaction to diseases, husk cover, grain yield and its components, and harvest index.

2. MATERIALS AND METHODS

2.1. Populations, evaluation

The 3 populations evaluated are: DEA, a single hybrid widely cultivated in France ; FS14, a synthetic created by the French National Institute of Agronomic Research at Montpellier (France) using 14 lines and BUGARD, a French population.

The populations were evaluated during two consecutive years at Allada (South Benin, degraded forest zone; latitude: 6°42'N; longitude: 2°7'E; altitude: 105 m) and Bembéréké (North Benin, savanna zone; latitude: 9°58'N; longitude: 2°44′E; altitude: 358 m).

The experimental design was a randomized complete block design with three replications. The early tropical population DMRESRW popularized in Benin was used as check. Plots consisted of six 5 m rows. Spacing was 0.80 m between rows and 0.50 m between hills along each row. Plots were overplanted and thinned to 2 plants per hill (50000 plants.ha^{-1}.). Weeding and fertilisation were optimal. Few drought periods were observed at Allada. At Bembéréké, rainfall was higher and better distributed. Days to 50% silking and maturity (dry husks) (days after planting), plant and ear heights were recorded on a plot basis. Plant or ear height was measured as the distance from the soil surface to the panicle base (plant height) or the superior ear insertion point (ear height).

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Diseases (rust caused by *Puccinia polysora*, tropical blight caused by *Exserohilum maydis* and maize streak due to maize streak virus) were scored after silking under natural infection using a 1 to 5 scale (1 = very mild infection; 5 = very high infection). Husk cover was scored at maturity with a 1 to 5 scale [(1 = excellent (tight husk going beyond the ear tip); 5 = very poor (naked ear tip)]. Grain yield and 1000 grain weight were recorded per plot at 15% moisture. Number of ears per plant (nep), number of grains per ear (nge) and harvest index (hi) were calculated as follows:

nep = ne/nph

with ne = number of ears harvested on the plot; nph = number of plants harvested on the plot

nge = (gwe/tgw) ×1000

gwe = grain weight per ear

tgw = 1000 grain weight

hi = ew/epw

ew = weight of all the ears harvested on the plot; epw = weight of all the plants harvested on the plot.

2.2. Statistical analysis

Analysis of variance was performed for each trait. When significant ($P<0.05$) differences occurred among populations, population means were compared using Newman-Keuls test. Pooling analysis was carried out when residual variances were homogeneous at the 5% level.

3. RESULTS AND DISCUSSION

Significant differences among populations appeared in all trials and for all traits. Tables 1 and 2 give the means of the temperate populations and the check.

3.1. Earliness

The 3 temperate populations were early maturing. They reached silking 40 to 50 days after planting and maturity 73 to 85 days after planting. Their number of leaves varied from 11 to 14. FS14 was the latest of the temperate populations. The 3 temperate populations matured earlier than the tropical check. Earliness variations with location and year, probably due to genotype × environment interaction were noted. Table 3 shows that that interaction was significant for days to silking during the first year of trial.

3.2. Plant and ear heights

Plant and ear heights of the temperate populations ranged from 134 to 183 cm and 42 to 77 cm respectively. Significant differences among those populations occurred only during the first year of trial and for plant height: at Allada, BUGARD had a plant height significantly lower than those of DEA and FS14 whereas at Bembéréké, plant heights of DEA and BUGARD were significantly lower than that of FS14. Plant and ear heights of the temperate populations were significantly lower than those of the tropical check or not different from them. Genotype × environment interaction may explain height and ranking variations noted. But, it was not significant as show tables 3 and 4.

3.3. Reaction to diseases, husk cover

Rust and tropical blight occurred in all trials. Maize streak appeared only in the second year of trial and only at Bembéréké. The 3 temperate populations were susceptible to the 3 diseases. The variation of scores (level of infection) with location or year are probably due to differences of pathogenic pressure and/or environmental conditions. These results agree with those reported by [13, 7, 5, 14, 15]. Those authors indicated that temperate maize populations are generally susceptible to tropical zone diseases. Husk cover was intermediate for FS14 and poor for DEA and BUGARD.

3.4. Grain yield components

BUGARD had the lowest numbers of ears per plant and grains per ear. The 3 temperate populations had 1000 grain weights lower than that of the tropical check and were not significantly different for that trait. Genotype × environment interaction may explain the variations of grain yield components observed.

Table. 1: Population means per trait at Allada.

TRAIT	YEAR	POPULATION				
		DEA	FS14	BUGARD	DMRESRW (TROPICAL CHECK)	CV (%)
DAYS TO 50% SILKING	1	45.5 B	48.5 A	44.2 B	51 A	3.2
	2	40.1 B	49 A	45.8 A	48 A	4.6
DAYS TO MATURITY	1	80.3 B	81.7 B	73 C	88 A	1.9
	2	76.8 C	81.2 B	83.4 B	87 A	1.8
NUMBER OF LEAVES	1	12 BC	12.7 B	11.3 C	16 A	3.6
	2	13.5 B	13.9 B	13.3 B	17 A	6.5
PLANT HEIGHT (CM)	1	180 A	183 A	147 B	207 A	8
	2	155 A	134 A	143 A	155 A	7.9
EAR HEIGHT (CM)	1	42 B	57 AB	52 AB	85 A	15.4
	2	50 B	51 B	46 B	77 A	15.5
RUST	1	5 A	2.7 C	4 B	1 D	26.5
	2	4.3 A	4 B	4.5 A	1 C	25.9
TROPICAL BLIGHT	1	4.7 A	4.2 A	5 A	1 B	23.1
	2	4.6 A	3.7 B	4.7 A	2 C	16.9
NUMBER OF EARS PER PLANT	2	0.63 B	0.35 C	0.39 BC	1.1 A	15.7
NUMBER OF GRAINS PER EAR	2	171 B	212 B	116 B	365 A	24
1000 GRAIN WEIGHT (G)	2	190 B	219 AB	199 B	264 A	11.7
GRAIN YIELD (KG/HA)	1	1033 B	1057 B	283 B	2379 A	21.6
	2	533 B	354 B	0 B	4309 A	19.8

CV = COEFFICIENT OF VARIATION

ON EACH LINE, MEANS FOLLOWED BY THE SAME LETTER ARE NOT SIGNIFICANTLY DIFFERENT AT THE 5% LEVEL.

Table. 2: Population means per trait at Bembéréké

Trait	Year	Population				
		DEA	FS14	BUGARD	DMRESRW (Tropical check)	cv (%)
Days to 50% silking	1	45.2 c	50.2 b	44.7 c	57 a	2.3
	2	42.8 d	48 b	44.8 c	55 a	1.8
Days to 50% maturity	1	84.5 b	85.5 b	79.5 b	94 a	2.2
	2	75.9 c	80.9 b	76.7 c	87 a	1.9
Number of leaves	1	11.2 c	13 b	11.2 c	17 a	3.9
	2	12.4 b	14.1 b	12.1 b	18 a	6.5
Plant height (cm)	1	153 c	178 b	157 c	226 a	5.2
	2	145 b	159 b	159 b	205 a	6.6
Ear height (cm)	1	47 b	58 b	62 b	107 a	12.5
	2	61 b	77 b	77 b	109 a	11.6
Rust	1	4 a	2.5 b	4.2 a	1 c	22.1
	2	4.9 a	3.8 b	5 a	1 c	23.2
Tropical blight	1	4 b	3.5 b	5 a	1 c	22.9
	2	4.8 a	3.2 b	5 a	1 c	28.4
Maize streak	2	3.3 a	3.2 a	3.8 a	1 b 1	21.8
Husk cover	2	4 a	2.8 a	3.7 a	3 a	29.1
Number of ears per plant	1	0.92 a	0.83 a	0.65 b	1 a	10.4
	2	0.82 a	0.97 a	0.15 b	1.04 a	16.7
Number of grains per ear	1	343 b	379 ab	199 c	464 a	10.7
	2	366 ab	262 bc	132 c	436 a	27
1000 grain weight (g)	1	165 b	202 b	191 b	290 a	8.7
	2	201 b	215 b	228 b	308 a	8.8
Grain yield (kg/ha)	1	1862 b	2098 b	874 c	5444 a	13.9
	2	2413 b	2666 b	0 c	6383 a	29.3
Harvest index	2	0.57 a	0.60 a	0.15 b	0.51 a	17.9

cv = coefficient of variation.
On each line, means followed by the same letter are not significantly different at the 5% level.

Table. 3: Pooling analysis for locations

Trait	Pooling of locations in the first year			Pooling of locations in the second year		
	Pooled error MS	Population × location interaction		Pooled error MS	Population × location interaction	
		MS	F		MS	F
Days to 50% silking	2.87	10.78	3.76*			
Plant height	194.99	663.43	3.40 ns	191.64	659.82	3.44 ns

* significant ($P < 0.05$).
ns = non significant ($P > 0.05$).

Table. 4: Pooling analysis for years

Trait	Pooling of years at Allada			Pooling of years at Bembéréké		
	Pooled error MS	Population × year interaction		Pooled error MS	Population × year interaction	
		MS	F		MS	F
Days to 50% silking	5.48	15.92	2.90 ns	0.78	2.25	2.88 ns
Plant height	185.76	595.47	3.21 ns	200.87	226.69	1.13 ns

ns = non significant ($P > 0.05$).

3.5. Grain yield

The 3 temperate populations gave low grain yields clearly inferior to those of the tropical check. No significant difference was noted among them at Allada. At Bembéréké, BUGARD was the least yielding population. The low yields given by the temperate populations are due to their bad adaptation to the environment shown especially by their susceptibility to the 3 major maize diseases in Benin and low grain yield components. Yield variations with location and year are probably due to genotype × environment interaction. Grain yields obtained at Bembéréké (savanna zone) were generally superior to those recorded at Allada (degraded forest zone). The populations may, therefore, be more adapted to Bembéréké environment, compared to Allada.

3.6. Harvest index

FS14 and DEA had high harvest indexes (0.60 and 0.57 respectively) not significantly different from that of the tropical check but significantly higher than the very low harvest index (0.15) of BUGARD.

4. CONCLUSION

The temperate maize populations, DEA, FS14, and BUGARD appeared early maturing in Benin. They were all susceptible to rust, tropical blight, and maize streak and had an intermediate or poor husk cover. Their grain yields were low even if DEA and FS14 yielded higher than BUGARD at Bembéréké. Harvest indexes of FS14 and DEA were high and significantly superior to that, very low, of BUGARD. These results show that, as expected, the temperate populations cannot be recommended as varieties to be cultivated in Benin. But, FS14 and DEA can be used in tropical breeding programs, through introgression, to improve tropical maize populations for traits such as earliness, reduced plant and ear heights, and harvest index. The difficulties to face include notably susceptibility to diseases: FS14 and DEA, susceptible to rust, tropical blight and maize streak may transmit susceptibility to those diseases. But, an appropriate methodology of introgression may permit to obtain good results.

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