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Characterization of traditional maize populations cultivated in Benin

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ABSTRACT

Traditional maize populations widely grown in southern Benin were evaluated in that zone for agronomic traits in order to improve them if necessary. A randomized complete block design with four repetitions was used. Significant differences among populations were observed for earliness, plant and ear heights, number of ears per plant and number of grains per ear. One population (PTMB4) was susceptible to rust. All populations except one (PTMB8) showed good husk cover. The populations gave relatively low grain yields (less than 4 t/ha) and were not significantly different for that trait. All the populations should be improved for grain yield. In addition, the populations PTMB4 and PTMB8 must be improved respectively for rust resistance and husk cover.
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Keywords: Agronomic traits, southern Benin, traditional varieties, *Zea mays*.

INTRODUCTION

Maize is a worldwide cereal crop. It is utilized as human food, animal feed and raw material for several industrial products. Maize world production was about 875 million tons in 2012 (FAO, 2013). The demand is continuously increasing and cannot be satisfied without strong technological interventions (Shiferaw et al., 2011). In Benin, maize is the most cultivated cereal crop and its production was estimated in 2012 at 1175000 tons (FAO, 2013) of which more than half was obtained in the south (ONASA, 2013). Technical, biological, socio-economic and climatic constraints limit maize production in Benin (Adegbola, 1994; Fiagan, 1994; Abadassi, 1997).

Two types of varieties are cultivated in Benin: traditional populations and improved varieties. The traditional populations are the most grown varieties despite important efforts made to popularize improved varieties. They may proceed from natural mating between maize introduced from the Americas via Europe (Westengen et al., 2012; Mir et al., 2013).

Beninese producers and consumers prefer those populations because notably of their adaptation to low-input farming systems, their relatively low susceptibility to storage pests and the good quality of their grains. But, grain yields obtained in farmers' fields are low (less than 1.5 t/ha) (FAO, 2013). It is, therefore, important to characterize the populations cultivated in order to improve them if necessary.

The present work was undertaken to determine the main agronomic traits of traditional maize populations widely grown in southern Benin with the aim of improving them in case of need.

MATERIALS AND METHODS
Populations and evaluation

Nine traditional maize populations (Table 1) widely cultivated in southern Benin (Departments of Ouémé, Plateau, Atlantique, Mono, Couffo and Zou) were characterized. They are all usually cultivated during the great rainy season (March to July). An improved maize population created by the International Institute of Tropical Agriculture (IITA) and popularized in Benin, DMRESRW, was used as check. The 10 populations were evaluated during the great rainy season in South Benin at Abomey-Calavi (latitude: 6°27′ N; longitude: 2°22′ E; altitude: 10 m) in a randomized complete block design with 4 replications. Plots consisted of four 4.5 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}). Applied fertilization was 200 kg/ha of NPKSB (14-23-14-5-1) before planting followed by 25 kg/ha of urea (46% N) two and six weeks after planting. Weeding was adequate. Rainfall was sufficient and well distributed.

The traits studied were: earliness (days to 50% pollen-shed, silking and maturity (dried husks) (days after planting), number of leaves), plant height (distance between soil level and panicle base), ear height (distance between soil level and the higher ear insertion point), reaction to diseases (rust caused by *Puccinia polysora*, tropical blight caused by *Exserohilum maydis*, and maize streak caused by maize streak virus), husk cover and grain yield and its components.

Diseases were scored after silking, under natural infection, using a 1 - 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)]. For individual plant observations (number of leaves, plant and ear heights, disease score, husk cover), ten plants were randomly taken per plot. Grain yield and 1000 grain weight were recorded on a plot basis at 15% moisture. Number of ears per plant (nep) and number of grains per ear (nge) were calculated as follows:

$nep = ne/nph$

with ne = number of ears harvested on the plot;

nph = number of plants harvested on the plot

$nge = (gwe/tgw) \times 1000$

gwe = grain weight per ear

tgw = 1000 grain weight.

Table 1: Few grain characteristics of the traditional populations studied.

| Population	Local name	Grain colour	Grain texture	Grain size
PTMB1	Yallode	White	Dent	Small
PTMB2	Agliki	White	Dent	Small
PTMB3	HOLLIKOUI	White	Dent	Small
PTMB4	AZANGBANGBE	White	Dent	Small
PTMB5	TCHAOUNKPO	White-yellow	Dent	Small
PTMB6	GANNANKOUN	White	Dent	Small
PTMB7	GBADEGA	White	Dent	Small
PTMB8	SOUNHATON	White	Dent	Small
PTMB9	GBADEWEWE	White	Dent	Small
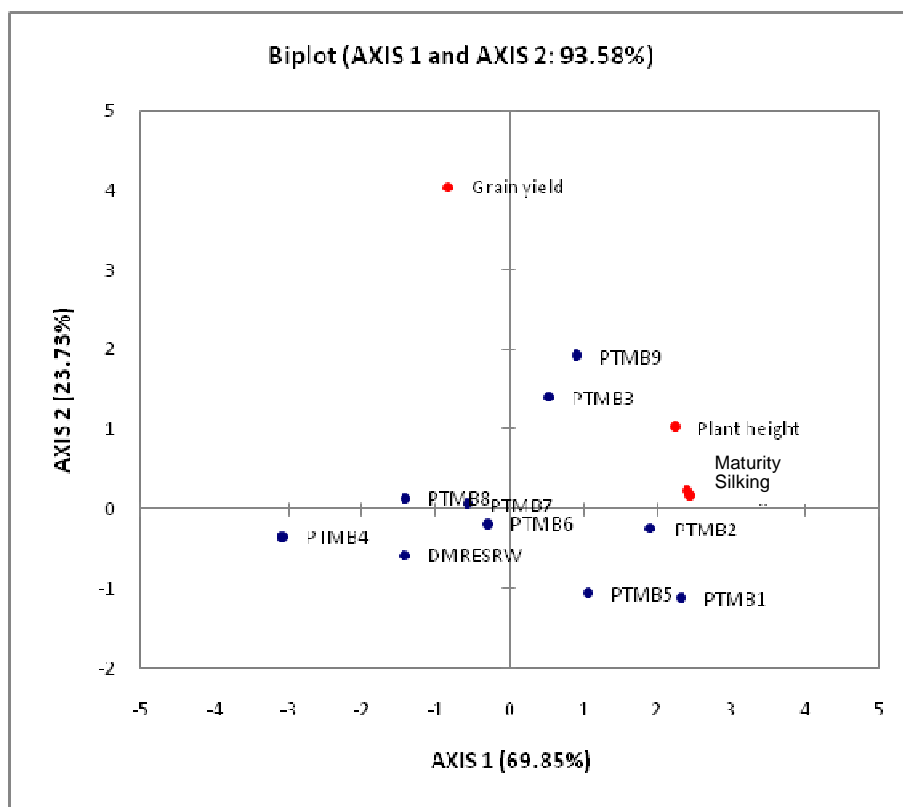
Figure 1: Principal components analysis: Biplot showing the representation of variables and populations in the main plan AXIS 1 AXIS 2. Silking = Days to 50% silking; Maturity = Days to 50% maturity.

Statistical analysis

Analysis of variance was carried out per trait. When significant (P<0.05) differences among populations appeared, population means were compared using Newman-Keuls test.

Principal components analysis was performed for four key agronomic traits (days to 50% silking, days to 50% maturity, plant height and grain yield) to study correlations between traits and examine the relative situations of the populations. The variables were given the same weight.

RESULTS

Single variable study

Analyses of variance showed

significant differences among populations for all traits except 1000 grain weight and grain yield. Population means are given by Tables 2 and 3. Days to 50% pollen-shed, silking and maturity ranged from 48 to 59, 49 to 62 and 80 to 92 respectively. The number of leaves varied from 18 to 22. Considering flowering and maturity, the improved population DMRESRW appeared later than one traditional population (PTMB4), earlier than 4 traditional populations (PTMB1, PTMB2, PTMB5 and PTMB9) and not significantly different from 3 traditional populations (PTMB6, PTMB7 and PTMB8). PTMB3 was later than DMRESRW for flowering and not significantly different from it for maturity. Significant differences between DMRESRW

and traditional populations ranged from 3 to 7 days.

Plant and ear heights of the traditional populations varied from 159 to 240 cm and 66 to 137 cm respectively. Seven populations (PTMB1, PTMB2, PTMB3, PTMB5, PTMB6, PTMB7 and PTMB9) had plant and ear heights significantly higher than those of DMRESRW (+ 46 to + 79 cm for plant height and + 27 to + 58 cm for ear height) whereas 2 (PTMB4 and PTMB8) were not significantly different from it.

Except PTMB4 which was susceptible to rust, all the populations showed very mild infection (score 1). Apart from PTMB8, all the traditional populations had a good husk cover. PTMB8 showed, like DMRESRW, an intermediate husk cover.

Number of ears per plant in the traditional populations was between 0.80 and 1.23 whereas the number of grains per ear varied from 235 to 336. Except PTMB4, the traditional populations were not significantly different from the improved population DMRESRW for the number of ears per plant. PTMB4 had a number of ears per plant higher than that of DMRESRW. Two populations (PTMB4 and PTMB7) had numbers of grains per ear significantly lower than that of the check DMRESRW; the other populations were not significantly different from the check for that trait. One thousand grain weight varied from 219 to 254 g but the differences noted among populations were not significant. Seven of the 9 traditional populations were not then significantly different from the improved population DMRESRW for the 3 grain yield components evaluated.

The traditional populations gave relatively low grain yields ranging from 2.6 to 3.8 t/ha. No significant difference was observed among populations.

Multivariable study: principal components analysis

Table 4 gives the proportion of the total variability explained by the axes. It appears that the first two axes (AXIS 1 and AXIS 2) explain respectively 69.85% and 23.73% of the total variability. The plan defined by the two axes explains, therefore, 93.58% of the total variability and was retained for the representation of variables and populations.

The squared cosines of the variables are shown in Table 5. Table 6 gives the matrix of simple linear correlations of the variables.

The earliness variables (days to 50% silking, days to 50% maturity) and plant height are well linked with AXIS 1 whereas grain yield is well linked with AXIS 2.

Days to 50% silking, days to 50% maturity and plant height were highly (significance at the 1% level) and positively correlated but were not significantly correlated with grain yield.

Figure 1 summarizes the relative situations of the populations for the traits studied. Four groups of relatively close populations appear:

Group 1: PTMB3 and PTMB9.
The two populations were relatively late, showed great plant heights and gave relatively low grain yields (less than 4 t/ha).
- Group 2: PTMB1, PTMB2 and PTMB5
The characteristics of this group are: relative lateness, great plant height and relatively low grain yield
- Group 3: PTMB6 and PTMB7.
The two populations of the group were relatively early, had relatively great plant heights and relatively low grain yields
- Group 4: PTMB8 and DMRESRW
Earliness, low plant height and relatively low grain yield characterize that group.

PTMB4 appears relatively isolated. It was the earliest population and had the lowest plant height and a relatively low grain yield.

Table 2: Population means and their standard errors for earliness variables and plant and ear heights.

Population	Trait					
	Days to 50% pollen-shed	**Days to 50% silking**	**Days to 50% maturity**	**Number of leaves**	**Plant height (cm)**	**Ear height (cm)**
PTMB1	58.7 ± 0.7a	62 ± 1a	92.5 ± 1.5a	21.7 ± 0.4a	221 ± 6ab	112 ± 10ab
PTMB2	56.7 ± 1.5b	60 ± 2ab	90 ± 1abc	21.7 ± 0.7a	240 ± 6a	137 ± 10a
PTMB3	55.7 ± 0.4b	58.7 ± 0.7b	87.5 ± 1.5cde	21 ± 0.5ab	220 ± 7ab	127 ± 10ab
PTMB4	48 ± 0.5d	48.7 ± 0.7d	80.5 ± 0.7g	17.7 ± 0.4e	159 ± 4c	66 ± 4c
PTMB5	56.7 ± 1.1b	59.7 ± 1.2ab	88 ± 2bcd	20.5 ± 0.5b	207 ± 12b	109 ± 18b
PTMB6	53.5 ± 0.7c	55 ± 1c	85.5 ± 0.7def	19.2 ± 0.7cd	210 ± 11b	106 ± 9b
PTMB7	53.2 ± 0.4c	55 ± 0c	84.5 ± 0.7f	20 ± 0.5bc	207 ± 12b	114 ± 14ab
PTMB8	52.7 ± 1.4c	54.2 ± 1.9c	84.5 ± 2.5f	18.5 ± 0.5de	175 ± 10c	80 ± 12c
PTMB9	57 ± 1ab	59 ± 1.5b	90.5 ± 0.7ab	20.5 ± 0.5bc	220 ± 7ab	127 ± 15ab
DMRESRW	52.5 ± 0.5c	54.5 ± 1c	85 ± 1ef	18.7 ± 0.7de	161 ±17c	79 ± 11c

For each trait, means followed by the same letter are not significantly different at the 5% level.

DISCUSSION

The seeds of the traditional populations were collected from farmers who usually draw them from their harvests without respecting the principles of conservative selection. The traditional populations evaluated resulted then from diverse evolutions depending on factors able to modify allelic frequencies (sample size, uncontrolled hybridizations, mutations, selection and mixtures notably).

Relatively important earliness differences up to 13 days were observed among traditional populations. Nevertheless, populations ranking for days to flowering (pollen-shed or silking) and days to maturity showed some dissimilarities due to differences of maturation phase (flowering – maturity phase) duration. The maturation phase which includes grain filling phase is an important period of yield elaboration. In tropical zone, any lengthening of the grain filling phase may be directly beneficial for yield (Edmeades and Tollenaar, 1988; Feil et al., 1992). For plant and ear heights, populations ranking was similar. The high correlation between those two traits reported by Kim and Hallauer (1989) may explain that. A great variability of grain yield shown by high standard error was observed for some populations. Its cause may be the heterogeneity of the experimental environment and/or the populations. Further evaluation may permit to obtain more precise values.

The principal components analysis showed that grain yield was not correlated with cycle duration. Such a result is unusual in maize. Generally, grain yield is positively correlated with cycle duration. The result obtained is, nevertheless, in agreement with those reported by Abadassi (2013). That author compared two types of improved tropical maize populations during two years in two locations of Benin and found that the most yielding variety was not the latest population but the earliest. The genetic constitution of the populations may explain the discordance.

Table 3: Population means and their standard errors for rust score, husk cover and grain yield and its components.

Population	Trait					
	Rust	**Husk cover**	**Number of ears per plant**	**Number of grains per ear**	**1000 grain weight (g) (1)**	**Grain yield (kg/ha) (1)**
PTMB1	1.7 ±0.4b	1 ±0b	0.80 ±0.24d	297±18abc	231±6	2592±1056
PTMB2	1.7 ±0.4b	1.2 ±0.4b	0.87 ±0.08cd	333 ±37a	219±2	2900±519
PTMB3	1.7 ±0.4b	1 ± 0b	1.17 ±0.04ab	326 ±26ab	233±24	3667±278
PTMB4	3.7 ±0.4a	1.7 ±0.4b	1.23 ±0.21a	235 ±18d	254±23	3263±451
PTMB5	1.7 ±0.4b	1.5 ±0.7b	0.94 ±0.10bcd	305 ±30abc	229±28	2700±461
PTMB6	1.5 ±0.5b	1 ±0b	1.12 ±0.14abc	270 ±32bcd	244±11	3088±537
PTMB7	1.7 ±0.6b	1.2 ±0.5b	1.18 ±0.07ab	256 ±19cd	245±17	3200±475
PTMB8	1.5 ±0.7b	3 ±0a	0.91 ±0.08cd	334 ±39a	248±23	3357±528
PTMB9	1.2 ±0.4b	1.5 ±0.7b	1.05 ±0.07abcd	336 ±14a	250±19	3852±386
DMRESRW	1.5 ± 0.5b	3 ±0a	0.93 ±0.07bcd	317±27ab	240±29	3108±473

For each trait, means followed by the same letter are not significantly different at the 5% level.
(1) For that trait, population effect was not significant ($P>0.05$).

Table 4: Principal components analysis: eigenvalues.

	AXIS 1	AXIS 2
Eigenvalue	2.794	0.949
Proportion of total variability represented (%)	69.847	23.734

Table 5: Principal components analysis: squared cosines of the variables.

	AXIS 1	AXIS 2
Days to 50% silking	0.961	0.002
Days to 50% maturity	0.924	0.003
Plant height	0.802	0.057
Grain yield	0.106	0.888

Table 6: Principal components analysis: simple linear correlation matrix of the variables.

Variables	Days to 50% silking	Days to 50% maturity	Plant height	Grain yield
Days to 50% silking	1	0.959**	0.836**	-0.269 [ns]
Days to 50% maturity	0.959**	1	0.786**	-0.245 [ns]
Plant height	0.836**	0.786**	1	-0.096 [ns]
Grain yield	-0.269 [ns]	-0.245 [ns]	-0.096 [ns]	1

** Highly significant (1% level); [ns] non-significant.

On the basis of the means, certain populations such as PTMB1 and PTMB2, PTMB3 and PTMB9, PTMB6 and PTMB7 appeared relatively close for most of the traits studied. They could have derived from the same original traditional population which could have evolved differently due to its growing in farmers' fields in different conditions and beside different populations with which natural mating could have occurred. They may also originate from different original populations which could have drawn nearer after natural mating favoured by growing in neighbouring fields. Another cause of original population evolution may be the empiric selection applied by farmers while drawing seeds from the harvests.

The absence of significant difference between the improved population DMRESRW and the traditional populations for grain yield was not expected. Introduced improved maize varieties generally have grain yield potentials higher than those of traditional populations (Kossou et al., 1993; Abadassi, 2001, 2013). The similarity observed may be due, partially, to gene flows between the improved population and the traditional populations cultivated sometimes side by side in farmers' fields in Benin. Further work involving several locations will permit to compare more precisely the traditional populations and DMRESRW for grain yield.

Molecular markers widely used to evaluate genetic relationships among populations (Sanou et al., 1997; Garcia et al., 2004; Beyene et al., 2005, 2006; Bige and Lorenzoni, 2007; Bernardo, 2008; Karanja et al., 2009; Morales et al., 2010; Arief et al., 2013) may permit to specify the genetic relationships among the populations studied.

Conclusion

Significant differences were noted among the traditional populations evaluated for earliness, plant and ear heights, number of ears per plant and number of grains per ear. One population (PTMB4) was susceptible to rust. All populations except one (PTMB8) had good husk cover. The traditional populations gave relatively low grain yields and no significant difference was observed among populations for that trait.

The 9 traditional populations are already preferred by Beninese producers and

consumers to the introduced improved varieties particularly for the good quality of their grains and their relatively low susceptibility to storage pests and are widely cultivated. But, their grain yields may be improved without modification of the characteristics needed in them. The populations PTMB4 and PTMB8 should, in addition, be improved respectively for rust resistance and husk cover. Release of such improved populations, will contribute to increase maize production in Benin.

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