Evaluation of Medium Maturity, High-tillering Pearl Millet Population Diallel in Niger

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Introduction

Pearl millet [*Pennisetum glaucum* (L.) R. Br.] is the most important staple crop of millions of people in the semi-arid and arid regions of Asia and sub-Saharan Africa. In 1998, ICRISAT pearl millet scientists in southern and western Africa and India initiated global pearl millet diallel crosses with the aim of promoting systematic diversification of elite regional germplasm (Bidinger et al. 2000). The project produced trait-based sets of diallel crosses among elite landrace and breeding materials from each of the three major pearl millet-growing regions. This study evaluates the potential of the medium-maturity, high-tillering population diallel as new source material for use in breeding programs in the Sahelian zone of West Africa, especially Niger.

Materials and Methods

The medium-maturity, high-tillering population diallel was derived from crossing 12 diverse pearl millet populations (Table 1) in all possible combinations without reciprocals (Bidinger et al. 2000). The corresponding 66 F_1 populations were grown together with 15 standards (11 local African cultivars, two Indian elite hybrids and their two restorer lines) in a 9 × 9 lattice design with three replications at the ICRISAT research station, Sadoré, Niger (13°29′N, 02°10′E; altitude 217 m.a.s.l.), in the rainy season of 2005. The total amount of rain received during the trial period was 457.5 mm, well-distributed apart from a dry spell of 12 days at the end of June (beginning two weeks after sowing). The field was fertilized with 37.5 kg N ha^{-1}, 15 kg P ha^{-1} and 15 kg K ha^{-1}. Plots were two rows of 4.80 m

Table 1. Pearl millet populations and varieties chosen as parents for the medium-maturity, high tillering-diallel cross (Bidinger et al. 2000).

Parent population/variety	Origin/description
High-tillering population 88 (HITIP 88)	Composite bred by ICRISAT-Patancheru from 13 high-tillering lines from the ICRISAT pollinator collection of both Indian and African origin
ICMP 89410	Cycle 10 bulk of the Medium Composite bred by ICRISAT-Patancheru from Indian and African parents
Senegal population	Population bred by ICRISAT-Patancheru from progenies selected for high growth rate and from crosses involving a *shibra* from Senegal
SDGP 2025	Elite landrace accession from Namibia, identified by the Department of Agricultural Research and Training, Namibia, and ICRISAT-Zimbabwe
RCB-IC 625	Variety bred by ICRISAT-Patancheru and the Rajasthan Agricultural University, Fatehpur, from the *Jakharna* landrace of central Rajasthan
RAJ II	Composite bred from selected landraces from central Rajasthan by the Rajasthan Agricultural University, Jobner
New Elite Composite II (NELC-II)	Composite bred by ICRISAT-Patancheru from crosses involving the original New Elite Composite and various other late-maturity populations
Early Composite II (EC-II)	Composite bred by ICRISAT-Patancheru from early-flowering progenies from a number of ICRISAT composites
Medium-Maturity Composite (MMC)	Broad-based composite bred by ICRISAT-Nigeria from 200 mainly West African varieties and landraces flowering between 50 and 70 days in trials in northern Nigeria
ICMV IS 89305	Released variety bred by ICRISAT-Niger from a cross of 3/4 *Hainei-Khirei, Souna* 38 and *CIVT*
SDGP 2045	Elite landrace accession from Namibia, identified by the Department of Agricultural Research and Training, Namibia and ICRISAT-Zimbabwe
SDGP 2182	Elite landrace accession from Namibia, identified by the Department of Agricultural Research and Training, Namibia and ICRISAT-Zimbabwe

length spaced 0.75 m apart. Sowing was done in hills spaced 0.8 m apart with the hills thinned to two plants per hill. Data were collected on a range of characters (Table 2). Plant height, panicle length, exsertion and circumference were recorded on the basis of three plants per plot; all other traits were determined on a plot basis. Data were analyzed according to the lattice design. Lattice-adjusted mean values were used in the diallel analysis according to Griffing's (1956) method 4 (crosses only). All computations were performed with the aid of computer software PLABSTAT (Utz 1998; 2001) and PZ14 (Utz 1992).

Results and Discussion

The overall yield level of the trial was 127 g m^{-2}, reflecting moderate stress levels in the experiment. The lattice efficiency for grain yield was 111%, pointing to the usefulness of the design at the test site with high soil microvariability. There were significant differences among the 66 population crosses with the entries revealing wide ranges of trait values for all characters except 1000-grain weight (Table 2). The plot-based heritability estimates were overall moderate to high (probably overestimated because of single-location data). While the majority of population crosses were earlier-flowering and lower-yielding than the local improved standards Zatib, Sosat-C88 and HKN, two out of the 66 population crosses (MMC × ICMV IS 89305, IS 89305 × SDGP 2045) significantly outyielded them. Another 12 crosses produced yields similar to the local standards (range 150–200 g m^{-2}) but had a wide range of flowering dates. These crosses are thus potentially useful for diversifying local breeding programs for flowering time, plant height or panicle characteristics. High grain yield in the population crosses was associated with late flowering (r = 0.64**, P = 0.01), tall plants (r = 0.65**, P = 0.01) and long panicles (r = 0.55**, P = 0.01). Grain yield was not associated with the number of tillers per hill. High tillering occurred mainly in early-flowering hybrids with shorter height, shorter heads and good panicle exsertion (data not presented).

The variance of general combining ability (*gca*) effects was highly significant for all traits (Table 3) except 1000-grain weight for which differences among the population crosses were nonsignificant. Variance of specific combining ability (*sca*) effects was significant for days to 50% flowering, head and grain yield, panicle length and circumference and number of tillers per hill. The size of *sca* variance relative to *gca* variance reflects a relatively high importance of *sca* effects for the traits head yield and grain yield. This was also reflected in the highly significant coefficient of correlation between hybrid performance and *sca* effects (r = 0.58**, P = 0.01) for grain yield.

Among the parental populations, HITIP 88 and ICMP 89410 were good general combiners for early flowering with little negative effects on grain yield (Table 3). The Senegal Population proved useful for reducing plant height without moving toward earlier flowering in its progenies. The best general combiners for head and grain yield were ICMV IS 89305 (Niger), MMC (Nigeria), SDGP 2025 and SDGP 2045 (Namibia). The parental populations originating from Rajasthan (RCB-IC 625 and RAJ II) had very low general combining ability for grain yield under the growing conditions in Niger.

Table 2. Mean, minimum (Min.) and maximum (Max.) values of 66 crosses forming the medium-maturity, high-tillering diallel, significance (Sign.) of genetic differences among the crosses, estimated heritabilities on plot basis (h^2), performance of the best local improved standard (HKN) and least significant differences for entry means at the 5% probability level (LSD 5%) for various traits assessed at Sadoré, Niger, rainy season, 2005.

Trait	Mean	Min.	Max.	Sign.	h^2	HKN	LSD (5%)
Days to 50% flowering (d)	55	45	68	**	0.93	67	4
Head yield (g m^{-2})	185	87	362	**	0.83	269	73
Grain yield (g m^{-2})	129	69	265	**	0.84	186	54
1000-grain weight (g)	7.4	6.4	8.4	NS	–	7.3	1.2
Plant height (cm)	227	180	284	**	0.71	276	36
Panicle length (cm)	35	24	54	**	0.87	62	6.0
Panicle circumference (cm)	8.7	7.0	10.7	**	0.79	8.0	1.0
Panicle exsertion (cm)	3.9	-5.6	9.4	**	0.52	–8.8	6.0
Tillers $hill^{-1}$	4.4	2.7	7.3	**	0.80	2.4	1.6

**Significant at P = 0.01.
NS = Nonsignificant.

Table 3. Estimated components of variance for general (Vgca) and specific combining ability (Vsca), and *gca* effects of parental populations at Sadoré, Niger, 2005.

	Days to 50% flowering	Head yield	Grain yield	Plant height	Panicle length	Panicle circumference	Panicle exsertion	Tillers $hill^{-1}$
Estimated variance components								
Vgca	13.2**	973.4**	571.8**	206.6**	13.2**	0.2**	2.3**	0.5**
Vsca	1.8**	701.9**	408.3**	40.1^{NS}	3.7**	0.1*	0.3^{NS}	0.2**
Estimated *gca* effects of the parental populations and their standard error (SE)								
HITIP 88	–4.5	0.6	–4.6	–16.9	–6.1	–0.6	2.4	1.7
ICMP 89410	–2.3	–5.1	–3.4	–11.6	–2.9	0.2	1.5	0.1
Senegal Population	0.5	–10.8	–6.7	–14.2	–1.1	0.1	–0.5	–0.3
SDGP 2025	6.5	20.3	21.2	18.2	2.4	0.4	–0.3	–0.9
RCB-IC 625	–4.7	–34.3	–27.6	–13.6	–1.0	–0.8	1.6	1.2
RAJ II	–3.1	–50.2	–36.1	–12.0	–1.1	–0.6	1.0	–0.1
NELC-2	–1.8	–18.9	–16.2	–8.6	–0.7	0.5	0.2	0.0
EC-2	–2.6	–24.6	–20.0	–5.4	–2.4	0.6	–0.3	–0.2
MMC	2.7	35.7	26.4	10.2	0.0	–0.4	–0.3	0.1
ICMV IS 89305	4.1	68.7	51.2	16.4	9.2	0.0	–3.2	–0.4
SDGP 2045	3.1	26.5	21.2	21.8	2.3	0.3	0.4	–0.6
SDGP 2182	2.3	–8.0	–5.5	15.6	1.4	0.4	–2.5	–0.8
SE±	0.7	11.4	8.6	6.7	1.0	0.2	1.1	0.3

*Significant at $P = 0.05$. **Significant at $P = 0.01$. NS = Nonsignificant.

Conclusions

The medium-maturity, high-tillering population diallel had significant genetic variation for phenological and morphological traits including grain yield when tested under rainfed Sahelian conditions in Niger. While the majority of the population crosses flowered too early and were lower-yielding than the adapted local standards, two population crosses derived from West African and Namibian materials were superior to the best local standards, and another 12 crosses were nearly equal to the standards for grain yield, but partially different for flowering date. It would be worth the effort to (1) directly exploit the two highest-yielding population crosses to produce experimental, open-pollinated varieties for further testing (stable performance after one generation of random mating); and (2) use selected parental populations with positive *gca* for traits of value as parents in crosses with good local materials in pearl millet breeding programs targeting the Sahelian zone of West Africa.

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