Z. Pflanzenzüchtg. 94, 201—207 (1985)

ISSN 0044-3298 / InterCode: ZEPZAD

International Crops Research Institute for the Semi-Arid Tropics (ICRISAT), Andhra Pradesh (India)

Inbreeding Depression in Pearl Millet Composites[1])

K. N. Rai, D. J. Andrews and V. Suresh Babu

With 3 tables

Received January 18, 1984 / Accepted February 25, 1984

Abstract

The objective of this investigation was to examine the effects of one generation of selfing on grain yield, plant height, head length, 1000 seed weight, and days to flowering in the base populations as well as in three successive full sib recurrent selection cycle bulks of the Medium Maturity Composite and Serere Composite-1 of pearl millet [*Pennisetum americanum* (L.) Leeke]. The experimental materials consisted of random mated bulks and single generation selfed bulks from 400 random plants corresponding to each cycle (cycle 0 to 3) of both the composites. Results showed that average inbreeding depressions in both the composites were highest for grain yield (25 % and 36 %) followed by 1000 seed weight (12 % and 14 %). Plant height, days to flowering and head length were least affected by selfing, with the average inbreeding depressions for these characters ranging from 4 % to 7 %. There were no indications that the extent of inbreeding depressions in the advanced cycle bulks were less than those in the base populations or initial cycle bulks which might have resulted, in part, due to the relatively large number of progenies (24—46) recombined in each cycle of recurrent selection.

Key words: *Pennisetum americanum* — recurrent selection — inbreeding depression

The literature on the genetic architecture of crop plants indicates that additive as well as non-additive genetic effects, mostly of dominance to partial dominance type, account for much of the genetic variability in many quantitative characters (Moll and Stuber 1974). In the presence of dominance, inbreeding in heterozygous materials will invariably lead to inbreeding depression which will be reflected in loss of vigour, reduced fecundity and exposure of deleterious recessives (Allard 1960). Since protogyny in pearl millet [*Pen-*

[1]) Approved as ICRISAT Journal Article No. JA 382.

nisetum americanum (L.) Leeke] leads to outcrossing rates ranging between 70—80 per cent (BURTON 1974), the population structure of this crop is expected to be highly heterozygous and heterogeneous, and, therefore, is likely to exhibit inbreeding depression upon selfing.

One or two generations of inbreeding in composite populations are used to generate S_1 or S_2 progenies, while conducting recurrent selection in pearl millet. More prolonged inbreeding is practiced when generating inbred lines for utilization as parents in the development of hybrids and synthetics. Depression in yield and other characters following inbreeding in this crop has been observed in almost every group of heterozygous materials (i.e., F_1's, F_2's, composites). However, only a few reports are available on the quantitative estimates of inbreeding depression (POKHRIYAL et al. 1966, KHADR and EL-ROUBY 1978, GOVIL and RANA 1983). The purpose of this paper is to provide further information on the magnitude of inbreeding depression for various quantitative characters following one generation of selfing in population bulks derived from several cycles of recurrent selection in two different pearl millet composites.

Materials and Methods

Recurrent selection cycle bulks of a Medium Maturity Composite and Serere Composite-1, were used in this study. The Medium Maturity Composite was developed at ICRISAT by random mating 197 geographically diverse lines of Indian and African origin, all flowering in 45—55 days. Serere Composite-1, which flowers in 47 days and has relatively narrower genetic base, was introduced from Uganda. The selection method followed, and the number of progenies evaluated and recombined in each cycle of both the composites are given in *Table 1*.

Tab. 1 Recurrent selection methods and number of progenies evaluated/recombined in two pearl millet composites

Composite	Progenies Test	$C_0 \longrightarrow C_1$	$\longrightarrow C_2$	$\longrightarrow C_3$*
Medium Maturity Composite	Selection method	Full-sib	Full-sib	Full-sib
	Progenies evaluated	538	206	278
	Progenies recombined	46	24	28
Serere Composite-1	Selection method	S_1	S_2	Full-sib
	Progenies evaluated	186	198	198
	Progenies recombined	24	26	29

*C_0, C_1, C_2 and C_3 refer to the base bulk and the subsequent cycle bulks, respektively

Four random mated bulks (cycles 0 to 3) from each composite were grown at ICRISAT Center during January—April offseason of 1980. Each bulk consisted of about 2600 plants. Four hundred random plants were selfed in each bulk and an equal amount of seed from each plant was bulked together to constitute the respective selfed bulks. The Medium Maturity Composite Bulk Trial and Serere Composite-1 Bulk Trial were conducted as separate experiments but in the same field, planted simultaneously side-by-side and receiving similar treatments in terms of plot size and management. Each experiment containing four random mated bulks and the four respective selfed bulks was planted in randomized complete block design with four replications. Plots consisting of eight rows spaced 75 cm apart and 4 m long were seeded continuously with a machine planter, and thinned to single plants 10 cm apart, 10—12 days after emergence.

Days to 50 % flowering was recorded on a plot basis. The central six rows of each plot were used for recording grain yield, with a sample of 25 competitive plants used for plant height and head length measurements. One kilogram of heads were sampled from each plot and threshed to estimate grain yield per plot. Thousand seed weight was obtained by weighing three samples of 100 seeds each from each plot. The analysis of variance was done according to STEEL and TORRIE (1960). Inbreeding depression was calculated as [100 (random mated bulk — selfed bulk)/random mated bulk].

Results and Discussion

The analysis of variance showed significant difference among bulks for all the characters except for 1000 seed weight in the Medium Maturity Composite and plant height in Serere Composite-1 (*Table 2*). The major proportion of this variability, however, was accounted for by differences between random mated bulks vs. selfed bulks, indicating significant inbreeding depression for all the characters in both the composites. In general, there were no significant differences either among random mated bulks or among selfed bulks, nor was there any indication of a trend in the magnitude of inbreeding depression over cycles (*Table 3*). Though not significant, the gain in grain yield over four cycles in both the composites averaged about 4 % per cycle.

One generation of selfing, which amounts to an inbreeding coefficient of 0.50, led to decline in grain yield, 1000 seed weight, ear length and plant height, and delayed days to 50 % flowering in both the composites (*Table 3*). Since the direction of inbreeding depression is always towards the value of more recessive alleles (FALCONER 1960), the results indicate that shorter plants, smaller heads, lower 1000 seed weight and grain yield, and lateness, are governed by a preponderance of recessive alleles. Inbreeding depression in both the composites was highest for grain yield (averaging about 36 % and 25 %) followed by 1000 seed weight (averaging about 12 % and 14 %). Plant height, days to 50 % flowering and head length were also affected by inbreeding but to a much lesser extent, with the average inbreeding depressions in both composites ranging between 4 % to 7 %. In their studies on the effects of inbreeding in two pearl millet populations, GOVIL and RANA (1983) observed more inbreeding depression for grain yield than for other characters, with its magnitude for the same character varying considerably from one population to the other. Though yield evaluation of all the three composites were not done in the same year, KHADR and EL-ROUBY (1978) also observed considerable variation in the levels of inbreeding depression from one composite to the other, with the levels similar to those observed in our study. This shows that effects of one generation of inbreeding in pearl millet are of similar nature to those reported in maize (see HALLAUER and MIRANDA 1981) where inbreeding had greater effects in reducing the grain yield, and lesser effects in reducing

Tab. 2 Analysis of variance for grain yield and four other characters in the selfed bulks (SB) and random mate bulks (RMB) of two pearl millet composites

Composite	Source of variation	Degrees of freedom	Mean square				
			Plant height (cm)	Days to 50% flowering	Head length (cm)	1000 seed weight (g)	Grain yield (kg/ha)
Medium Maturity Composite	Replication	3	138.2*	7.37**	1.71	0.13	339620*
	Bulks	7	224.7**	10.53**	3.27**	1.10	488030**
	RMB	3	35.0	0.90	2.73*	0.31	92400
	SB	3	55.7	0.67	2.23	0.68	27285
	RMB vs–SB	1	1300.5**	69.03**	8.00**	4.73*	3057140**
	Error	21	33.9	0.86	0.85	0.80	73110
Serere Composite-1	Replication	3	722.3**	4.79**	9.75**	0.16	271540**
	Bulks	7	90.6	6.34**	5.72**	2.14**	311910**
	RMB	3	72.3	2.25**	2.40	0.54	92120
	SB	3	34.9	0.50	7.60**	0.86	29100
	RMB vs–SB	1	312.5*	36.13**	10.13**	10.81**	1819710**
	Error	21	52.0	0.39	1.06	0.51	47510

*, ** Significant at 0.05 and 0.01 probability levels, respectively

Tab. 3 Mean values (RMB) and inbreeding-depression (ID in percent) for grain yield and other characters in four population bulks (C_0 to C_3) in two pearl millet composites

Composite	Cycle	Plant height (cm)		Days to 50% flowering		Head length (cm)		1000 seed weight (g)		Grain yield (kg/ha)	
		RMB	ID	RMB	ID	RMB	ID	RMB	ID	RMB	ID
Medium Maturity Composite	C_0	206	5.5	45.8	-4.9	25.0	5.0	6.2	8.1	1563	36.7
	C_1	200	6.6	44.8	-7.3	23.0	-1.1	6.6	7.6	1664	34.4
	C_2	202	7.3	45.0	-7.8	23.8	4.2	6.5	20.0	1924	38.4
	C_3	199	5.9	44.8	-6.2	24.0	8.3	6.9	11.6	1721	34.3
	Mean	202	6.3	45.1	-6.6	24.0	4.1	6.6	11.8	1718	36.0
	SE ±	2.9		0.46		0.46		0.04		135	
Serere Composite-1	C_0	189	2.1	46.3	-5.4	22.0	4.6	8.2	19.5	1779	20.2
	C_1	198	5.6	46.3	-4.9	21.8	8.1	8.4	10.7	1985	27.0
	C_2	191	3.2	47.8	-3.1	22.5	6.7	7.5	12.0	1824	25.6
	C_3	197	5.1	46.3	-4.9	23.5	1.1	7.9	15.2	2102	25.9
	Mean	194	4.0	46.7	-4.6	22.5	5.1	8.0	14.4	1924	24.7
	SE ±	3.6		0.31		0.51		0.04		109	

the plant height, cob size, 1000 kernel weight and increasing the days to flowering. The type of gene action and gene frequencies at loci governing the characters undergoing recurrent selection would determine the magnitude of inbreeding depression (FALCONER 1960). Unlike KHADR and EL-ROUBY (1978), we found no indication of reductions in the magnitude of inbreeding depression in the advanced cycle bulks as compared to initial (base) cycle bulks. Such varied results have been obtained in maize as well. For instance, GENTER (1971) studied inbreeding depression in the base populations as well as advanced populations of two maize synthetics (BSSS and BCBS) and observed that advanced populations registered less inbreeding depression for grain yield than the base populations, irrespective of the genetic gains made by recurrent selection. SMITH (1969), however, found no change in the levels of inbreeding depression over four cycles of selection in the maize cultivar BSK. The type of progeny and the effective population size used during selection program would be expected to affect the estimates of inbreeding depression over cycles, and may account for some of the differences.

Studies on the changes in the performance in relation to inbreeding levels are complicated by associated changing relationship between the heterozygosity levels and the environments. ADAMS and SHANK (1959) and SHANK and ADAMS (1960) reported that stability and expected heterozygosity in corn were positively correlated. In other words, materials derived from inbreeding, which would be relatively less heterozygous and hence less stable, would bear differing relationships with their parental and relatively more heterozygous base populations, depending on the test environments. The inbreeding depression studies may, in part, be also complicated by sampling effects. Random samples of 400 selfed plants from each population bulk used in the present study, however, may be considered adequate enough as not to be significantly influenced by sampling effect.

We may conclude that the overall genetic changes at the dominant loci have been neither steady nor significant and that at such loci there is as much variability in the advanced cycle bulks as in the initial cycle bulks. Also, inbreeding effects in pearl millet can be expected to be substantial for grain yield followed by seed size, and marginal for other characters like plant height, days to flowering and ear length which has relevance to the development of inbred lines from Composites.

Zusammenfassung

Inzuchtdepression in Composite-Populationen von Perlhirse (*Pennisetum americanum*)

Die Inzuchtdepression für die Eigenschaften Ertrag, Pflanzenhöhe, Blütenstandslänge, 1000-Korngewicht und Blütezeit wurde in den Ausgangspopulationen sowie in drei aufeinanderfolgenden Zyklen rekurrenter Vollgeschwisterselektion ermittelt. Sie war am höchsten beim Ertrag (25 % und 36 %) und beim 1000-Korngewicht (12 % und 14 %). Für die anderen drei Eigenschaften

wurden nur Werte zwischen 4 % und 7 % ermittelt. Es gab keinen Hinweis, daß das Ausmaß der Inzuchtdepression nach späteren Zyklen der rekurrenten Selektion geringer war als in den früheren Zyklen oder in der Ausgangspopulation.

Part of the work presented here forms a portion of the Masters thesis work submitted by Mr. SURESH BABU to the Andhra Pradesh Agricultural University, Rajendranagar with the research work done at the International Crops Research Institute for the Semi-Arid Tropics (ICRISAT), Andhra Pradesh (India). An abstract of this work was presented at the XV. International Congress of Genetics, 11—21 December, 1983, New Delhi (India).

References

ADAMS, M. W., and D. B. SHANK, 1959: The relationship of heterozygosity to homeostasis in maize hybrids. Genetics 44, 777—786.

ALLARD, R. W., 1960: Principles of Plant Breeding. New York—London: John Wiley and Sons.

BURTON, G. W., 1974: Factors affecting pollen movement and natural crossing in pearl millet. Crop Sci. 14, 802—805.

FALCONER, D. S., 1976: Introduction to Quantitative Genetics. New York: The Ronald Press Company.

GENTER, C. F., 1971: Yields of S1 lines from original and advanced synthetic varieties of maize. Crop Sci. 11, 821—824.

GOVIL, J. N., and B. S. RANA, 1983: Inbreeding effects of full-sib mating in pearl millet populations. Ind. J. Genet. 43, 33—36.

HALLAUER, A. R., and J. B. MIRANDA, 1981: Quantitative Genetics in Maize Breeding. Iowa State University Press.

KHADR, F. H., and M. M. EL-ROUBY, 1978: Inbreeding depression in the quantitative traits of pearl millet (*Pennisetum typhoides*). Z. Pflanzenzüchtg. 80, 149—157.

MOLL, R. H., and C. W. STUBER, 1974: Quantitative genetics — empirical results relevant to plant breeding. Adv. Agron. 26, 277—313.

POKHRIYAL, S. C., S. B. P. RAO, K. S. MANGATH, and D. D. RAJPUT, 1966: Effects of inbreeding on yield and other characters in pearl millet. Indian J. Genet. 26, 210—216.

SHANK, D. B., and M. W. ADAMS, 1960: Environmental variability within inbred lines and single crosses of maize. J. Genet. 57, 119—126.

SMITH, O. S., 1978: Application of a diallel analysis to evaluate recurrent selection for grain yield in maize. Crop Sci. 19, 819—822.

STEEL, R. G. D., and J. H. TORRIE, 1960: Principles and procedures of statistics. New York: McGraw-Hill Book Company.

Authors' addresses: Dr. K. N. RAI and D. J. ANDREWS, Pearl Millet Improvement, International Crops Research Institute for the Semi-Arid Tropics, ICRISAT — Patancheru P.O., Andhra Pradesh 502 324 (India); V. SURESH BABU, Andhra Pradesh Agricultural University, Rajendranagar, Andhra Pradesh (India).