Morphological Characteristics of Tall and Dwarf Pearl Millet Isolines

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ABSTRACT

Among all the dwarfing genes reported in pearl millet [*Pennisetum glaucum* (L.) R. Br.], the d_2 gene has been most extensively utilized in breeding programs. Its effect on morphological characters, however, has not been adequately studied in the past due to lack of isogenic lines. The objective of this research was to study the effect of the d_2 dwarfing gene on several morphological characters by comparing six pair of tall and dwarf near-isogenic lines (isolines) developed in genetic backgrounds of two diverse composites. Tests conducted on plant and seed characteristics at the ICRISAT Center, Patancheru, India and Tifton, GA, showed that dwarf isolines were shorter but had longer peduncles, longer panicles, narrower panicles, thicker culms, wider leaves, and smaller seeds than their tall counterparts. The differences between tall and dwarf isolines for number of total and effective tillers plant^{-1}, leaf sheath length, and time to 50% anthesis were either nonsignificant or inconsistent across locations. Plant height was the only characteristic studied that was not influenced by genetic background. Genetic variation among isolines for effects of the d_2 gene on numerous characters indicate the gene can be used to advantage by incorporating it into diverse germplasm.

UTILIZATION of dwarfing genes in the development of short-statured cultivars has led to dramatic increases in cereal grain yields (Athwal, 1971). Semidwarf cultivars, as compared to tall ones, respond positively to N fertilization with yield increases, are less susceptible to lodging under high management conditions, and are more amenable to mechanized production systems. Traditional landrace cultivars and improved cultivars of pearl millet are mostly tall, measuring up to 3 m under good growing conditions. The discovery of several dwarfing genes (Burton and Fortson, 1966) made it possible to breed improved cultivars with substantial reduction in plant height. The d_2 dwarfing gene has been most extensively used because it is inherited as a monogenic recessive and it reduces plant height by about 50% (Burton and Fortson, 1966).

Pearl millet improvement programs for forage or grain production in the USA are based to a large extent on the utilization of the d_2 dwarfing gene for the development of semidwarf hybrids. Its utilization in the breeding programs located in traditional pearl millet growing regions in India and Africa has been much less extensive. A major effort in the backcross transfer of this gene into the diverse genetic backgrounds of seven tall composites was initiated in 1975 at the International Crops Research Institute for the Semi-Arid Tropics (ICRISAT), India. Comparison of tall recurrent composites with their dwarf versions, derived after three backcrosses, showed the d_2 gene apparently had no adverse effects on grain yield or several of its components (data not shown). Thakare and Murty (1972) also observed that the d_2 gene had no adverse effects on general combining ability and several developmental traits. These studies, however, were based on the comparisons of tall and dwarf lines or populations that were variable and nonisogenic for the d_2 gene. The objective of this study was to evaluate the effects of the d_2 dwarfing gene on several morphological characters in six pairs of near-isogenic lines developed in the genetic backgrounds of two diverse composites.

MATERIALS AND METHODS

The genetic material in this study consisted of six pairs of near-isogenic lines (hereafter referred to as isolines) in the genetic background of two maturity composites (early composite and medium composite) developed at the ICRISAT Center. The d_2 dwarfing gene from GAM73 (a synthetic developed in Senegal) had been backcrossed three times into both composites. Seven tall plants in each of five BC_3F_3 progenies segregating for tall and dwarf plants were selfed. The F_4 progenies were planted in family blocks. One segregating F_4 progeny from each family block was selected and seven tall plants were again selfed. The F_5 progenies were again planted in family blocks to self 7 to 8 tall plants in one segregating F_5 progeny from each block. This process was repeated until the F_8 generation when both tall and dwarf plants in one segregating progeny of each block were selfed to identify tall and dwarf isolines in F_9 progeny tests in 1984. The tall and dwarf components of each isoline pair would theoretically have a high percentage (98.5%) of common alleles since they were derived from prolonged selfing of plants heterozygous at the D_2/d_2 locus advanced head-to-row in each generation. The six isoline pairs are, however, expected to differ from one another for several genes because five isoline pairs were derived from different BC_3F_2 plants of two composites. Isoline Pairs 5 and 6 were derived from two heterozygous plants of the same BC_3F_3 progeny.

All six pairs of isolines were evaluated in two tests: one conducted at the ICRISAT Center, Patancheru, India during the rainy season of 1987, and the other conducted at the Coastal Plain Experiment Station, Tifton, GA, in the summer season of 1987. At the ICRISAT Center, the test was planted on 26 June in 4-row plots of 2-m length with 75-cm spacing between rows. At Tifton, the test was planted on 30 June in 2-row plots of 5-m length with 60-cm spacing between rows of a plot and 120-cm between plots. At both locations, plots were overplanted and thinned 13-d later to single plants with 20-cm spacing between plants at the ICRISAT Center and 30-cm spacing at Tifton. At the ICRISAT Center, 40 kg N and 17.5 kg P ha^{-1} were applied preplant, with another 40 kg N ha^{-1} side dressed 21 d after planting. Plots received 14 kg N, 12.2 kg P, and 34.9 kg K ha^{-1} preplant at Tifton.

Time to 50% anthesis (days) was recorded on a plot basis when the main panicle of 50% of the plants in a plot exserted stigmas. Five plants from the central two rows of each plot at the ICRISAT Center and from both rows of each plot at Tifton were used to determine plant height, peduncle length, panicle length, length of leaf sheath and leaf blade, leaf width, thickness of panicle and culm, and number of tillers

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per plant according to the procedure given in descriptors for pearl millet (IBPGR/ICRISAT, 1981). At the ICRISAT Center, main panicles were harvested and sun-dried for 10 d. Main panicles of the plants used for the above observations at Tifton were covered within a week after anthesis with brown bags. At maturity, bagged panicles were harvested and oven-dried at 37 °C for 5 to 7 d. Individual panicles from both tests were threshed, and a random sample of 100 seeds from each of five panicles within each of four replications was weighed to determine 100 seed weight. The treatment design for both locations was a split-plot with isoline pairs as main plots, and tall and dwarf isolines within a pair as subplots placed in a randomized complete-block design with four replications. Plot means were used for analyses of variance to determine location effects. A *t*-test was used to detect differences due to the d_2 gene at each location.

RESULTS AND DISCUSSION

The differences among isoline pairs and between locations were highly significant ($P < 0.01$) for all the characters indicating that the effect of the d_2 dwarfing gene was studied in diverse genetic background and environment.

The d_2 dwarfing gene significantly ($P < 0.01$) reduced the average plant height by 45% at Tifton and by 38% at the ICRISAT Center (Table 1). However, mean peduncle length increased by 33% at Tifton and 22% at the ICRISAT Center, respectively, due to the d_2 gene. Peduncle length for one pair at each location (different pair at each location) was of similar length for both the dwarf and tall isolines. Reduction in plant height coupled with general increase in peduncle length due to the d_2 gene in pearl millet is in contrast to the positive association between these two characters reported in wheat, *Triticum aestivum* L., (Powell and Schlehuber, 1967), oat, *Avena sativa* L., (Kolb and Marshall, 1984), and sorghum, *Sorghum bicolor* (L.) Moench, (Brooks, 1967; Campbell and Cassady, 1969). Some studies in sorghum (Cassady, 1967; Schertz, 1973), however, have reported a neutral or negative association between plant height and peduncle length.

Effect of the d_2 gene was generally significant ($P < 0.01$) for increasing the mean panicle length, culm diameter, and leaf width, and in decreasing the mean panicle diameter and 100 seed weight in tests at both locations (Table 1). Magnitude of the d_2 gene effects on these characters, however, showed variation among isoline pairs and between locations. For instance, the panicle length of dwarf isolines was longer than for their tall counterparts in two isoline pairs and equal in four isoline pairs at Tifton. At ICRISAT Center, however, the panicle length of dwarf isolines was longer than for their tall counterparts in three pairs, shorter in one pair and equal in two pairs. Similarly, dwarf isolines had wider leaves than their tall counterparts in three isoline pairs in the Tifton test, but only in one isoline pair in the ICRISAT test.

The dwarf isolines had a significantly longer leaf sheath ($P < 0.01$) and took less time to 50% bloom ($P < 0.05$) than their tall counterparts in the test at ICRISAT Center (Table 1). These differences, however, were nonsignificant in the Tifton test. The effect of the d_2 gene on mean number of total tillers plant^{-1} or effective (with inflorescence) tillers plant^{-1} was nonsignificant at both locations. For some pairs, however, the difference between tall and dwarf isolines were significant either at one or both locations, and the direction of change was generally in favor of the dwarfs having more tillers than their tall isolines.

Dwarfing genes may become active during the early stages of plant development and hence could pleiotropically affect numerous other characters. Peduncle length may be one such character. The effect of linkages on peduncle length and other characters, however, cannot be ruled out. The isogenic lines of the present study were produced by inbreeding of plants heterozygous at the D_2/d_2 locus, which would tend to overcome linkages between the d_2 gene and genes af-

Table 1. Morphological characteristics of tall (T) and dwarf (D) pearl millet isolines.

Character	Location	Mean T	Mean D	*t*-test	No. of isoline pairs where† T > D	T = D	T < D
Plant height, cm	Tifton	171	94	**	6	0	0
	ICRISAT	133	83	**	6	0	0
Peduncle length, cm	Tifton	20.3	26.9	**	0	1	5
	ICRISAT	22.8	27.9	**	0	1	5
Panicle length, cm	Tifton	21.9	23.4	**	0	4	2
	ICRISAT	19.0	20.7	**	1	2	3
Panicle diam., mm	Tifton	21.9	20.5	**	1	5	0
	ICRISAT	19.9	19.2	**	2	4	0
Culm diam., mm	Tifton	8.8	9.8	**	0	4	2
	ICRISAT	7.8	8.1	*	0	5	1
Leaf width, mm	Tifton	35.9	39.3	**	0	3	3
	ICRISAT	25.1	26.4	*	0	5	1
Leaf sheath length, cm	Tifton	13.6	13.7	NS	1	4	1
	ICRISAT	13.5	14.0	**	0	4	2
Time to 50% bloom, d	Tifton	61.3	61.5	NS	1	4	1
	ICRISAT	57.2	56.0	*	0	6	0
Total tillers plant^{-1}	Tifton	6.6	7.5	NS	0	4	2
	ICRISAT	5.2	5.2	NS	0	6	0
Effective tillers plant^{-1}‡	Tifton	3.6	4.1	NS	0	5	1
	ICRISAT	2.6	2.8	NS	1	4	1
100 seed wt., g	Tifton	0.68	0.62	**	3	3	0
	ICRISAT	0.59	0.54	**	2	4	0

*,** Statistically significant at 0.05 and 0.01 levels of probability.
† No. of pairs where differences were statistically significant ($P = 0.05$).
‡ Tillers that produced inflorescences.

fecting other characters. However, close linkages in some studies have been shown to persist much longer than would ordinarily be expected (Harding and Allard, 1965; Tsunewaki and Koba, 1979). Large genetic variation between isoline pairs for the effect of the d_2 gene on numerous characters indicate that the positive effects of this gene can be exploited to advantage by incorporating it in germplasm of diverse genetic background.

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