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Sources of dwarfism in pigeonpea

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ABSTRACT

Twelve dwarf pigeonpea stocks available at ICRISAT Center were characterized for their phenology and various agronomic traits to assist breeders in selecting donor parents. Variation among the dwarfs was highly significant for all the traits studied. Plant spread, number of primary branches, length of fruiting branches, pods/cluster, and pods/plant were positively associated both with plant height and yield. As such, all the dwarf stocks yielded less than the standard tall types. Studies on the dominance relationships indicated the presence of non-allelic genes for dwarfism in D_0, D_1, D_2, D_3, D_4, D_5, D_8 and C_0. On the contrary, D_6, PD_1 and PBNA had the same gene for dwarfism.

Pigeonpea (*Cajanus cajan* (L.) Millsp.) is an important pulse crop on the 3.4 million hectares of rainfed dry areas of Indian subcontinent, Africa and the West Indies. The long-duration tall cultivars grown in these areas are well suited to the traditional intercropping situations since they effectively utilize residual soil moisture in rainfed subsistence agriculture. Realization of the full yield potential of these pigeonpea types is often restricted due to insect damage. Surveys conducted by entomologists have estimated that in farmers' fields insect damage ranges from 33.8 to 49.9% (2). In the absence of insect-resistant varieties, it appears that any attempt to increase pigeonpea productivity is unlikely to make an impact without effective chemical control of the insect pests. This is probably one of the reasons that pigeonpea yields from conventional tall types are persistently low over decades even in areas where it has higher yield potential. Earliness and determinate growth habit are helpful parameters in reducing canopy height in pigeonpea. However, when these types are grown around the longest day at higher latitudes, they also tend to grow over 2 m in height. Agronomic shortening of plant stature is also possible in pigeonpea by planting the crop during reducing daylengths (10). This approach, however, cannot be utilized commercially because of the existing rainy season-dependent cropping systems. This paper characterizes the sources of genetic dwarfism available at ICRISAT Center for their inheritance and some qualitative and quantitative traits.

MATERIALS AND METHODS

For characterization, 12 dwarf sources were planted alongwith two normal height cultivars, C 11 and BDN 1, on Vertisols in a

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Complete Randomized Block Design with three replications. The planting was done on July 7, 1988 on ridges 60 cm apart with an intra-row spacing of 20 cm. Each plot consisted of six rows, 4 m long. The experiment was irrigated thrice during the postrainy season. A mixture of pre-emergence herbicides Basalin and Prometryn was applied and two post-emergence weedings were done to keep the experiment weed-free. Six sprays of Thiodan were given to control pod-boring insects.

Data on days to 50% flowering and 75% maturity were recorded on a plot basis. In each plot five competitive plants were tagged randomly to record observations on yield, yield components, and leaf characters. Data on qualitative traits such as growth habit, plant spread, brittleness of branches and stem, pod and seed colour were also recorded. To measure leaf traits the methodology followed by Saxena and Sharma (7) was used. Simple correlation coefficients were estimated after eliminating the data of the tall cultivars.

To study the dominance relationships among dwarfs, all the lines except D_7 and ICPL 85059 were crossed in a diallel scheme including reciprocals in 1985. In the subsequent season, F_1's and the parents were grown in three-row plots in two replications in Vertisols. Planting was done on ridges 60 cm apart with plant-to-plant spacing of 20 cm. Data on plant type were recorded at the time of flowering.

RESULTS AND DISCUSSION

Origin

Dwarfs D_8 (3) and D_7 were identified from segregating populations of intergeneric crosses of pigeonpea and *Atylosia scarabaeoides* (L.) Benth. Three dwarfs D_1, D_2 and D_3 having different phenotypic expressions were selected from an F_2 population of the cross GW-3-191 x Br 465. D_4 originated spontaneously in a progeny derived from cross EC 100465 x ICP 1. D_5 is a spontaneous mutant from germplasm accession ICP 3940 while D_6 was identified from an X_2 population of cv. BDN 1, irradiated with 25 kr of gamma radiation. C_0, PD_1, and PBNA were introduced from Coimbatore, Gulbarga, and Parbhani, respectively and their exact source is not known. ICPL 85059 was bred at ICRISAT Center from the cross D. x Prabhat.

Morphological description

The plant and seed characteristics of different dwarfs are summarized in Table 1. Differences among the dwarfs were highly significant for all the traits studied. ICPL 85059 was the earliest to flower and mature while D_1 was the latest. D_0 and C_0 were the shortest dwarfing sources. Plant height in other dwarfs ranged between 51.1 and 97.7 cm as against 146.5 and 178.7 cm for controls BDN 1 and C 11, respectively. In D_1, D_8, PD_1 and PBNA the basal internodes are extremely compacted so that the branches appear to radiate from a narrow region of the main stem with an acute angle. The attachment of primary branches to the main stem is very weak and they break easily at the nodes. In D_0 and C_0 every internode is shortened giving an appearance of a miniature plant. Shortening of the internodes in D_2 dwarf is restricted and, unlike D_1 types, the angle between the central axis and the main branches is obtuse resulting in an open plant canopy. In D_3, the dwarfism is a consequence of abnormal internode condensation that is confined to the top 25-30 cm of the main stem while the rest of the plant stature resembles a typical compact normal

Table 1. Some phenological and agronomic characteristics of pigeonpea dwarfs grown at ICRISAT Center, 1988 rainy season

Dwarf line	Days to 50% flower	Days to 75% mature	Plant height (cm)	Plant width (cm)	Primary branches	Fruiting branch length (cm)	Leaf area (mm²)	Leaf weight (g)	Specific leaf weight (mg/mm²)	Petiole length (mm)	Pod length (cm)	Seeds pod	Pod width (mm)	Pods/ cluster	Pods/ plant	100-seed weight (g)	Seed yield/ plant (g)
D_0	135	184	40.5	18.1	4.8	9.2	84	1.7	20.3	12.7	4.4	2.8	7	2.0	27.0	6.0	3.2
D_1	159	240	70.4	58.6	9.6	27.2	133	2.5	18.6	23.6	4.6	3.3	7	3.4	185.6	10.7	35.4
D_2	132	181	97.7	59.4	15.2	30.3	164	3.4	20.6	28.9	5.0	3.3	10	2.3	87.1	12.9	22.5
D_3	145	206	94.7	40.4	13.0	25.7	212	4.3	20.2	24.3	5.4	3.2	12	3.5	82.7	17.1	30.6
D_4	135	184	70.0	46.3	11.3	15.8	146	3.2	21.7	21.2	5.1	3.5	12	3.4	77.5	13.4	26.6
D_5	153	235	84.4	33.6	5.6	20.5	186	3.9	21.8	22.0	4.8	3.0	7	3.0	121.4	9.8	19.1
D_6	127	175	84.4	64.3	12.4	31.8	174	3.0	17.3	24.2	4.4	3.0	7	3.8	261.1	7.7	37.2
D_7	111	155	72.2	54.2	9.6	25.2	161	3.3	20.6	22.1	5.3	3.6	6	3.4	211.2	7.4	37.7
PD_1	132	181	80.0	56.4	11.9	35.9	182	3.4	18.5	22.7	4.8	3.3	7	3.0	224.6	8.8	34.5
PBNA	131	179	78.9	59.0	13.6	28.3	188	3.1	16.7	24.1	4.3	3.0	6	3.5	287.2	6.8	42.8
C_0	129	177	30.3	23.8	5.4	9.9	53	1.4	26.5	17.3	4.3	3.0	6	1.9	41.7	7.4	5.2
ICPL 85059	84	131	51.1	26.7	11.1	18.1	143	2.6	18.2	18.8	4.2	2.9	6	2.3	72.0	5.6	6.0
BDN1 (C)	120	168	146.5	40.8	11.5	33.0	190	3.4	17.9	23.4	4.5	3.3	8	3.2	191.3	8.9	45.5
C 11 (C)	135	177	178.7	37.6	17.3	31.8	201	3.3	16.6	32.6	4.7	3.1	7	3.9	230.2	7.6	89.8
SEm ±	0.8	1.0	3.15	2.93	1.66	3.45	11.2	0.20	0.93	1.39	0.19	0.17	0.6	0.26	18.03	0.43	6.56
CD at 5%	2.33	2.91	9.16	8.52	4.83	10.03	32.55	0.58	2.70	4.04	0.55	0.49	1.74	0.76	52.41	1.25	19.07
CV%	1.0	0.9	6.5	11.5	26.4	24.6	12.2	11.4	8.19	10.6	7.1	9.1	12.5	15.1	20.8	8.0	40.2

pigeonpea plant. The D_5 dwarf has a very distinct main stem which is characterized by the presence of rough, dark brown bark on its outer surface. This is the only pigeonpea genotype reported to have secondary growth (5). It is also highly susceptible to stem canker disease.

There was a large variation for the number of primary, secondary, and tertiary branches. D_0 and C_0 produced about five primary branches while D_2 dwarf had the maximum (15.2) number of primary branches. In D_1, D_6, PD_1 and PBNA there were many secondary and tertiary branches with thin (low specific weight) leaves and profuse leafy growth. In contrast to other dwarfs, PBNA was found to retain green leaves even after maturity. Dwarfs D_0, C_0, D_3 and D_7 were compact in growth habit and the rest were classified as semi-spreading. D_6 had the maximum plant width.

The stem colour of all the dwarfs was green. D_0 and D_3 had the smallest and the largest leaves but, interestingly, their specific leaf weights were similar. D_0 and D_2 had the shortest and longest petiole. Pod colour varied considerably among the dwarfs. D_0 was green podded while D_3 and D_4 had purple pods. In other dwarfs the pod colour was green with purple streaks on its surface. Pods of D_2 dwarf were slightly curved and had pointed beaks. Pod length in the dwarfs varied from 4.2 (ICPL 85059) to 5.4 (D_3) cm; while seeds/pod ranged between 2.8 (D_0) and 3.6 (D_7). Fruiting branches were found to be the longest in PD_1. In D_2, D_3 and D_4 dwarfs, the pods were wide and the seeds were large. D_6 and PBNA had the largest number of pods/cluster and pods/plant. Yield differences among the dwarfs are difficult to discern in view of the high coefficient of variation. Broadly, dwarfs D_0, C_0 and ICPL 85059 formed the lowest yielding group, and the remaining were between them and the controls.

Character associations

Knowledge of character associations helps in formulating breeding strategies to develop an appropriate plant type for optimizing yield. Reddy (4) reviewed the associations among morphological traits in normal tall pigeonpeas and concluded that yield was positively associated with pods/plant, plant height, plant width, number of primary branches, length of pod bearing branch and pods/cluster. In dwarf genotypes also these relationships were of a similar nature (Table 2). A significant positive correlation ($r = 0.71^{**}$) was observed between yield and plant height. Phenological traits such as plant width, number of primary branches, and length of fruiting branch, which directly contribute to plant biomass, exhibited significant positive association with plant height as well as yield. Also, pods/cluster and pods/plant had significant positive association both with plant height and yield.

Genetic control of dwarfism

Saxena and Sharma (8) while reviewing the subject summarized that both additive as well as non-additive genetic variations were responsible for determining plant height in pigeonpea. Heritability estimates for plant height also varied considerably (27-97%), which may be attributed to differences in the materials and methods used in different studies. The genetics of dwarfism has been published for five sources only. A dwarf, phenotypically similar to D_1 was reported to be controlled by a single recessive gene by Sen *et al.* (9) and Deokar (1). The dwarfness in D_2 was controlled by two non-allelic recessive pigeonpea genotypes

Trait	Correlation with	
	Yield	Plant height
Plant width	0.80**	0.72**
Number of primary branches	0.64*	0.71*
Fruiting branch length	0.75**	0.80**
Leaf area	0.76*	0.90**
Leaf weight	0.66**	0.90**
Specific leaf weight	0.71*	0.89**
Petiole length	0.65*	0.89*
Pods/plant	0.80*	0.57*
Pods/cluster	0.63*	0.65*

Correlation between yield and plant height = 0.71**

* ** Significant at 5% and 1% level of probability, respectively

genes (11). Dwarfism in D_6, PD_1 and PBNA was also found to be controlled by single recessive genes (6).

A study of the dominance relationships in a 10-parent F_1 diallel revealed that all except three cross combinations produced normal tall phenotypes in the F_1 generation suggesting the presence of non-allelic genes in determining dwarfness in D_0, D_1, D_2, D_3, D_4, D_5, D_6 and C_0 dwarfs. The F_1s of D_6 x PD_1, D_6 x PBNA and PD_1 x PBNA were dwarf in growth habit indicating that the gene locus involved in these dwarfs was the same. Detailed studies of the three crosses (6) further revealed the presence of multiple alleles. No reciprocal differences were observed for growth habit. It is interesting to note that the origin of D_1, D_2 and D_3 is from the same cross (GW. 3-191 x Br 465), where both the parents have normal tall plant height, and in order to develop a clear understanding of their genetic control a comprehensive study is essential. Our unpublished observations show that the genetic dwarfs described here are stable in their phenotypic expression and maintain their relative dwarfism under varying environmental conditions. Pigeonpea breeders can select dwarf donors of their choice to develop high-yielding genotypes of appropriate plant stature for different agro-ecological conditions and cropping systems.

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