Indian J. Genet., **50** (3): 233–239 (1990)

INHERITANCE OF PLANT HEIGHT IN PEARL MILLET

PREM SAGAR

Department of Plant Breeding, Haryana Agricultural University, Hisar 1225004

(Received: November 7, 1988; accepted: July 7, 1990)

ABSTRACT

The inheritance of plant height was studied in six crosses of pearl millet using six generations at two stages of crop growth, i.e. seedling to panicle initiation and anthesis, in four environments representing various levels of moisture stress during summer (March–June) season. The F_1 of all the crosses exhibited heterosis over better parent (BP), and the analysis of F_2 and the back crosses indicated the prevalence of nonallelic interactions. Additive dominance model was inadequate in 27 of the 36 cases. Testing for four and five-parameter models, in case of inadequacy of three parameters, before direct switching over to six-parameter model appeared to be essential in order to have unbiased and representative estimates. Both additive and dominance effects were important with preponderance of the latter. The presence of epistasis, observed from the analysis of generation means, was concluded and confirmed by the existence of digenic interactions. Duplicate epistasis played a major role in character expression.

Key words: Pearl millet, inheritance, genetic parameters.

Pearl millet (*Pennisetum typhoides* (Burm) S. & H.) is one of the most important crops of semiarid tropics, meeting the food requirements of both human and cattle population. Plant height is one of the important contributors to grain and fodder productivity. Earlier [1] it was found that plant height recorded in early stages of crop growth was correlated with final plant height even under moisture stress conditions. In the present study the inheritance of plant height at two stages of crop growth is reported.

MATERIALS AND METHODS

Six generations namely, P_1, P_2, F_1, F_2, BC_1 and BC_2, of six crosses, viz., 5141 B x 5054 B, 5141 B x HS 1-71-2-2-P_2, 5054 B x 111 B, 111 B x 78/838-7, SSC 202 x HS 2-71-2-2-P_2, and NEC 38-2 x 78/838-7 were raised in randomized block design with two replications in four environments during summer season (March-June) at Haryana Agricultural University Research Farm, Hisar. Four environments were created artificially by manipulating the irrigation timing: control (fully irrigated), i.e., irrigated as and when required; short stress, i.e., exposed to moisture stress from seedling emergence to panicle initiation; prolonged stress, i.e., stress continued from seedling emergence to ear emergence, followed by irrigation as and when required in both cases; and complete stress, i.e., no irrigation except presowing. Single-row 22 m long plots were spaced at 45 cm with 15 cm spacing between plants. Each parent and F_1 had two, BC_1 and BC_2 had four, and F_2 populations of each cross had eight rows per replication.

Data on plant height were recorded on five competitive plants in each row at two stages of crop growth: 25 days after seedling emergence (panicle initiation) and at anthesis in all the environments, and only at panicle initiation in the environments of prolonged and complete stress. The data on the parent 78/838-7 were recorded only at panicle emergence in all the environments. The estimates for anthesis stage were worked out without using the values for the parent (P_2).

The joint scaling test [2], was used for testing the adequacy of additive–dominance model. In case of inadequacy of additive–dominance model, four out of the six parameters (m, d, h, i, j, l) were fitted successively following [3] for the estimation of these parameters, and the residual sums of squares were compared against the χ^2 value for the respective degrees of freedom. The adequacy of the four and five-parameter models was tested by the nonsignificant variation accounted for by the residual variation in the Y variate and χ^2 values. Where all the generations were used for parameter estimation, the fitness of the six-parameter model could not be tested by χ^2 test and regression analysis. The significance of the parameters was tested against their corresponding standard errors.

RESULTS AND DISCUSSION

There were not much difference in mean plant height at panicle initiation, albeit these were significantly pronounced at anthesis, indicating that final expression of plant height was much affected by moisture stress (Table 1). Similar observations, i.e., reduction in plant height with the moisture stress shifted to advanced stages of plant growth, were reported earlier [1, 4]. Except for the crosses 5141 B x HS 1-71-2-2-P_2 under prolonged stress, 111B x78/838-7 in control, short and complete stress, and SSC 202 x HS 1-71-2-2-P_2 in complete stress in panicle initiation, the F_1 of all the crosses exceeded both the parents, indicating heterosis over better parent (BP). The BC_1 and BC_2 also superior to their respective parents, except BC_2 of the crosses 5141 B x HS 1-71-2-2-P_2 under prolonged stress at panicle initiation and its BC_1 under short stress at anthesis, BC_2 of cross 111 B x 78/838-7 in control and also BC_2 of cross NEC 38-2 x 78/838-7 in prolonged and complete stress, while BC_2 in control under short stress at panicle initiation showed poorer growth than the respective parents, thereby indicating nonallelic interactions. The F_2 mean showed a mixed trend, i.e. lower, equal or greater height than the F_1 mean at panicle initiation, but it was lower at anthesis in all the crosses except 5141 B x 5054 B in control and for SSC 202 x HS 1-71-2-2-P_2 under prolonged stress, indicating inbreeding depression. These observations indicate pronounced role of epistatic interactions.

Table 1. Mean plant height in six generations of pearl millet crosses at two stages of crop growth in two environments

Cross	Generation	Control		Short stress		Prolonged stress	Complete stress
		panicle initiation	anthesis	panicle initiation	anthesis	panicle initiation	panicle initiation
5141 B x 5054 B	P_1	21.4	94.4	18.8	86.6	19.1	18.0
	P_2	24.5	115.1	27.8	92.6	26.1	25.1
	F_1	26.5	115.9	32.9	113.4	31.1	32.4
	F_2	34.9	132.6	35.9	110.0	40.4	41.6
	BC_1	28.2	118.1	40.8	110.3	35.4	34.6
	BC_2	27.7	118.0	36.2	111.0	33.1	38.8
5141 B x HS 1-71-2-2-P_2	P_1	21.4	94.4	18.8	86.6	19.1	18.0
	P_2	30.1	111.5	31.0	101.7	38.4	37.9
	F_1	38.9	135.3	39.7	118.1	37.6	40.0
	F_2	33.7	129.3	31.8	98.7	39.6	34.3
	BC_1	39.7	140.5	36.7	111.3	35.2	33.3
	BC_2	37.2	129.7	36.6	92.4	35.7	49.2
5054 B x 111 B	P_1	24.5	115.1	27.8	92.6	26.1	25.1
	P_2	24.3	88.5	22.8	64.6	30.2	30.0
	F_1	32.0	155.7	30.1	100.3	38.7	31.5
	F_2	37.6	141.0	30.7	92.0	35.6	38.2
	BC_1	32.1	166.7	32.7	97.0	38.4	34.5
	BC_2	34.6	141.8	32.7	98.4	35.9	34.6
111 B x 78/838-7	P_1	24.3	88.5	22.8	64.6	30.2	30.0
	P_2	39.5	—	36.4	—	36.9	43.3
	F_1	31.5	184.0	35.2	104.2	38.7	34.8
	F_2	37.8	144.2	36.6	97.5	39.7	38.4
	BC_1	30.1	140.4	37.2	104.4	37.8	33.2
	BC_2	34.9	151.6	40.2	114.7	39.0	40.0
SSC-202 x HS 1-71-2-2-P_2	P_1	33.6	152.3	24.2	77.6	36.9	27.0
	P_2	45.2	111.5	33.8	101.7	28.7	38.6
	F_1	46.9	139.6	49.6	103.8	42.8	30.4
	F_2	38.9	134.0	37.5	107.0	38.1	40.2
	BC_1	49.8	158.3	37.6	124.8	38.4	47.8
	BC_2	50.7	138.6	36.9	111.2	41.8	41.0
NEC 38-2 x 78/838-7	P_1	45.2	147.6	33.8	115.0	28.7	38.6
	P_2	39.5	—	36.4	—	36.9	43.3
	F_1	43.1	169.6	40.6	124.7	38.9	49.2
	F_2	37.7	148.7	30.9	94.7	38.7	36.9
	BC_1	33.9	161.4	31.9	125.2	40.8	47.3
	BC_2	41.5	157.6	38.3	127.9	36.0	35.3

The results of joint scaling test showed that the additive-dominance model was inadequate for all the crosses under all environments at both stages except at panicle initiation for the crosses 5141 B x HS 1-71-2-2-P_2, SSC-202 x HS1-71-2-2-P_2 under short stress, 111 B x 78/838-7 under prolonged and complete stress, and NEC 38-2 x 78/838-7 under prolonged stress, and at anthesis for the crosses 5141 B x 5054B and 5054 B x 111 B under short stress, and SSC 202 x HS 1-71-2-2-P_2 and NEC 38-2 x 78/838-7 in control. The inadequacy of the model indicates the presence of epistasis, which is also inferred from the generations means. The maximum variation accounted for by the additive-dominance model was 92.9% for cross 5141 B x HS 1-71-2-2-P_2 under short stress at panicle initiation, 91.0% and 99.5% for cross SSC 202 x HS 1-71-2-2-P_2 under short stress at panicle initiation, and in control at anthesis.

After the establishment of inadequacy of three parameter model, it was observed that the number of parameters of the model fitting in a particular cross in a few cases was same at both stages and in all environments, except where the model showed adequacy at a particular stage or in a particular environment. The criterion for choosing the best fitting model, as explained in Materials and Methods, was nonsignificance of χ^2 value and the maximum variation accounted for by the residual variance for the variance of the Y variate.

The estimates of parameters were significant in majority of cases. The significance of dominance in 26 and additive in 20 out of 36 cases (Table 2) indicated that both dominance and the additive components were important in the inheritance of plant height. The dominance component exceeded the additive one almost in all cases, indicating the preponderance of dominance variation. The preponderance of dominance effects for plant height in pearl millet is in agreement with earlier reports [1, 5, 6].

Among the digenic interactions, the significance of additive x additive (i) effects in most cases and that of additive x dominance (j) and dominance x dominance (l) effects in fewer cases only indicated a significant role of simple epistasis in the inheritance of plant height in the present material. Genic interactions for plant height in pearl millet have already been reported [7]. Singh [5] and Virk [6] speculated and Gupta and Phul [8] found trigenic and linked digenic interactions controlling plant height. Interestingly all the cases showed maximum adequacy of the four-, five-, or six-, parameter models, indicating the absence of trigenic or higher order interactions, or linked digenic interactions.

It is evident from the data of Table 2 that after ascertaining the inadequacy of the three-parameter model, it is not advisable to switch over to the six-parameter model directly. The four-, five- and six-parameter models should be tested first based on their χ^2 values and the percentage of the variation, as explained in the present case, in order to have unbiased estimates.

In general, the genes with positive effect on plant height showed dominance over those

Table 2. Estimates of genetic parameters for plant height in six pearl millet crosses at two stages of crop growth in two environments

Cross	Environment, stages	m	d	h	i	j	l	χ^2 value	Variation accounted for residual variance, %
5141 B x 5054 B	Control, panicle initiation	40.4*	–1.1	–14.7*	–17.5	—	—	1.99	78.7
	Control, anthesis	146.2*	–11.9*	–31.4*	–43.2*	24.1	—	1.33	79.0
	Short stress, panicle initiation	39.5*	–4.4*	–4.6	–16.1*	—	—	5.01	86.7
	Short stress, anthesis	92.4*	–1.8	32.3*	—	—	—	2.14	76.5
	Prolonged stress, panicle initiation	49.9*	–3.3*	–18.7*	–27.3*	–10.3	—	0.06	99.8
	Complete stress, panicle initiation	51.5*	–3.8	–17.1*	–29.8*	—	—	1.49	97.4
5141 B x HS1-71-2-2P2	Control, panicle initiation	–6.8	–4.3*	75.7*	19.0*	13.7	–43.5*	—	—
	Control, anthesis	79.7*	–8.6	142.7*	23.2	38.7	–87.1	—	—
	Short stress, panicle initiation	24.7*	–5.7*	15.8*	—	—	—	4.44	92.9
	Short stress, anthesis	90.2*	–0.7	25.1*	—	—	—	6.42	33.8
	Prolonged stress, panicle initiation	41.3*	-9.6*	–4.0	-12.6*	18.6	—	0.11	99.6
	Complete stress, panicle initiation	–0.1	–9.9*	97.2*	28.0*	–11.9	–57.1*	—	—
5054 B x 111B	Control, panicle initiation	43.3*	–0.12	–11.1*	–18.9	—	—	0.64	97.5
	Control, anthesis	48.8*	13.3*	261.9*	53.0*	23.2	155.0*	—	—
	Short stress, panicle initiation	17.3*	2.5	40.8*	8.0	–5.0	–28.0	—	—
	Short stress, anthesis	79.9*	9.8*	20.9*	—	—	—	3.79	53.9
	Prolonged stress, panicle initiation	33.3*	–2.3	7.0	4.7	12.5	—	3.15	79.7
	Complete stress, panicle initiation	45.0*	–2.5	–12.8	–17.4	5.2	—	0.18	97.4
111 B x 78/838-7	Control, panicle initiation	42.0*	–6.4*	–11.0*	–11.2*	—	—	2.73	85.9
	Control, anthesis	74.1*	20.4*	174.1*	5.8*	–1.4	–108.6*	—	—
	Short stress, panicle initiation	21.0*	–6.8*	48.0*	8.6	7.6	–33.8	—	—

(Contd.)

Table 2. *(contd.)*

Cross	Environment, stages	m	d	h	i	j	l	χ^2 value	Variation accounted for residual variance, %
	Short stress, anthesis	45.6*	–12.1*	187.3*	44.0*	51.3*	–129.1*	—	—
	Prolonged stress, panicle initiation	41.5*	–3.4*	–2.6	–7.7	4.2	—	0.15	95.3
	Complete stress, panicle initiation	41.5*	–6.7*	–6.8	–5.0	—	—	0.09	99.0
SSC-202 x HS1-71-2-2-P2	Control, panicle initiation	–6.2	–5.8*	127.1*	45.6*	9.8	–74.0	—	—
	Control, anthesis	104.6*	–13.4	79.9*	—	—	—	0.46	99.5
	Short stress, panicle initiation	28.8*	–4.3*	18.4*	—	—	—	1.77	91.0
	Short stress, anthesis	91.7*	–73.5*	12.5	46.4	126.4*	—	—	—
	Prolonged stress, panicle initiation	34.4*	4.1	9.9	–1.5	-16.9*	—	1.00	88.1
	Complete stress, Panicle initiation	16.0	–5.8*	82.4*	16.8	25.2*	–68.0*	—	—
NEC-38-2 x 78/838-7	Control, panicle initiation	30.7*	3.1	10.7	11.2*	–21.0	—	1.61	65.9
	Control, anthesis	130.7*	–2.0	39.5*	20.1	—	—	1.38	74.6
	Short stress, panicle initiation	21.6*	–1.3	19.2*	13.6*	–10.0	—	0.15	95.3
	Short stress, anthesis	64.7*	–77.1*	60.0*	127.4*	148.8*	—	—	—
	Prolonged stress, panicle initiation	32.2*	–2.5	8.8	—	—	—	7.68	54.4
	Complete stress, panicle initiation	24.7*	–2.3	24.5*	16.3*	28.4*	—	0.01	99.7

with negative effects. In the cases where the three-, four-, or five-parameter models failed to detect the variation, duplicate epistasis was observed in the six-parameter model, as (h) and (l) were having opposite signs and levels of significance. The presence of duplicate epistasis would be detrimental for rapid progress, making it difficult to fix genotypes with increased level of character manifestation because the positive effect of one parameter would be cancelled out by the negative effect of another. The preponderance of duplicate epistasis in the inheritance of plant height in pearl millet is almost confirmed [5, 7–10]. Under preponderance of dominance effects with duplicate epistasis, reciprocal recurrent selection would help to improve the character.

ACKNOWLEDGEMENTS

Thanks are due to Dr. R. L. Kapoor, Senior Plant Breeder (Bajra), HAU, for keen interest and encouragement and Dr. M. Singh, Statistician, ICRISAT, for help in statistical analysis.

REFERENCES

1. Prem Sagar. 1982. Genetics of Grain Yield and Other Quantitative Characters Under Different Levels of Water Stress in Pearl Millet (*Pennisetum typhoides* (Burm) S. & H.). Ph.D. Thesis. Haryana Agricultural University, Hisar.

2. L. L. Cavalli. 1952. An analysis of linkage of quantitative inheritance. *In:* Quantitative Inheritance (eds. E. C. R. Rieve and H. Weddington). H. M. S. O., London: 135–144.

3. K. Mather and J. L. Jinks. 1971. Biometrical Genetics (2nd ed.) Chapman and Hall, London.

4. Prem Sagar and R. L. Kapoor. 1986. A field screening technique for drought tolerance. Exptl. Agric., **22**: 117–122.

5. Râjesh Singh. 1986. Genetic Analysis of Grain Yield and Other Quantitative Characters in Pearl Millet (*Pennisetum typhoides* (Burm) S. & H.). M.Sc. Thesis. Haryana Agricultural University, Hisar.

6. D. S. Virk. 1988. Biometrical analysis in pearl millet— a review. Crop Improv., **15**(1): 1–29.

7. D. Singh and S. Lal. 1969. Gene effects and heterosis in pearl millet. Indian J. Genet., **29**: 18–28.

8. S. K. Gupta and P. S. Phul. 1981. Analysis of quantitative genetic variation from generation means in pearl millet. Z. Pflanzenzuchtg., **87**: 319–329.

9. H. R. Yadav. 1970. Inheritance of Some Quantitative Characters in Bajra (*Pennisetum typhoides* B. Stapf and Hubbard). M.Sc. Thesis. Haryana Agricultural University, Hisar.

10. F. Singh and A. B. Singh. 1972. Studies on gene effects and their contribution in explaining the heterosis on some quantitative traits in pearl millet. Haryana Agric. Univ. J. Res., **2**: 135–139.