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Genetic and cytoplasmic effects on chlorophyll content in pearl millet *

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Summary. Genetic and cytoplasmic effects on chlorophyll content in pearl millet were studied using a complete 10-parent diallel cross under two dates of sowing. Chlorophyll a, chlorophyll b and chlorophyll a+b were not affected by the sowing dates. The estimation of components of genetic variance indicated a predominantly non-additive gene action in the inheritance of chlorophylls. Reciprocal cross differences and maternal effects were pronounced in several cross combinations.

Key words: *Pennisetum typhoides* – Pearl millet – Chlorophyll a – Chlorophyll b – Cytoplasmic effects – Inheritance

Introduction

Chlorophyll is an essential factor in photosynthesis and chlorophyll a and b are the two main forms of chlorophyll which contribute to the green colouring matter in the plants. Chlorophyll a is yellowish green whereas chlorophyll b is blue green. Chlorophyll a donates energy directly to the photosynthetic reaction and all other pigments transfer their absorbed energy to it. Chlorophyll b and the carotenoides play a key role in protecting the plant cell against the photochemical reaction induced by the illumination of chlorophyll (Davies et al. 1964).

In pearl millet (*Pennisetum typhoides*) (Burm) Stapf and Hubb; also designated as *Pennisetum americanum* (L) Leeke, a number of studies have been carried out in order to obtain information on the genetic architecture of grain yield and its components. However, rather scanty information is available on the chlorophyll attributes which are related to photosynthetic activity and hence to productivity. Phul et al. (1974) found that chlorophyll a and b were positively and significantly correlated with grain yield in pearl millet. Thus, information on reciprocal cross differences and maternal effects is of immense value in judging the breeding behaviour of the parental lines. The present investigation was undertaken to determine the genetic and cytoplasmic effects of chlorophyll contents from a complete diallel analysis in pearl millet.

Materials and methods

Ten genetically diverse inbred lines of pearl millet viz., L 67B (P_1), Pb 103B (P_2), Pb 111B (P_3), BIL 3B (P_4), PIB 171 (P_5), PIB 191 (P_6), PIB 223 (P_7), PIB 1009 (P_8), PIB 1231 (P_9) and PIB 1474 (P_{10}) were crossed in all possible combinations, including reciprocals, in 1976. The 90 F_1 hybrids, along with the 10 parents, were grown at Ludhiana during 1977 and sown at two different dates, 8th (Env. I) and 28 th of July (Env. II), in a randomized complete block design with two replications each. Each entry was grown in a single 2 metre row. Inter-row and inter-plant spacings were maintained at 60 and 15 cm, respectively. The amounts of chlorophyll a and b in terms of mg of chlorophyll/gm tissue were estimated from representative samples of fresh tissue taken from 5 fully extended second leaves from the top of each genotype by using the method of Witham et al. (1971).

The statistical analysis was carried out according to Griffing (1956) using method I, models I and II. On the fixed effect model (I), the inferences were specifically drawn for reciprocal cross effects whereas on the random effect model (II), the components of variance ($\hat{\sigma}_g^2$ and $\hat{\sigma}_s^2$) were estimated to generalize the nature of gene effects. Griffing's (1956) approach extended to multi-environments by Singh (1973) was

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used to derive information on the interaction of combining ability variances with the environments. The analysis of variance for diallel tables was conducted following Hayman's method (1954).

Results and discussion

The pooled analysis of variance revealed highly significant differences among the genotypes for chlorophyll a, b and chlorophyll a + b (Table 1). Genotype × sowing date interaction was non-significant for all three chlorophyll attributes suggesting that sowing date had little effect on altering the chlorophyll expression.

Variance due to general combining ability (gca) and specific combining ability (sca) were highly significant for all three chlorophyll attributes in individual plants as well as when these were pooled over two environments (Table 2). This suggests that both additive as well as dominance gene effects were responsive to the inheritance of chlorophyll. However, the ratio $\hat{\sigma}_s^2/\hat{\sigma}_g^2$ indicated a predominant role of non-additive gene effects for the expression of chlorophyll and hence suggested the development of hybrid varieties in pearl millet. The present findings are in conformity with the earlier results of Harinarayana (1968), Thakare and Murty (1972) and Phul et al. (1977). The non-significance of variances due to gca × E and sca × E demonstrated that the combining ability effects were not influenced with the change of sowing times.

Analysis of variance for the diallel table pooled over two environments is given in Table 3. The non-significance of the b_1 component for all three attributes suggested ambidirectional dominance of the genes in the parents. The b_2 was highly significant in all cases which indicated assymetrical distribution of the favourable and unfavourable genes in the parents.

Cytoplasmic effects

The role of cytoplasmic effects in causing reciprocal and maternal differences for various quantitative as well as qualitative traits has been emphasized by many workers in different crop plants (Richey 1920; Fleming et al. 1960; Bhat and Dhawan 1970; Gupta and Nanda 1968; Khehra and Bhalla 1976). Reciprocal cross effects are specific to cross combinations, whereas maternal effects refer to the line; in other words, maternal effects

Table 1. Analysis of variance for the design of the experiment pooled over two environments

Source of variation	DF	Mean squares		
		Chlorophyll a	Chlorophyll b	Chlorophyll a + b
Environment (E)	1	0.2302*	0.0015	0.2682
Replication (R)	1	0.6122**	0.3475**	1.8822**
E × R	1	0.7171**	0.1430**	1.5002**
Genotypes (G)	99	0.4386**	0.3034**	1.4510**
G × E	99	0.0224	0.0157	0.0671
Error	198	0.0479	0.0272	0.1305

*, ** Significant at 5 and 1% respectively

Table 2. Analysis of variance for combining ability

Source of variation	DF	Mean squares		
		Chlorophyll a	Chlorophyll b	Chlorophyll a + b
Environment I				
gca	9	0.2023**	0.1483**	0.6840**
sca	45	0.1232**	0.0772**	0.3824**
rce	45	0.1224**	0.0794**	0.3924**
Error	99	0.0205·	0.0084	0.0434
$\hat{\sigma}_g^2$		0.004	0.004	0.015
$\hat{\sigma}_s^2$		0.056	0.038	0.186
$\hat{\sigma}_s^2/\hat{\sigma}_g^2$		14.00	9.50	12.40
Environment II				
gca	9	0.1347**	0.1040**	0.4668**
sca	45	0.1065**	0.0816**	0.3713**
rce	45	0.0870**	0.0622**	0.2936**
Error	99	0.0274	0.0188	0.0872
$\hat{\sigma}_g^2$		0.001	0.001	0.002
$\hat{\sigma}_s^2$		0.043	0.035	0.156
$\hat{\sigma}_s^2/\hat{\sigma}_g^2$		43.00	35.00	78.00
Pooled over environments				
gca	9	0.3263**	0.2429**	1.1152**
sca	45	0.2192**	0.1528**	0.7258**
rce	45	0.1980**	0.1323**	0.6472**
Environments (E)	1	0.1151*	0.0007	0.1341
gca × E	9	0.0108	0.0094	0.0356
sca × E	45	0.0104	0.0060	0.0279
rce × E	45	0.0120	0.0093	0.0388
Error (Me)	198	0.0240	0.0136	0.0653
$\hat{\sigma}_g^2$		0.0027	0.0022	0.0097
$\hat{\sigma}_s^2$		0.0574	0.0403	0.1917
$\hat{\sigma}_s^2/\hat{\sigma}_g^2$		21.26	18.32	19.76

*, ** Significant at 5 and 1% respectively

Table 3. Analysis of variance of diallel tables over pooled environment

Source	DF	Mean squares		
		Chlorophyll a	Chlorophyll b	Chlorophyll a + b
a	9	0.3263**	0.2429**	1.1152**
b	45	0.0212	0.0205	0.0786
b_1	1	0.0115	0.0137	0.0250
b_2	9	0.0817**	0.0488**	0.2458**
b_3	35	0.0059	0.0134	0.0371
c	9	0.2757**	0.1848**	0.8995**
d	36	0.1786**	0.1192**	0.5841**
Pooled error	198	0.0240	0.0136	0.653

*, ** Significant at 5 and 1% respectively

Table 4. Crosses showing reciprocal cross effects

Cross	Chlorophyll a			Chlorophyll b			Chlorophyll a + b		
	Env. I	Env. II	Pooled	Env. I	Env. II	Pooled	Env. I	Env. II	Pooled
$P_1 \times P_2$	0.243**	0.122	0.183*	0.263**	0.152	0.207**	0.506**	0.274	0.390**
$P_1 \times P_3$	-0.456**	-0.024	-0.240**	0.354**	-0.050	-0.152**	-0.810**	0.026	-0.392**
$P_1 \times P_5$	0.358**	0.198	0.278**	0.236**	0.166	0.201**	0.593**	0.364	0.479**
$P_1 \times P_6$	0.579**	0.512**	0.546**	0.502**	0.470**	0.486**	1.081**	0.982**	1.032**
$P_1 \times P_8$	0.160	0.167	0.164*	0.071	0.140	0.106	0.232	0.307	0.269**
$P_1 \times P_9$	0.486**	0.490**	0.488**	0.441**	0.406**	0.423**	0.927**	0.895**	0.911**
$P_1 \times P_{10}$	0.150	-0.373**	-0.261**	0.212**	0.213*	0.213**	0.362*	0.586**	0.474**
$P_2 \times P_3$	-0.405**	-0.429**	-0.417**	-0.328**	-0.357**	-0.343**	-0.733**	-0.786**	-0.759**
$P_2 \times P_4$	-0.356**	-0.138	-0.247**	-0.135*	-0.069	-0.103	-0.491*	-0.207	-0.349*
$P_2 \times P_5$	-0.008	-0.075	-0.042	0.061	-0.058	-0.001	0.526**	-0.134	-0.041
$P_2 \times P_6$	-0.176	-0.104	-0.140	-0.108	-0.135	-0.122*	-0.284	-0.240	-0.262*
$P_2 \times P_8$	0.212*	0.262*	0.237**	0.111	0.199*	0.155**	0.323*	0.461*	0.392*
$P_2 \times P_9$	-0.214*	-0.166	-0.190*	-0.128	-0.136	-0.132*	-0.341*	-0.302	-0.322*
$P_2 \times P_{10}$	0.099	0.171	0.135	0.117	0.148	0.132*	0.216	0.319	0.267*
$P_3 \times P_4$	0.128	0.086	0.107	0.153*	0.018	0.085	0.281	0.104	0.193
$P_3 \times P_5$	0.338**	0.142	0.240**	0.258**	0.057	0.157**	0.596**	0.199	0.397**
$P_3 \times P_8$	0.683**	0.595**	0.639**	0.537**	0.493**	0.515**	1.221**	1.088**	1.154**
$P_3 \times P_9$	0.336**	0.176	0.256**	0.354**	0.179	0.266**	0.689**	0.355	0.522**
$P_3 \times P_{10}$	0.184	0.259*	0.221**	0.171**	0.250*	0.210**	0.354*	0.509*	0.432**
$P_4 \times P_6$	0.427**	0.332**	0.379**	0.269**	0.278**	0.273**	0.695**	0.610**	0.652**
$P_4 \times P_8$	0.411**	0.336**	0.374**	0.226**	0.230*	0.228**	0.637**	0.565**	0.601**
$P_5 \times P_6$	-0.056	-0.216	-0.136	-0.076	-0.227*	-0.151*	-0.132	-0.443*	-0.287*
$P_5 \times P_9$	0.248*	0.144	0.196*	0.259**	0.135	0.197**	0.506**	0.279	0.393**
$P_6 \times P_7$	-0.229*	-0.211	-0.220**	-0.186**	-0.192*	-0.189**	-0.415**	-0.402	-0.409**
$P_6 \times P_9$	-0.184	-0.047	-0.115	-0.111	-0.019	-0.065	-0.295*	-0.065	-0.180
$P_6 \times P_{10}$	-0.157	-0.138	-0.148	-0.134*	-0.119	-0.127*	-0.291*	-0.257	-0.274*
SE (r_{ij})	0.101	0.117	0.077	0.065	0.097	0.058	0.147	0.209	0.127
CD at 5%	0.200	0.232	0.152	0.129	0.192	0.114	0.291	0.414	0.250
CD at 1%	0.266	0.308	0.200	0.171	0.255	0.151	0.387	0.550	0.330

*, ** Significant at 5 and 1% respectively

Table 5. Maternal effects of the parental inbred lines pooled over two environments

Sr. no.	Inbred	Chlorophyll a	Chlorophyll b	Chlorophyll a + b
1	L 67 B	0.125	0.129	0.359
2	PB 103 B	0.058	-0.027	-0.076
3	PB 111 B	0.081	-0.077	0.157
4	Bil 3 B	0.068	0.056	0.127
5	PIB 171	0.066	0.054	0.130
6	PIB 191	0.005	-0.002	0.005
7	PIB 223	0.015	-0.009	0.027
8	PIB 1009	0.172	0.114	0.286
9	PIB 1231	0.090	0.087	0.184
10	PIB 1474	0.009	0.010	0.119

are average reciprocal cross effects of a line used as a female over a series of crosses. Such differences are due to an unequal contribution of cytoplasmic determinants from the female and the male gametes to the zygote. Therefore, the sequence of the parents showing beneficial cytoplasmic effects is important for taking advantage of cytoplasm – gene interaction.

The variance due to reciprocal cross effect was significant for all three chlorophyll attributes in the individual as well as when pooled over environments (Table 2). This implied that there were certain specific combinations in which reciprocal cross effects were more pronounced than in others. The non-significance of rce × E interaction variances indicated that the two sowing dates played a minor role in modifying the reciprocal cross effects for the chlorophyll attributes.

Estimates of reciprocal cross effects, shown in Table 4, indicated that five crosses, namely, L 67B × PIB 191, L 67B × PIB 1231, Pb 111B × PIB 1009, Bil 3B × PIB 191 and Bil 3B × PIB 1009, had significant positive effects in the individual as well as when pooled over environments for all three chlorophyll attributes. In general, reciprocal cross effects were consistent over the two dates of sowing, which again indicated that the expression of chlorophyll was little influenced by the genotype × sowing dates interaction. The analysis of variance for the diallel tables (Table 3) also suggested the presence of maternal (c) as well as reciprocal cross effects not accounted for by the maternal effects (d) for all three chlorophyll attributes. Further, a perusal of the maternal effects for different chlorophyll attributes (Table 5) indicated that inbreds L 67B, PIB 1009 and PIB 1231 exhibited maximum maternal effects for all three chlorophyll attributes. This shows that these inbreds have differential behaviour when used as male or female parents.

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