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Genetic analysis of phytic acid content in pearl millet

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Summary. The genetics of phytic acid content in pearl millet (*Pennisettum typhoides* (Burm) S & H) was studied using a 12 parent diallel. The analysis of variance of diallel progenies exhibited significant genotypic differences. Different analyses, i.e., combining ability analysis, analysis of variance of diallel tables and genetic component analysis, showed that both additive and non additive gene effects were significant. It is suggested that a population improvement is possible by breeding for low phytic acid cultivars of pearl millet.

Key words: Diallel – Combining ability – Gene effects – *Pennisettum typhoides*

Introduction

Pearl millet, a coarse grain cereal, has high nutritional value and is the major source of dietry protein for a sizable section of the population in Africa and Asia. In fact, it is among the six leading cereals which provide calories and protein for human consumption (Evans 1975). However, due to the presence of a high content of phytic acid, pearl millet grain is barely digestable (Gupta 1980).

Phytic acid is a hexaphosphoric acid ester of inositol which is found in cereal seeds. Common (1940) found that 60–80% of the total phosphorus present in cereals is in the form of phytic acid in most of them. Its nutritional importance lies in its ability to chelate several mineral elements, especially those of Ca, Mg, Fe, Zn and Mo, and thus reduce their bioavailability (Oberleas 1973). In this case, as in that of oxalic acid in other foodstuffs, the possible harmful effects depend on the quantity of phytate intake. Taylor (1965) observed that incidence of rickets is due to Ca deficiency caused by the impairment of Ca absorption due to the presence of phytate.

In pearl millet phytic acid content varies considerably, its range in proportion to total phosphorus being 0.38 to 0.88 (Gupta 1980). Due to the high content of phytic acid in pearl millet, the need to develop better cultivars with low phytic acid content can hardly be overemphasized. Hence, in this context, the present study on pearl millet was initiated on a 12×12 complete diallel cross in order to understand the nature and magnitude of gene effects on phytic acid content and to evaluate the parents and crosses for combining ability with respect to low phytic acid content. Different biometrical genetic techniques have been employed so as to provide reliable information on the nature of gene effects.

Material and methods

Twelve lines of pearl millet were crossed in the form of a complete diallel. The 144 progenies comprising 12 parents and 132 hybrids were grown in a randomised block design with three replications, during the monsoon season of 1982 at Punjab Agricultural University Ludhiana, Punjab, India.

The samples for phytic acid analysis were constituted by mixing together the threshed seed of five randomly chosen plants of each progeny from three replications. Duplicate estimates were made for each sample. The estimation of phytic acid was based on the method of Wheeler and Ferrel (1971). The phytate was extracted with trichloroacetic acid and precipitated as the ferric salt. The iron content of the precipitate was determined colorimetrically and the phytate content calculated from this value assuming a constant 4 Fe:6 P molecular ratio in the precipitate. The iron content in the unknown was read from the previously prepared standard curve (different solutions of ferric nitrate having varied concentrations of Fe^{+++}). Phytic acid content was determined by multiplying the phytate phosphorus content by a constant factor of 3.55.

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The combining ability analysis was carried out according to method-1, model-1 of Griffing (1956). The analysis of variance of diallel tables and component analysis were conducted using the methods of Hayman (1954b) and Hayman (1954a), respectively. The graphic analysis was based on the variance-covariance analysis following the methodology given by Jinks (1954).

Table 1. Analysis of variance for phytic acid content

Source of variation	d.f.	Mean squares
Genotypes	143	9.37**
Parents	11	8.93**
Hybrids	131	12.49**
Parents v/s Hybrids	1	32.24**
Error	144	0.07

* Significant at $P=0.05$; ** Significant at $P=0.01$

Table 2. Analysis of variance of combining ability for phytic acid content

Source of variation	d.f.	Mean squares
g.c.a.	11	48.49**
s.c.a.	66	1.68**
r.c.a.	66	0.38**
M'_e	144	0.04
Components		
$\frac{1}{11}\Sigma g_i^2$		2.01
$\frac{1}{66}\Sigma\Sigma s_{ij}^2$		1.64

** Significant at $P=0.01$

Results and discussion

The analysis of variance showed highly significant differences among parents as well as the hybrids for phytic acid content (Table 1). The parents differed significantly from the hybrids indicating the presence of significant heterosis for phytic acid content.

The analysis of variance for combining ability revealed significant differences among gca, sca and reciprocal cross effects (Table 2). The estimates of gca variance and sca variance showed that the former had a much higher magnitude than the latter. This indicated that the additive gene effects were more important in governing the inheritance of phytic acid content.

The estimates of general and specific combining ability effects and the mean performance of the parents and F_1's are presented in Table 3. Except for parent L104, all parents recorded significant general combining ability effects. Parents L101, L105, A10, L20 and L5, which had high negative gca estimates, were good combiners for low phytic acid content. Parent L103 was the poorest combiner, having the highest positive gca estimate. The per se performance of the parents provided a fairly good indication of their combining ability. For example, parent L101 was the best combiner for low phytic acid and also had minimum phytic acid content. However, the ranking on a per se performance basis did not parallel that derived on the basis of their general combining ability. It would be thus desirable to consider both combining ability and per se performance when selecting parents for hybridization.

For phytic acid content, negative cross effects which indicate low phytic acid content are desirable. Highest negative specific combining ability effect was recorded in cross A7×L105 followed by other good crosses, i.e., A5×L105, L10×L105, L5×L20, L5×L10, L20×L101, L5×A10, etc. An examination of the per se performance and the specific

Table 3. Mean performance of parents (bottom) and F_1 (lower left) and estimates of general combining ability effects (diagonal) and specific combining ability effects (upper right) for phytic acid content

Parents	L5	L10	L20	A5	A7	A10	L101	L102	L103	L104	L105	L106
L5	−0.93	−0.98	−1.02	0.46	0.51	−0.82	−0.70	−0.11	2.92	0.52	−0.19	0.82
L10	5.30	0.22	0.20	1.38	1.21	0.76	−0.06	−0.02	−0.35	0.15	−1.15	0.64
L20	3.85	6.21	−1.19	0.53	0.82	−0.79	−0.84	0.81	−0.41	0.38	−0.15	1.21
A5	8.55	10.16	8.36	2.03	1.29	0.79	−0.22	−0.48	1.96	−0.67	−1.18	−0.35
A7	7.44	9.28	7.49	1.18	0.87	0.34	−0.13	−0.44	0.01	−0.77	−1.22	0.90
A10	3.72	6.44	3.48	8.28	6.67	−1.52	−0.35	−0.11	−0.12	0.68	−0.13	0.33
L101	3.63	5.41	3.22	7.06	6.00	3.38	−1.73	0.40	0.78	1.04	−0.06	0.48
L102	6.31	7.57	6.96	8.89	7.77	5.71	6.01	0.36	1.35	−0.52	0.35	0.01
L103	11.50	9.38	7.92	9.58	10.38	7.87	8.56	11.21	2.53	−0.55	1.60	1.85
L104	6.59	7.36	6.18	8.35	7.10	6.14	6.30	6.83	8.97	0.06	0.64	−0.42
L105	4.33	4.52	4.12	6.31	5.10	3.80	3.65	6.15	9.57	6.10	−1.53	0.83
L106	7.79	8.74	7.91	9.58	7.87	6.70	6.64	8.27	8.58	7.49	7.19	0.91
Mean	3.65	5.57	3.80	10.40	7.94	3.30	3.09	6.39	9.58	6.49	4.49	7.95

SE $g_i = \pm$ 0.038; SE sij $= \pm$ 0.174

combining ability (sca) effects of the crosses indicate that the crosses having high sca effects may not necessarily have higher per se performance. For example, the combination A7×L105 had the highest sca effect for low phytic acid content but it was not first with respect to its per se performance. On the other hand, the best cross with lowest phytic acid content, L20×L101, was sixth with respect to its sca effect. The crosses between two high combiners were not always good. For example, L20×L105 involved good combiners for low phytic acid content but it was an average cross with nonsignificant sca estimate. Understandably it is not necessary that high mean performance will be inherited in the crosses. Singh et al. (1974) and Khangura et al. (1980) also reported that there was no correlation between the mean performance of the hybrids and their sca effects.

In the present investigation the crosses which exhibited high specific combining ability effects involved at least one high or an average combining ability parent. The superiority of the average×average or average×low combination may be due to the presence of genetic diversity among the parents. Gupta (1968) and Gill et al. (1974) also reported that the best cross combinations were obtained when either or both parents were good combiners and emphasized the importance of genetic diversity.

The analysis of variance of the diallel tables showed that component (a) as well as (b) were significant, revealing the presence of additive as well as dominance gene effects (Table 4). The partitioning of (b) resulted in the significance of (b_1), (b_2) and (b_3). The significance of b_1 implies that dominance deviations of the genes are predominantly in one direction, that is, there is a directional dominance effect; the significance of (b_2) shows that there is asymmetrical gene distribution and that of (b_3) indicates residual dominance effects. The item (c) was nonsignificant, implying the absence of maternal effects.

The uniformity of V_r and W_r due to a non significant t^2 value and the agreement of the regression slope with unity indicates that the assumptions underlying the diallel cross have been fulfilled. Moreover, in the present study the maternal effects were also found to be absent. The positive intercept of the regression line on the W_r axis suggested that average level of dominance was partial (Fig. 1). The array points of L106 and L103, being nearest to the point of origin, have a maximum frequency of dominant genes, whereas L5, being farthest from the origin, has a maximum frequency of recessive genes. The remainder of the parents, which occupied intermediate positions, possessed a balanced number of dominant and recessive genes. The correlation between parental order of dominance (W_r+V_r) and mean of common parent was significantly negative. This indicated that low phytic acid content was controlled by recessive alleles. The anamalous position of A5, which while being the parent with highest phytic acid content, has an intermediate value of W_r+V_r shows, however, that not all the alleles for high phytic acid content can be dominant and suggests an ambidirectional element in the dominance. The V_r, W_r graph also depicted variation among parents.

Estimates of variance components revealed that additive (D) as well as non-additive (H_1 and H_2) components were significant (Table 5). The value of D was greater than that of H_1 which suggested that this trait is largely governed by additive gene effects. F, the measure of covariance between the additive and dominance effect, was nonsignificant, depicting an equal distribution of recessive and dominant genes. The

Table 4. Analysis of variance of the diallel table for phytic acid content

Item	d.f.	Mean square
a	11	48.49**
b	66	1.68**
b_1	1	11.33**
b_2	11	0.71*
b_3	54	1.70**
c	11	0.48
d	55	0.36

* Significant at $P=0.05$; ** Significant at $P=0.01$

Table 5. Components of genetic variance for phytic acid content

$D=6.14\pm0.42$	$F=-1.11\pm0.94$
$H_1=3.82\pm0.83$	$E=0.03\pm0.11$
$H_2=3.92\pm0.69$	$(H_1/D)^{1/2}=0.78$

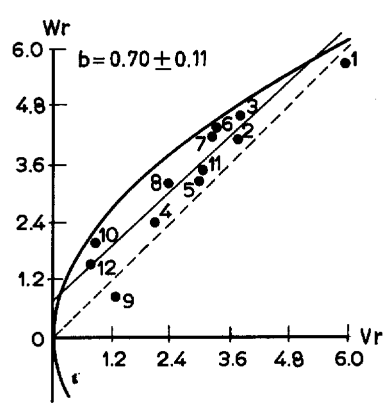

Fig. 1. Graph of W_r against V_r for phytic acid content (the array points for parents L5, L10, L20, A5, A7, A10, L101, L102, L103, L104, L105 and L106 have been designated 1 to 12, respectively)

estimate of degree of dominance $(H_1/D)^{1/2}$ was less than one, showing a partial dominance. The estimate of $\overline{uv}$ was less than 0.25 (the theoretical maximum when $u=v=0.5$), which indicated that alleles determining high or low phytic acid content were not distributed equally among the parents.

In the literature there is no published record about the inheritance pattern of phytic acid content in pearl millet, or in any other crop. In the present investigation different genetic analyses depicted the presence of both additive and nonadditive genetic variation. Under such a situation, it is advisable to follow a population improvement programme using recurrent selection to breed for low phytic acid content. If a sufficient number of lines with low phytic acid content become available, a programme for the development of synthetics or composites can also be initiated.

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