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Genetic variability studies and interrelationships among nutritional quality characters, phytate phosphorus and grain yield in the seeds of pearl millet [*Pennisetum glaucum* (L.) R. Br.]

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Abstract

The data on chemical constitution of pearl millet [*Pennisetum glaucum* (L.) R. Br.] grain and grain yield were recorded for sixty three hybrids and their sixteen parents during post rainy season of 2004. Significant differences were observed for all the characters studied. More or less equal magnitude of both genotypic and phenotypic coefficient of variation was observed for all the characters. Heritability in broad sense and genetic advance were found to be high to moderate for recorded characters. Highly significant negative correlation was observed between grain yield and protein. Phytate phosphorus is positively associated with phosphorus and negatively associated with iron and zinc. This study suggested that simultaneous improvement of both grain quality characters and grain yield is difficult.

Key words: Pearl millet, variability, correlation, grain quality characters, anti nutritional compound

Introduction

Pearl millet [*Pennisetum glaucum* (L.) R. Br.] is one of the major world cereals and grown principally for human food in tropical and subtropical areas of Africa and the Indian Subcontinent. As a food crop, pearl millet grain possesses the highest amount of calories per 100 grams [1] which is mainly supplied by carbohydrates, fats and proteins [2]. Its mineral content is also comparable with other cereals [1, 3]. Even though pearl millet grain is considered good for human diet, it has an anti-nutritional compound phytate phosphorus, called as myo-inositol hexakisphosphate and which is the most important storage form of phosphorus in cereal grains constituting about 60-80 percent of seed total phosphorus [4]. Moreover, phytate phosphorus is virtually indigestible by humans, as it is not hydrolyzed by the intestinal enzymes. Hence, pearl millet grain is hard to digest [5]. In addition to that phytate phosphorus present in pearl millet seeds will bind to nutritionally important minerals such as calcium, iron and zinc and it causes mineral deficiency in human, particularly with respect to iron and zinc [6]. Relatively little information is available on aspects of genetic variation with respect to grain quality in pearl millet, which needs to be improved along with grain yield. Such information is, however, essential to understand the genetic potential of a particular population and to develop an effective breeding programme to manipulate quality traits. Also, information on relationships among different nutritional quality characters, anti-nutritional compound and grain yield is necessary for genetic improvement of any material. The present study was, therefore, under taken to assess genetic variation and to study the relationships among different nutritional quality characters, anti-nutritional compound, phytate phosphorus and grain yield in pearl millet.

Materials and methods

The present investigation was carried out on seven male sterile lines (81 A, L 111 A, 732A, ICMA 91444, ICMA 91777, ICMA 94222 and Tib 2A), nine testers (PT 811/10, PT 1793, PT 2060, PT 4450, PT 5442, PT 5591, PT 5749, ICMV 221 and Palladam local) and their sixty three hybrids produced by crossing male sterile lines with testers in a line × tester mating design. The material was grown in a randomized blocks design with two replications during post rainy season of 2004 (January to April) at the Millet Breeding Station of the Tamil Nadu Agricultural University, Coimbatore. Grain yield per plant was recorded individually at the time of crop maturity on five randomly taken plants in each replication excluding border plants. After threshing, cleaning and weighing, the grains from each entry were dried in hot air oven at 60°C for 6 hours. Replication wise, the grains were then ground in Willey mill, labeled properly and flour was stored in butter paper covers still further analysis. The procedures adopted for each quality estimation are furnished below.

The procedure, standard preparation and calculations for starch estimation were adopted from method suggested by Hodge and Hofreiter [7]. The nitrogen content was estimated by conventional Micro-Kjeldahl method (Humphries) [8] and the estimated value of nitrogen was multiplied by 6.25 to obtain the crude protein per cent on the assumption that the protein of pearl millet contains 16 per cent nitrogen. Crude fat was estimated by subjecting a known weight (2g) of the grain sample to continuous extraction with petroleum ether in a Soxhlet apparatus and the loss of weight was expressed as crude fat content as per the methoa of A.O.A.C. [9]. Calcium was estimated in pearl millet grain samples following Versenate titration method (Jackson) [10], phosphorus as per Vanadomolybdo phosphoric yellow colour method of Piper [11], triple acid extract used for iron and zinc estimation in Atomic Absorption Spectrophotometer method (Jackson) [10] and phytate phosphorus based on the method of Wheeler and Ferrel [12].

The experimental data were subjected to the analysis of variance as suggested by Panse and Sukhatme [13]. Genotypic and phenotypic coefficient of variation were computed based on the method given by Burton [14]. Heritability in the broad sense was calculated according to Lush [15]. Genetic advance was expressed as percentage of mean by using the formula suggested by Johnson *et al.*, [16]. The genotypic correlations among nutritional quality characters, phytate phosphorus and grain yield were calculated as per the method suggested by Johnson *et al.*, [16]. The significance of genotypic correlation coefficient was tested by referring to the standard table given by Snedecor [17].

Results and discussion

Analysis of variance for nutritional quality characters, phytate phosphorus and grain yield revealed highly significant differences among genotypes for all characters under study (Table 1). The mean values and range for each trait are given in Table 2 along with genotypic and phenotypic coefficient of variation, heritability in broad sense and genetic advance as percentage of mean.

Though range is a crude measure of variability present in genotypes and it does give an idea of spread of variation for a particular character. A wide spread of variation was observed for starch, crude protein, calcium, phosphorus, zinc, phytate phosphorus and grain yield (Table 2) which was expected from the results of analysis of variance.

The relative values of genotypic and phenotypic coefficient of variation provide important information on the magnitude of variation. Zinc had the highest genotypic coefficient of variation followed by iron, calcium, crude fat and phytate phosphorus (Table 2). The magnitude of both genotypic and phenotypic coefficient of variation for all characters was comparable for all recorded characters except crude protein and calcium. This narrow difference between these two coefficients of variation implies low environmental influence and predominant role of genetic factors on the expression of these characters. This was further confirmed by high heritability estimates for starch, crude fat, phosphorus, iron, zinc, phytate phosphorus and grain yield as observed in the present study. So selection for improvement of these characters is likely to be rewarding. These observations corroborate well with those of Berwal *et al.*, [18].

Heritability in broad sense includes both fixable (additive) and non fixable (dominant and epistatic) variances. The estimates of heritability for different characters (Table 2) ranged from 86.77 to 99.87 percent. Heritability estimates along with genetic advance would be helpful in predicting gain under selection than heritability estimates alone. In the present study, crude fat, iron, zinc and phytate phosphorus recorded high heritability as well as high genetic advance over their respective mean. This indicates predominance of additive gene effects for the expression of these characters. Starch and phosphorus showed high heritability with relatively lower genetic advance than other traits. This is an indication of more environmental influence on these characters.

In breeding programmes, a clear understanding of the relationships among different nutritional quality characters, anti-nutritional compound and grain yield is very helpful for improving these characters in pearl millet.

Table 1. Mean squares from analysis of variance for nutritional quality characters, phytate phosphorus and grain yield in pearl millet

Source	df	Nutritional quality characters (in 100g basis)							Phytate phosphorus	Grain yield per plant
		Starch (g)	Crude protein (g)	Crude fat (g)	Calcium (mg)	Phosphorus (mg)	Iron (mg)	Zinc (μg)	(mg $100g^{-1}$)	(g)
Replication	1	0.04	0.04	2.67	5.32	2.52	0.04	1.07	9.14	0.39
Entries	78	95.42**	7.43**	4.07**	213.59**	4093.43**	3.19**	4702.85**	4322.11**	497.90**
Error	78	5.49	0.98	0.09	26.91	11.43	0.01	94.88	5.47	17.03

**Significance at 1 per cent level of probability

Table 2. Mean, range, genotypic and phenotypic coefficient of variation, heritability and genetic advance for nutritional quality characters, phytate phosphorus and grain yield in pearl millet

Characters	Meant ± SE	Range	GCV (%)	PCV (%)	h^2 (bs)	GA (% of mean)
Starch (g $100g^{-1}$)	59.85±1.66	42.24-70.42	11.19	11.53	94.27	22.40
Crude protein (g $100g^{-1}$)	11.96±0.70	7.67-16.90	15.01	16.11	86.77	28.80
Crude fat (g $100g^{-1}$)	5.12±0.22	1.82-8.18	27.52	27.84	97.71	56.05
Calcium (mg $100g^{-1}$)	33.94±3.67	20.00-76.00	28.46	30.44	87.40	54.81
Phosphorus (mg $100g^{-1}$)	313.70±2.39	189.15-403.65	14.40	14.42	99.72	29.62
Iron (mg $100g^{-1}$)	4.21±0.07	2.39-9.03	29.93	29.98	99.66	61.55
Zinc (μg $100g^{-1}$)	146.49±6.89	84.50-300.00	32.76	33.10	97.98	66.81
Phytate phosphorus (mg $100g^{-1}$)	186.64±1.65	73.20-291.55	24.89	24.90	99.87	51.24
Grain yield per plant (g)	83.70±2.91	45.13-115.69	18.53	18.85	96.58	37.50

Although association between grain yield and other plant characters has been studied in pearl millet by earlier workers [19-21], information on the nutritional quality is very scanty. The nature of the association of grain yield with protein indicated negative association between these two characters (Table 3) thereby indicating that the simultaneous improvement of grain yield and protein is somewhat difficult. This was in accordance with the findings of Deosthale *et al.*, [22], Gupta *et al.*, [23] and Reddy and Sharma [24]. Crude fat was significantly and positively correlated with grain yield. Starch had a significant and positive correlation with grain yield though degree of association was low (r = 0.234*). Calcium, phosphorus, iron, zinc and phytate phosphorus had non significant association with grain yield. This result contradicts that of Feil and Fossati [25] who observed significant negative association between grain yield and phytate phosphorus content in triticale grain.

phosphates. Phosphorus contributes to the supportive structures of the body and it is an essential component in nucleic acid. Therefore, an efficient selection scheme is to be designed to reduce phytate phosphorus concentration to some extent, while maintaining the optimum level of phosphorus content in seeds of pearl millet.

The large negative correlation of phytate phosphorus existed with iron (r = –0.718**) and zinc (r = –0.815**) content, which suggested that bioavailability of zinc and iron are more dependant on the phytate phosphorus concentration and thus phytate phosphorus appears to be an inhibitor of iron and zinc availability. This was in conformity with Udayasekhara Rao and Deosthale [26].

An inverse relationship of zinc and iron with phytate phosphorus is so high that a breeding programme involving simultaneous selection for high zinc and iron and low phytate phosphorus would be desirable and highly rewarding. No significant association was observed between phytate phosphorus and crude protein [27], which indicates phytate phosphorus concentration, does not affect the availability of protein in diet. However, Raboy *et al.*, [28] observed positive correlation between phytate phosphorus and protein content in winter wheat.

Table 3. Genotypic correlation coefficients among nutritional quality characters, phytate phosphorus and grain yield in pearl millet

Characters	Crude protein	Crude fat	Calcium	Phosphorus	Iron	Zinc	Phytate phosphorus	Grain yield per plant
Starch	–0.242*	0.155	–0.307**	–0.036	–0.101	0.073	0.014	0.234*
Crude protein		–0.815**	0.405**	0.018	0.016	–0.004	0.032	–0.649**
Crude fat			0.161	0.113	–0.123	–0:023	0.110	0.313**
Calcium				–0.094	0.061	0.047	0.028	–0.130
Phosphorus					–0.696**	–0.744**	0.908**	–0.057
Iron						0.563**	–0.718**	0.005
Zinc							–0.815**	0.068
Phytate phosphorus								–0.075

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

Since phosphorus and phytate phosphorus were strongly and positively correlated (r = 0.908**), it is therefore, inferred that simple selection against phytate phosphorus is likely to lower phosphorus concentration in pearl millet. A downward trend in phosphorus concentration is undesirable because diets based on cereals usually require supplementation of inorganic

Reference

1. **Burton G. W., Wallace A. T. and Rachie K. O.** 1972. Chemical composition and nutritive value of pearl millet [*Pennisetum typhoides* (Burm.) Stapf and E. C. Ubbard] grain. Crop Sci., **12**: 187-189.
2. **Fleck H.** 1981. Introduction to nutrition. Macmillan Publishig Co., India. Pp. 49.
3. **Sharma A. and Kapoor A. C.** 2000. Effect of various processing treatments of total zinc, available zinc (*in vitro*), total phosphorus, phytate phosphorus and non phytate phosphorus in pearl millet. Natnl. J. Pl. Improv., **2**: 18-21.
4. **Common R. H.** 1940. The phytic acid content of some poultry feeding stuffs. Analyst, **65**: 79.
5. **Gupta V. P.** 1980. Genetics of quality improvement. *In*: Trends in genetical research on Pennisetums, Gupta, V.P. Minnocha, J.L. (eds). PAU. Ludhiana. PP. 291-294.
6. **Oberleas D.** 1973. Phytates in toxicants occurring naturally in food. Nat. Acad. Sci. Washington, D.C.
7. **Hodge J. E. and Hofreiter B. T.** 1962. Determinaion of reducing sugars and carbohydrates, *In*: Methods in carbohydrate chemistry, (eds. Whistler R.L. and Wolfrom M.L.), Academic Press New York, pp. 380-394.
8. **Humphries E. S.** 1956. Mineral components and ash analysis. Modern methods of plant analysis, Springer Verlag. Berlin, **1**: 468-502.
9. **A.O.A.C.** 1960. Oils, Fats and Waxes. Official Methods of Analysis. 14th edn. Association of Official Agril. Chemists, Washington, D.C. 2009, 358-378.
10. **Jackson M. L.** 1973. Soil and plant analysis. Prentice Hall of India Private Limited, New Delhi.
11. **Piper C. S.** 1966. Soil and plant analysis. Inter Science Publications. New York.
12. **Wheeler E. L. and Ferrel R. E.** 1971. A method for phytic acid determination in wheat and wheat fractions. Cereal Chem., **48**: 312-319.
13. **Panse V. G. and Sukhatme P. V.** 1961. Statistical methods for agricultural workers. 2nd Ed. ICAR., New Delhi.
14. **Burton G. W.** 1952. Quantitative inheritance in grasses. Proc. 6th Int. Grassland Cong., **1**: 277-283.
15. **Lush J. L.** 1940. Intra - sire correlation and regression of offspring on dams as a method of estimating heritability of characters. Proc. Amer. Soc. Animal Production. **33**: 293-301.
16. **Johnson H. W., Robinson H. F. and Comstock R. E.** 1955. Estimation of genetic variability and environmental variability in soybean. Agron. J., **47**: 314-318.
17. **Snedecor G. W.** 1946. Statistical methods. Iowa state College Press, Ames, Iowa, USA.
18. **Berwal K. K., Khairwal I. S. and Lekh Raj.** 2001. Genetic variability in core collections of pearl millet [*Pennisetum glaucum* (L.) R. Br.]. Natal. J. Pl. Improv., **3**: 98-101.
19. **Anarase S. A., Ugale S. D. and Shinde G. C.** 2001. Correlation and path coefficient analysis in pearl millet. The Andhra Agric. J., **48**: 33-36.
20. **Yadav O. P., Weltzien R. E. and Bhandari D. C.** 2001. Genetic variation and trait relationship in the pearl millet land races from Rajesthan. Indian J. Genet., **61**: 322-326.
21. **Pareek S.** 2002. Correlation in pearl millet [*Pennisetum glaucum* (L.) R. Br.]. Research on Crops, **3**: 75-77.
22. **Deosthale Y. G., Rao K. V., Nagarajan V. and Pant K. C.** 1971. Varietal differences in protein and amino acids of grain bajra (*Pennisetum typhoides*). The Ind. J. Nutr. Dietet., **8**: 301-308.
23. **Gupta V. P., Dhillon B. S. and Sethi A. S.** 1976. The path analysis of protein, mineral content and grain yield of pearl millet. Crop Improv., **3**: 80-85.
24. **Reddy N. S. and Sharma R. K.** 1982. Variability and inter-relationships for yield characters and protein content in inbred lines of bajra. Crop Improv., **9**: 124-128.
25. **Feil B. and Fossati D.** 1997. Phytic acid in tritical grains as affected by cultivar and environment. Crop Sci., **37**: 916-921.
26. **Udayasekhara Rao P. and Deosthale Y. G.** 1988. *In vitro* availability of iron and zinc in white and coloured ragi (*Eleusine coracana*): Role of tannin and phytate. Plant Foods for Human Nutrition, **38**: 35-41.
27. **Lolas G. M. and Markakis P.** 1975. Phytic acid and other phosphorus compounds of beans (*Phaseolus vulgaris* L.). J. Agric. Food Chem., **23**: 13-15.
28. **Raboy V., Noaman M. M., Taylor, G. A. and Pickett S. G.** 1991. Grain phytic acid and protein are highly correlated in winter wheat. Crop Sci., **31**: 631-635.