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Trait association among beta carotene content and yield attributes in recombinant inbred lines of pearl millet [*Pennisetum glaucum* (L.) R. Br.]

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ABSTRACT

Pearl millet [*Pennisetum glaucum* (L.) R. Br.] is the staple diet for a vast majority of poor farmers in arid and semi-arid regions of India. An experiment was conducted at Millet Breeding Station, Tamil Nadu Agricultural University, Coimbatore to determine the interrelationship between yield and yield component traits in 250 recombinant inbred lines (RILs) of pearl millet during summer 2015. A perusal of the results of this study showed positive significant and strong genotypic and phenotypic correlations between grain yield per plant and plant height, number of productive tillers per plant, earhead length, earhead girth, single earhead weight, single earhead grain weight, 1000- grain weight and beta carotene content. Path coefficient analysis indicated that number of productive tillers per plant and single earhead grain weight had high direct effect on grain yield per plant. High indirect effect on grain yield per plant was caused by single earhead weight *via* single earhead grain weight and single earhead weight, single earhead grain weight and 1000- grain weight influences grain yield per plant through moderate positive indirect effect of number *via* productive tillers per plant. Based on the present results, it could be concluded that number of productive tillers per plant, earhead girth, single earhead weight and single earhead grain weight could be identified as the most important traits that are associated with grain yield in pearl millet. Hence these traits can be used as selection criteria for yield improvement in pearl millet.

Key words: Beta carotene content, Correlation, Path coefficient analysis, Pearl millet.

INTRODUCTION

Pearl millet [*Pennisetum glaucum* L. (R.) Br.] stands to be the most drought tolerant of all the domesticated cereals and soon after domestication, it has become widely distributed across the semi-arid tropics of Africa and Asia. It is the principal food crop across sub-Saharan Africa and northwestern India. It is considered to be a nutritious cereal crop in providing high quality grain both for human and animal consumption and will continue to play an important role in the Indian economy. This crop can be grown in harsh environments where other crops fail to grow well. Improvement in production, utilization and consumption of this crop will significantly contribute to food and nutritional security of the people across the globe.

Though pearl millet is the staple cereal supplying 80 to 90% of the calories for many millions of the poor people in semi-arid regions, the nutritive value of this crop has not received extensive attention. Grain quality of pearl millet is divided into two categories, the evident quality character based on appearance and cooking quality and the cryptic quality characters based on nutritional value (Govindaraj *et al.*, 2009). In pearl millet breeding programme, strong emphasis has been placed on selection for evident quality characters. For the cryptic quality characters, the research effort is focused on improving nutritional quality traits. Pearl millet grains are nutritionally rich and contain sufficient amount of beta carotene which is the precursor of vitamin A. Vitamin A deficiency is a threatening concern across the globe and accounts for about 70 per cent of childhood death (Chandler *et al.*, 2013). Vitamin A deficiency causes hundreds of thousands of cases of irreversible blindness every year, especially among children in developing countries. Human beings are unable to synthesize their own Vitamin 'A'. Plant derived carotene is metabolized to produce Vitamin 'A'. Pearl millet grains contain sufficient amount of beta carotene which is the precursor of Vitamin A. Beta carotene content in pearl millet was reported to be 0.1 ìg/g by Khalil and Sawaya (1984) and thus it can serve as an additional source of Vitamin A. Increasing the concentration of provitamin A in the edible portions of staple crops through plant breeding, termed biofortification, may have greater promise to reduce the incidence of vitamin A deficiency (Bouis and Welch, 2010).

Before placing strong emphasis on breeding for quality traits, the knowledge on the association between yield and yield attributes and also interrelation between yield and

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nutritional quality traits will enable the breeder for simultaneous improvement of yield along with nutritional traits. Correlation coefficients help to identify characters that have little or no importance in the selection programme. The existence of correlation may be attributed to the presence of linkage or pleiotropic effect of genes or physiological and development relationship or environmental effect or in combination of all. To tailor the yield potential of the crop, plant knowledge on associations among component traits is a pre-requisite for achieving genetic improvement in any crop (Chaudhry *et al*., 2003).

The complex nature of yield is associated with a number of component characters which are interrelated among them. Such interdependence of the contributory factors often affects their direct relationship with yield, thereby making correlation coefficients alone unreliable as selection indices. Path coefficient analysis is simply a standardized partial regression coefficient and as such it measures the direct influence of one variable upon the other and permits the separation of correlation coefficients into components of direct and indirect effects. Correlation measured the relationship existing between pairs of traits. However dependent trait is an interaction product of many mutually associated components. Path analysis takes into account the cause and effect relationship between the variables by partitioning the association into direct and indirect effects through other independent variables. The knowledge on inter relationship between beta carotene content and grain yield is limited in pearl millet. Hence the present study was formulated to determine the association of yield attributing characters and beta carotene content on grain yield and to study the direct and indirect effect of yield component traits and beta carotene content on grain yield in pearl millet.

MATERIALS AND METHODS

Genetic material: A set of 250 recombinant inbred lines (RILs) in $F_{2:8}$ generation of pearl millet (developed from a cross between PT 6029, an agronomically superior inbred with low beta carotene content of 0.059 µg/g and PT 6129, golden millet having high beta carotene content of 2.417 µg/g) was obtained from Millet Breeding Station (MBS), Tamil Nadu Agricultural University (TNAU), Coimbatore. Parental lines *viz*. PT 6029 and PT 6129 and the RILs were sown along with a promising inbred line, PT 6067 and commercial varieties, CO (Cu) 9 and CO 10 which were used as checks.

Experimental design: All the 255 entries were planted during the summer season of 2015 in a randomized block design (RBD) under the prevailing environmental conditions at the MBS, TNAU, Coimbatore which lies between 11° North latitude and 77° East longitude. All the genotypes were sown in a RBD fashion with three replications. In each replication, all the 255 genotypes were grown in 4m long rows with the spacing of 60 cm between rows and 15 cm between the plants. Initially, extra seed was planted (two to three seeds/hill) and later the plants were thinned to maintain an optimum population density (10-12 plants/row). The crop was grown under uniform conditions to minimize environmental variability to the maximum possible extent.

Data collection: Data were recorded on randomly selected five plants in each RIL in each replication for eleven morphological (Days to 50% flowering, SPAD chlorophyll meter reading (SCMR), plant height (cm), number of productive tillers per plant, ear head length (cm), ear head girth (cm), days to maturity, single ear head weight (g), single ear head grain weight (g), 1000- grain weight (g) and grain yield per plant (g) and beta carotene content (µg/g). After threshing, cleaning and weighing, grains from each entry were ground in Wiley mill separately and labeled properly and were stored in butter paper cover for quality analysis. Beta carotene content was estimated in pearl millet grains of all the 250 RILs, two parents and three checks in all three replications following the method described by Santra *et al.* (2006) and Sathya *et al.* (2014) with slight modifications.

Statistical analysis: Association between beta carotene content, grain yield and its component traits was computed based on genotypic and phenotypic correlation coefficients using the formula suggested by Al-jibouri *et al.* (1958). Path coefficient was worked out by the method suggested by Dewey and Lu (1959). By keeping yield as dependent variable and the other eleven traits as independent variables, simultaneous equations which expressed the basic relationship between the path coefficients were solved to derive the direct and indirect effects contributed by eleven traits on yield by themselves and also through other traits. Both correlation and path coefficient analysis was carried out using TNAUSTAT statistical package (Manivannan, 2014).

RESULTS AND DISCUSSION

Genotypic and phenotypic correlation coefficients of grain yield per plant with other traits are presented in Table 1. Genotypic correlation coefficient values for most of the traits were higher in magnitude than corresponding phenotypic correlation coefficient values showing the existence of inherent association among the traits. Grain yield per plant showed significant positive phenotypic and genotypic correlation with plant height, number of productive tillers per plant, earhead length, earhead girth, single earhead weight, single earhead grain weight, 1000- grain weight and beta carotene content Similar results were observed by Vetriventhan and Nirmalakumari (2007), Arulselvi *et al.* (2008) and Abuali *et al.* (2012). Negative significant genotypic correlation between grain yield per plant and SPAD chlorophyll meter reading (SCMR) was observed for genotypic correlation. Negative genotypic correlation of grain yield per plant with SPAD chlorophyll meter reading

Table 1: Genotypic and phenotypic correlation coefficients among 12 characters in RIL population of pearl millet

Characters		Days to 50 per cent flowering	SCMR	Plant height (cm)	Number of productive tillers per plant	Earhead length (cm)	Earhead girth (cm)	Days to maturity	Single earhead weight (g)	Single earhead grain weight (g)	1000-grain weight (g)	Beta carotene content (µg/g)	Grain yield per plant (g)
Days to 50 per cent flowering	G	1.000	0.013	-0.013	0.051	0.011	0.097	0.700**	-0.123	-0.087	-0.028	-0.091	-0.033
	P	1.000	0.010	-0.017	0.038	0.013	0.045	0.591**	-0.103	-0.075	-0.009	-0.079	-0.031
SCMR	G		1.000	0.036	-0.084	-0.013	-0.055	0.095	0.042	-0.030	-0.058	0.020	-0.128*
	P		1.000	0.030	-0.081	-0.012	-0.043	0.077	0.036	-0.030	-0.042	0.019	-0.121
Plant height (cm)	G			1.000	0.159*	0.194**	0.203**	0.077	0.008	-0.018	0.115	-0.110	0.140*
	P			1.000	0.143*	0.179**	0.160*	0.059	0.003	-0.015	0.087	-0.106	0.140*
Number of productive tillers per plant	G				1.000	0.225**	0.247**	-0.052	0.387**	0.324**	0.345**	0.236**	0.811**
	P				1.000	0.208**	0.188**	-0.036	0.340**	0.298**	0.249**	0.224**	0.768**
Earhead length (cm)	G					1.000	0.095	-0.017	0.130*	0.088	0.231**	0.058	0.253**
	P					1.000	0.092	-0.017	0.114	0.084	0.183**	0.057	0.236**
Earhead girth (cm)	G						1.000	0.019	0.227**	0.206**	0.180**	0.029	0.355**
	P						1.000	0.016	0.167**	0.159*	0.140*	0.020	0.273**
Days to maturity	G							1.000	-0.100	-0.065	0.021	-0.135*	-0.101
	P							1.000	-0.068	-0.054	0.011	-0.117	-0.096
Single earhead weight (g)	G								1.000	0.860**	0.446**	0.305**	0.651**
	P								1.000	0.780**	0.349**	0.280**	0.592**
Single earhead grain weight (g)	G									1.000	0.369**	0.303**	0.656**
	P									1.000	0.281**	0.282**	0.617**
1000- grain weight (g)	G										1.000	0.090	0.452**
	P										1.000	0.075	0.352**
Beta carotene content (µg/g)	G											1.000	0.307**
	P											1.000	0.292**
Grain yield per plant (g)	G												1.000
	P												1.000

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

(SCMR) indicates that selection based on higher SCMR will decrease grain yield in pearl millet.

Beta carotene content in pearl millet was found to have positive and significant correlation with number of productive tillers per plant, single earhead weight and single earhead grain weight. Hence simultaneous improvement of these traits is possible. Negative genotypic association of beta carotene content with days to maturity suggested that early maturing RILs would have high beta carotene content. Thousand grain weight exhibited positive correlation with number of productive tillers per plant, earhead length, earhead girth, single earhead weight and single earhead grain weight. Single earhead grain weight showed positive association with number of tillers per plant, earhead girth and single earhead weight whereas single earhead weight expressed positive correlation with number of productive tillers per plant and earhead girth. Both earhead girth and earhead length showed positive and significant correlation with plant height and number of productive tillers per plant. Plant height and number of productive tillers per plant exhibited positive correlation. Similar findings were confirmed by Govindaraj *et al.* (2009), Vagadiya *et al.* (2010) and Singh *et al.* (2014) in pearl millet.

Correlations alone may not give a clear picture of the association between different traits of a crop. For this, one should go for path coefficient analysis which is based on cause effect relationship. Path coefficient analysis permits the separation of direct effects from indirect effects through other related characters by partitioning the genotypic correlation coefficients, providing a clear picture of the characters that can be relied upon in a selection programme for improvement of yield in pearl millet. Selection procedure should be formulated so that the advance in one trait is not jeopardized by the deterioration effect of the other trait.

The direct and indirect effects of beta carotene content and other yield attributing traits on grain yield per plant were partitioned from the genotypic correlation matrix by path coefficient analysis and are presented in Table 2. Residual effect of 0.3837 indicated the adequacy of the traits chosen for path analysis. The present study revealed that high direct effect on grain yield per plant was contributed by number of productive tillers per plant and single earhead grain weight. Earhead girth exhibited moderate direct effect on grain yield per plant. This revealed the true relationship of these characters with grain yield per plant. Hence direct selection for these traits could be rewarding for the improvement of grain yield in pearl millet. This was in accordance with Izge *et al.* (2006), Kumari and Nagarajan (2008), Abuali *et al.* (2012), Govindaraj and Selvi (2012) and Singh *et al.* (2014). The traits *viz.* 1000- grain weight, earhead length, beta carotene content, single earhead weight and plant height showed negligible direct effects on grain yield per plant. The maximum indirect effect on grain yield

Table 2: Genotypic path coefficients for 11 characters on grain yield per plant in RIL population of pearl millet

Characters	Days to 50 per cent flowering	SCMR	Plant height (cm)	Number of productive tillers per plant	Earhead length (cm)	Earhead girth (cm)	Days to maturity	Single earhead weight (g)	Single earhead grain weight (g)	1000-grain weight (g)	Beta carotene content (µg/g)	Genotypic correlation with grain yield per plant (g)
Days to 50 per cent flowering	**-0.0142**	-0.0007	-0.0003	0.0315	0.0006	0.0097	-0.0191	-0.0034	-0.0329	-0.0014	-0.0026	-0.033
SCMR	-0.0002	**-0.0559**	0.0008	-0.0510	-0.0007	-0.0055	-0.0026	0.0012	-0.0114	-0.0031	0.0006	-0.128*
Plant height (cm)	0.0002	-0.0020	**0.0207**	0.0965	0.0098	0.0204	-0.0021	0.0002	-0.0067	0.0060	-0.0031	0.140*
Number of productive tillers per plant	-0.0007	0.0047	0.0033	**0.6083**	0.0114	0.0248	0.0014	0.0108	0.1223	0.0180	0.0066	0.811**
Earhead length (cm)	-0.0002	0.0007	0.0040	0.1371	**0.0507**	0.0096	0.0005	0.0036	0.0330	0.0121	0.0016	0.253**
Earhead girth (cm)	-0.0014	0.0031	0.0042	0.1500	0.0048	**0.1005**	-0.0005	0.0063	0.0777	0.0094	0.0008	0.355**
Days to maturity	-0.0099	-0.0053	0.0016	-0.0313	-0.0009	0.0019	**-0.0272**	-0.0028	-0.0245	0.0011	-0.0038	-0.101
Single earhead weight (g)	0.0017	-0.0023	0.0002	0.2352	0.0066	0.0228	0.0027	**0.0279**	0.3243	0.0233	0.0086	0.651**
Single earhead grain weight (g)	0.0012	0.0017	-0.0004	0.1972	0.0044	0.0207	0.0018	0.0240	**0.3772**	0.0193	0.0085	0.656**
1000- grain weight (g)	0.0004	0.0033	0.0024	0.2100	0.0117	0.0181	-0.0006	0.0125	0.1392	**0.0522**	0.0025	0.452**
Beta carotene content (µg/g)	0.0013	-0.0011	-0.0023	0.1434	0.0030	0.0029	0.0037	0.0085	0.1143	0.0047	**0.0282**	0.307**

*, ** Significant at 5% and 1 % level respectively Residual effect = 0.3837

per plant was caused by single earhead weight *via* single earhead grain weight. The traits such as single earhead weight, single earhead grain weight and 1000- grain weight influences grain yield per plant through moderate positive indirect effect of number of productive tillers per plant. Low indirect effects of earhead length, earhead girth and beta carotene content was observed for grain yield per plant through number of tillers per plant. Similarly, number of productive tillers per plant, 1000- grain weight and beta carotene content expressed low indirect effects on grain yield per plant *via* single earhead grain weight. The rest of the yield attributes showed negligible indirect effects on grain yield per plant through other yield attributing traits.

CONCLUSION

The present study revealed the existence of association of most of the yield attributing traits with beta carotene content and grain yield per plant in pearl millet. Based on results of this study it could be concluded that plant height, number of productive tillers per plant, earhead length, earhead girth, single earhead weight, single earhead grain weight, 1000- grain weight and beta carotene content appeared to be the prominent traits when selecting for grain yield per plant in pearl millet. High direct effect on grain yield per plant was contributed by number of productive tillers per plant and single earhead grain weight whereas moderate direct effect by earhead girth. High indirect effect on grain yield per plant was caused by single earhead weight through single earhead grain weight. This investigation therefore suggests that number of productive tillers per plant, earhead girth, single earhead weight and single earhead grain weight should be given maximum consideration as the appropriate selection criteria for yield improvement in pearl millet.

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