Electronic Journal of Plant Breeding, 8(2): 548-553 (June 2017)
ISSN 0975-928X
DOI: 10.5958/0975-928X.2017.00082.5

Research Article

Direction of association among β-carotene, grain yield and its component traits in RIL population of pearl millet

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(Received: 05 Feb 2017; Revised: 09 April 2017; Accepted: 24 April 2017)

Abstract
Pearl millet grain is nutritionally rich and contains higher protein content than many other cereals. Besides protein, pearl millet grains also contain sufficient amount of β-carotene. β-carotene is a precursor for vitamin A biosynthesis. Hence genetic biofortification of β carotene in pearl millet, will have a profound effect on human nutrition in Africa and India. Towards this objective, an experiment was conducted with two hundred RILs (F_6) which were developed from the cross PT 6029 (0.059 µg/g) × PT 6129 (2.417 µg/g) for β-carotene to ascertain the information of magnitude and direction of association among β-carotene, grain yield and its component traits in pearl millet. The study indicated that, number of productive tillers per plant, earhead length, earhead girth, single earhead weight, single earhead grain weight, 1000 grain weight, chlorophyll content and β-carotene recorded highly significant and positive genotypic correlation with grain yield per plant during summer, 2013 and *kharif*, 2013. Correlation coefficients are helpful in determining the component of a complex trait like yield, they do not provide an exact picture of the relative importance of direct and indirect influence of each of the component characters towards yield. Path coefficient analysis furnishing the cause and effect of different yield components would provide better index for selection rather than correlation coefficients. In the present investigation, Number of productive tillers per plant, single earhead weight, single earhead grain weight, 1000 grain weight, chlorophyll content and β-carotene content recorded positive direct effect on grain yield per plant in both seasons *viz.*, summer, 2013 and *kharif*, 2013. This showed simultaneous improvement of this trait through single selection programme.

Key words
Pearl millet, β-carotene, correlation, grain yield and direct and indirect effect

Introduction

Pearl millet [*Pennisetum glaucum* (L.) R. Br.] known as bulrush or cattail millet, is the most important among a number of unrelated millet species grown for food worldwide (Angarawai *et al*., 2008). In India pearl millet is fifth most important grain crop next to rice, wheat, maize and sorghum. It is grown in a area of 7 million ha with 9.25 million tones production (AICRP, Annual Repot, 2015). Breeding for high β-carotene pearl millet genotypes is an effective strategy for reducing Vitamin A Deficiency (VAD). Pearl millet contain sufficient amount of β carotene which is the precursor of vitamin A. Vitamin A is an essential nutrient needed by humans; however, humans are unable to synthesize their own vitamin A, which need to be provided through diet as provitamin A. Vitamin A deficiency (VAD) causes about 70 per cent of childhood deaths worldwide and blindness in 0.25 to 0.5 million children every year (Vignesh *et al*., 2012). Vitamin A Deficiency, widely prevalent worldwide, affects people predominantly dependent on cereals diet that is mostly deficient in β carotene (Vignesh *et al*., 2014). A stable food with rich β carotene would be the easiest way to alleviate vitamin A deficiency which is one of the most important nutritional problems in developing countries. Correlation and path analysis aid in the selection of superior genotypes from the breeding population. Correlation coefficient helps to differentiate vital associations from those of the non vital ones. Study on correlation coefficient facilitates simultaneous improvement of two or more characters and is essential for the formulation of breeding programme aimed at achieving the desired combinations of various yield components. Correlation coefficients are helpful in determining the component of a complex trait like yield; they do not provide an exact picture of the relative importance of direct and indirect influence of each of the component characters towards yield. Path coefficient analysis furnishing the cause and effect of different yield components would provide better index for selection rather than correlation coefficients.

Materials and methods

The experimental material comprised of two hundred RILs (F_6) which were developed from the cross between agronomically superior inbred line PT 6029 with golden millet line PT 6129 by ear to row method. The materials for the field experiments were obtained from the pearl millet unit at Department of Millets, TNAU, Coimbatore. Seeds from selfed single earhead of F_5 generation were divided into two parts, the first part of the seeds were sown during summer, 2013 and second part of the seeds were sown during *kharif*, 2013. A total of 200 RILs along with its parents were grown in a Randomized Block Design (RBD) with two replications during summer, 2013 and *kharif*,

DOI: 10.5958/0975-928X.2017.00082.5

2013. Each RIL was raised in a row with 45 × 15 cm. Normal cultural practices were followed as per standard recommendations. The observation were recorded for five randomly selected plants in each RILs for 11 characters *viz.*, days to 50 % flowering, days to maturity, plant height, number of productive tillers, ear head length (cm), ear head girth (cm), single ear head weight (g), single ear head grain weight (g), 1000 grain weight (g), chlorophyll content and single plant yield (g). The selfed seeds (F_6) collected from 200 RILs during summer, 2013 and *kharif*, 2013 was used to estimate β-carotene. The estimation of β-carotene in this study was followed as described by Sandra *et al.* (1995) in wheat with minor modifications. This modified protocol was standardized in pearl millet for β-carotene estimation (Sathya *et al.*, 2014). The association between β-carotene, grain yield and its component traits was computed based on genotypic correlation coefficients (Goulden, 1952). The data recorded during summer, 2013 and *kharif*, 2013 were statistically analyzed separately. Significance of genotypic and phenotypic correlation coefficient was tested by referring to the standard table given by Snedecor (1961). Path coefficient analysis was carried out as suggested by Dewey and Lu (1959). The direct and indirect effects were classified based on the scale given by Lenka and Misra (1973).

Results and discussion

The genotypic correlation coefficients between yield and the component traits and the inter-correlations among the different component traits are presented in the table 1.

In the present study, number of productive tillers per plant, earhead length, earhead girth, single earhead weight, single earhead grain weight, 1000 grain weight, chlorophyll content and β-carotene recorded highly significant and positive genotypic correlation with grain yield per plant during both the season. This confirmed that these characters were mostly responsible for determining yield in pearl millet. Hence, selection based on these characters will help in improving the grain yield. This was in accordance with the findings of Sumanth *et al.* (2014) for number of productive tillers per plant, earhead length, earhead girth and 1000 grain weigh. Kilic and Yagbasanlar (2010) and Guendouz *et al.* (2014) reported that chlorophyll content positively associated with grain yield in durum wheat.

The trait, days to 50 per cent flowering showed highly significant positive genotypic correlation with days to maturity in both the seasons, it indicates early flowering influences early maturity. Similar results were reported by Sowmiya *et al*. (2016). Days to 50 per cent flowering showed highly significant positive genotypic correlation with earhead girth during *kharif* 2013 whereas, days to maturity showed highly significant positive genotypic correction with earhead length, earhead girth, single earhead weight, chlorophyll content and β-carotene content during *kharif*, 2013.

Plant height recorded highly significant and positive genotypic correlation with number of productive tillers per plant, earhead length, earhead girth, single earhead grain weight and grain yield per plant, whereas, it showed significant and positive genotypic correlation with 1000 grain weight during summer, 2013. Number of productive tillers per plant showed highly significant positive association with earhead girth, single earhead weight, single earhead grain weight, 1000 grain weight and chlorophyll content across the seasons. Earlier, it was reported by Sowmiya *et al*. (2016) for single earhead weight and single earhead grain weight. Number of productive tillers per plant showed highly significant positive association with β-carotene during *kharif*, 2013.

Earhead length and earhead girth recorded highly significant positive association with single earhead weight, single earhead grain weight, 1000 grain weight and with β-carotene, which indicates an increase in earhead length and earhead girth increases the single earhead grain weight, single earhead weight and 1000 grain weight in both the seasons. Hence, simultaneous improvement of β-carotene content is possible while selecting for yield traits like earhead size, weight, and grain weight. Earhead length and earhead girth showed highly significant positive association with chlorophyll content during *kharif*, 2013, whereas earhead girth alone showed significant positive association with chlorophyll content during summer, 2013. The traits, single earhead weight, single earhead grain weight, 1000 grain weight chlorophyll content and β-carotene were positively and significantly inter correlated with each other in both the seasons. Sumanth *et al.* (2014) reported for single earhead grain weight with 1000 grain weight. This will be advantageous for developing high yielding pearl millet varieties with high β-carotene in order to overcome vitamine A deficiency in India.

Correlation coefficients are helpful in determining the component of a complex trait like yield; they do not provide an exact picture of the relative importance of direct and indirect influence of each of the component characters towards yield. Path coefficient analysis furnishing the cause and effect of different yield components would provide better index for selection rather than correlation coefficients.

Plant height recorded positive direct effect on grain yield per plant during summer 2013, whereas it showed negative direct effect on grain yield per plant during *kharif* 2013. Number of productive

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tillers per plant, single earhead weight, single earhead grain weight, 1000 grain weight, chlorophyll content and β-carotene content recorded positive direct effect on grain yield per plant across the seasons (Table 2). This showed simultaneous improvement of this trait through single selection programme. This is similar to the earlier findings of Naveen *et al.* (2016) and Sowmiya *et al.* (2016) for number of productive tillers per plant, single earhead weight and single earhead grain weight.

Indirect effect of number of productive tillers per plant on grain yield per plant through days to maturity, plant height, single earhead weight, single earhead grain weight, 1000 grain weight and chlorophyll content was positive in both the seasons. Hence, indirect selection could be made through days to maturity, plant height, single earhead weight, single earhead grain weight, 1000 grain weight, chlorophyll content and β-carotene. This was in accordance with the studies of Naveen *et al.* (2016) and Sumathi *et al*. (2016) for single earhead weight. Earhead length showed positive indirect effect towards grain yield per plant through plant height, number of productive tillers per plant, single earhead weight, single earhead grain weight and 1000 grain weight across the seasons, whereas earhead girth recorded positive indirect effect towards grain yield per plant through plant height, number of productive tillers per plant, single earhead weight, single earhead grain weight, 1000 grain weight and chlorophyll content across the seasons.

Single earhead weight showed positive indirect effect towards grain yield per plant through days to 50 per cent flowering, number of productive tillers per plant, single earhead grain weight, 1000 grain weight and chlorophyll content were positive in both the seasons. Single earhead grain weight showed positive indirect effect towards grain yield per plant through days to 50 per cent flowering, number of productive tillers per plant, single earhead weight, 1000 grain weight and chlorophyll content in both the season. Similar findings were reported by Sowmiya *et al.*, 2016 for single earhead weight.

Indirect effect of 1000 grain weight on grain yield per plant through days to 50 per cent flowering, number of productive tillers per plant, single earhead weight, single earhead grain weight and chlorophyll content were positive in both the seasons. Similar findings were reported by Sumanth *et al.* (2014) for single earhead grain weight. Chlorophyll content and β-carotene showed positive indirect effect towards grain yield per plant through number of productive tillers per plant, single earhead weight and single earhead grain weight during summer and *kharif*, 2013 season. Hence, indirect selection could be made through number of productive tillers per plant, single earhead weight, single earhead grain weight for the improvement of chlorophyll content and β-carotene in pearl millet. A residual effect of 0.40 was observed. The residual effect determines how best the causal factors account for the variability of the dependent factor. Low residual value in this study indicated the adequacy of the characters included in the present study.

The studies on association analysis in pearl millet have brought out the importance of the traits, number of productive tillers per plant, earhead length, earhead girth, single earhead weight, single earhead grain weight, 1000 grain weight, chlorophyll content and β-carotene in improving the grain yield per plant. Hence, it could be inferred that selection should be positive for these traits and selection based on these traits would automatically increase the yield of the plant.

Acknowledgement
Funding by UGC, New Delhi to undertake the above research is gratefully acknowledged.

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Electronic Journal of Plant Breeding, 8(2): 548-553 (June 2017)
ISSN 0975-928X
DOI: 10.5958/0975-928X.2017.00082.5

Table 1. Genotypic correlation coefficients among 12 characters in RIL population

Characters		Days to 50 per cent flowering	Days to maturity	Plant height (cm)	Number of productive tillers per plant	Earhead length (cm)	Earhead girth (cm)	Single earhead weight (g)	Single earhead grain weight (g)	1000 grain weight (g)	Chlorophyll content	β-carotene (µg/g)	Grain yield per plant (g)
Days to 50 per cent flowering	S	1.000	0.658**	-0.051	0.089	-0.140*	-0.124	-0.035	-0.050	-0.023	-0.084	-0.012	-0.009
	K	1.000	0.825**	-0.094	-0.072	0.106	0.190**	-0.045	-0.101	-0.057	0.044	0.049	-0.098
Days to maturity	S		1.000	-0.014	0.023	-0.053	-0.243**	-0.089	-0.121	-0.012	-0.052	-0.049	-0.111
	K		1.000	-0.146*	0.109	0.865**	0.295**	0.184**	-0.026	-0.008	0.279**	0.382**	-0.015
Plant height (cm)	S			1.000	0.423**	0.340**	0.249**	0.114	0.218**	0.181*	-0.072	-0.022	0.303**
	K			1.000	0.047	0.037	0.041	-0.111	-0.159*	-0.093	-0.062	0.089	-0.085
Number of productive tillers per plant	S				1.000	0.172*	0.224**	0.238**	0.252**	0.209**	0.220**	0.114	0.578**
	K				1.000	0.422**	0.583**	0.572**	0.579**	0.498**	0.544**	0.348**	0.747**
Earhead length (cm)	S					1.000	0.314**	0.373**	0.440**	0.503**	-0.021	0.188**	0.442**
	K					1.000	0.554**	0.571**	0.476**	0.414**	0.565**	0.734**	0.698**
Earhead girth (cm)	S						1.000	0.760**	0.833**	0.858**	0.162*	0.459**	0.830**
	K						1.000	0.464**	0.599**	0.707**	0.411**	0.577**	0.596**
Single earhead weight (g)	S							1.000	0.838**	0.832**	0.312**	0.495**	0.828**
	K							1.000	0.865**	0.758**	0.760**	0.380**	0.863**
Single earhead grain weight (g)	S								1.000	0.883**	0.275**	0.489**	0.859**
	K								1.000	0.893**	0.764**	0.429**	0.878**
1000 grain weight (g)	S									1.000	0.204**	0.416**	0.853**
	K									1.000	0.524**	0.452**	0.874**
Chlorophyll content	S										1.000	0.445**	0.398**
	K										1.000	0.297**	0.824**
β-carotene (µg/g)	S											1.000	0.581**
	K											1.000	0.405**

*, ** Significance at 5 and 1 per cent level, respectively

S - Summer 2013, K - *Kharif* 2013

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DOI: 10.5958/0975-928X.2017.00082.5

Table 2. Path analysis showing direct and indirect effect of 11 characters on grain yield

Characters		Days to 50 per cent flowering	Days to maturity	Plant height (cm)	Number of productive tillers	Earhead length (cm)	Earhead girth (cm)	Single earhead weight (cm)	Single earhead grain weight (cm)	1000 grain weight (g)	Chlorophyll content	β-carotene (µg/g)	Grain yield per plant (g)
Days to 50 per cent flowering	S	**-0.0703**	0.0487	-0.0024	0.0314	0.0034	0.0179	-0.0187	-0.0141	-0.0034	-0.0001	-0.0017	-0.0094
	K	**-0.2148**	0.1755	-0.0020	-0.0130	0.0020	-0.0106	-0.0110	-0.0150	-0.0198	0.0158	-0.0050	-0.0979
Days to maturity	S	-0.0987	**0.0347**	-0.0006	0.0082	0.0013	0.0352	-0.0473	-0.0343	-0.0018	-0.0001	-0.0072	-0.1106
	K	-0.2759	**0.1367**	-0.0031	0.0198	0.0243	-0.0166	0.0450	-0.0039	-0.0026	0.1002	-0.0391	-0.0152
Plant height (cm)	S	0.0035	-0.0004	**0.0482**	0.1492	-0.0083	-0.0361	0.0609	0.0618	0.0273	-0.0001	-0.0032	0.3029**
	K	0.0203	-0.0199	**0.0219**	0.0086	0.0007	-0.0023	-0.0270	-0.0238	-0.0321	-0.0222	-0.0091	-0.0849
Number of productive tillers	S	-0.0062	0.0008	0.0204	**0.3525**	-0.0042	-0.0325	0.1268	0.0716	0.0315	0.0004	0.0167	0.5778**
	K	0.0154	0.0148	0.0013	**0.1824**	0.0080	-0.0328	0.1397	0.0866	0.1719	0.1953	-0.0356	0.7470**
Earhead length (cm)	S	0.0098	-0.0018	0.0164	0.0608	**-0.0245**	-0.0455	0.1985	0.1249	0.0758	-0.0004	0.0277	0.4417**
	K	-0.0227	0.1738	0.0008	0.0769	**0.0191**	-0.0311	0.1393	0.0711	0.1430	0.2031	-0.0751	0.6982**
Earhead girth (cm)	S	0.0087	-0.0084	0.0120	0.0789	-0.0076	**-0.1453**	0.5729	0.1220	0.1293	0.0002	0.0679	0.8306**
	K	-0.0407	0.0403	0.0009	0.1064	0.0106	**-0.0562**	0.1132	0.0895	0.2439	0.1476	-0.0590	0.5965**
Single earhead weight (g)	S	0.0024	-0.0030	0.0055	0.0639	-0.0091	-0.1563	**0.5325**	0.2233	0.1254	0.0005	0.0432	0.8283**
	K	0.0097	0.0252	-0.0024	0.1043	0.0109	-0.0260	**0.2442**	0.1561	0.1066	0.2730	-0.0389	0.8627**
Single earhead grain weight (g)	S	0.0035	-0.0042	0.0105	0.0888	-0.0107	-0.1646	0.5059	**0.2841**	0.1330	0.0005	0.0123	0.8591**
	K	0.0216	-0.0035	-0.0035	0.1057	0.0090	-0.0337	0.2551	**0.1494**	0.1472	0.2746	-0.0439	0.8780**
1000 grain weight (g)	S	0.0016	-0.0004	0.0087	0.0738	-0.0123	-0.1246	0.4430	0.2508	**0.1507**	0.0003	0.0615	0.8531**
	K	0.0123	-0.0010	-0.0020	0.0908	0.0079	-0.0397	0.1851	0.1334	**0.3452**	0.1884	-0.0462	0.8742**
Chlorophyll content	S	0.0059	-0.0018	-0.0034	0.0776	0.0005	-0.0234	0.1661	0.0780	0.0307	**0.0018**	0.0657	0.3977**
	K	-0.0095	0.0381	-0.0014	0.0991	0.0108	-0.0231	0.1855	0.1142	0.1810	**0.2593**	-0.0304	0.8236**
β-carotene (µg/g)	S	0.0008	-0.0016	-0.0010	0.0400	-0.0046	-0.0667	0.2637	0.1390	0.0627	0.0008	**0.1478**	0.5809**
	K	-0.0105	0.0522	0.0019	0.0634	0.0140	-0.0324	0.0927	0.0640	0.1559	-0.1024	**0.1065**	0.4053**

Direct effects on diagonal, S- summer and K- *kharif*, 2013

*, ** Significance at 5 and 1 per cent level, respectively