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Research Note

Correlation and path analysis studies among biochemical traits and yield in chilli (*Capsicum annuum* L.) genotypes

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Abstract
The present investigation was conducted at Horticultural Research Station, Lam, Guntur, Andhra Pradesh to elucidate the interrelationship among seven biochemical traits and fruit yield and to estimate the direct and indirect effects of biochemical traits on yield in seventy one genotypes of chilli comprising 54 F_1 hybrids, 15 parents and two commercial checks. Fruit yield per plant has showed positive, non-significant association with ascorbic acid and capsaicin whereas, it's association with oleoresin was negative and significant. The path analysis revealed that the quality parameters *viz.*, ascorbic acid, capsaicin, red and yellow carotenoids had positive direct effect on fruit yield per plant. Among these four, only red and yellow carotenoids have recorded high positive direct effect indicated that direct selection for fruit yield per plant through these traits will be effective.

Keywords
Chilli, *Capsicum annuum*, capsaicin, correlation, path analysis, carotenoids

Chilli, also known as hot pepper (*Capsicum annuum* L., 2n = 24) is one of the most important commercial crops of India and finds a variety of uses as a spice, condiment, culinary supplement, medicine, vegetable and ornamental plant. Chilli fruits are known for their flavour, pungency and are considered as one of the richest sources of vitamin C (Bosland and Votava, 2000). Capsicinoids and carotenoids are the major chemical constituents of chilli fruits and add commercial value to the crop. The carotenoids are responsible for the final red colour (Davies *et al*., 1970) which act as dietary precursors of vitamin A. Pungency (hotness) has been established due to presence of "Capsaicinoids" (Torabi, 1997) and the degree of pungency varies widely with the genotypes of five cultivated species (Kumar *et al*., 2006). Capsaicin and dihydro capsaicin are accounts for more than 80% of total capsaicinoids (Bosland and Votava, 2000) present in placenta of the fruit and can directly scavenge various free radicals (Reddy and Lokesh, 1992; Kogure *et al*., 2002; Bhattacharya *et al.*, 2010) and also have antioxidant, anticancerous, antiarthritic and analgesic properties (Prasad *et al.*, 2006). The oleoresins extracted from chilli fruits are extensively used in food and pharmaceutical industry. In view of changing life styles and health concerns quality improvement in crop plants has assumed greatly significance as quality not only improves human health but also adds to farm income (Janaki *et al*., 2016). The data on pungency and carotenoids among the accessions in *Capsicum* gene banks are currently limited (Jarret *et al*., 2003) which was utmost important for selection of genotypes from a gene bank for further use in crop improvement. Thus, breeding programmes of late are targeted to improve quality traits along with yield and tolerance to biotic and abiotic stresses.

To carry out any selection programme, the knowledge of interrelationship among characters is very important in plant breeding for indirect selection of characters that are not easily measured.

However, under complex situation, correlation alone becomes insufficient to explain relationships among characters and thus path analysis is important. For selection, it is essential to know the importance and association of various components and also their association with yield. The correlation coefficient analysis measures the mutual relationship between various characters and determines the component traits on which selection can be relied upon the effect of improvement. Assessing the direct and indirect effects of each component towards yield through path coefficient analysis would help in identifying the component traits contributing to yield. Correlation and path

analysis studies for quality traits in chilli have also been reported by earlier workers *viz.*, Farhad *et al*. (2008), Arup *et al*. (2011) and Naresh *et al*. (2013). Thus, the major objective of this study was to determine the nature and degree of association among the yield and quality characters and their direct and indirect effects on chilli yield. Based on this information an effective selection programme can be proposed for the genetic improvement of the crop.

An experiment was conducted at Horticulture Research Station, Dr. Y. S. R. Horticultural University, Lam farm, Guntur**.** The experimental material and their characters used in this experiment were presented in Table 1. The experimental material comprised of nine lines (LCA 504, LCA 615, LCA 446, LCA 466, LCA 442, LCA 654, LCA 607, LCA 655 and LCA 355) and six testers (G4, LCA 678, LCA 453, LCA 703-2, LCA 705-2 and LCA 315). These parents were crossed in Line × Tester fashion during *Kharif*, 2013-14 and developed 54 F_1 hybrids. A total of sixty nine genotypes of chilli along with two commercial checks (Tejaswini and Indam-5) were evaluated during *Kharif*, 2014-15 in a Randomized Block Design with three replications in two rows (one row of 4 m length) of each genotype at a spacing of 75 cm x 30 cm. The crop was raised as per the standard package of practices. The crop was maintained healthy till last harvest and fruit samples were collected from five randomly selected plants in each plot (one row of 4m length) to estimate the quality traits *viz.*, ascorbic acid (mg/100g), oleoresin (%), capsaicin (%), red carotenoids (mg/100g), yellow carotenoids (mg/100g), total carotenoids (mg/100g) and total color value (ASTA units).

The red ripe fruits were sun dried and ground in an electronic grinder and passed through a 0.5 mm sieve and the dry chilli powder was used to measure biochemical constituents whereas, mature green fruits were used to estimate the Vitamin 'C' content. Ascorbic acid content of mature green fruits was estimated by volumetric (2, 6 dichlorophenol indophenol dye) method described by Sadasivam and Balasubramanian (1987). The oleoresin content was estimated as per the procedure given by Ranganna (1986). The capsaicin content was estimated by colorimetric method described by Balasubramanian *et al.* (1982). Total red (C^R; capsanthin, capsorubin and capsanthin5, 6epoxide) and yellow (C^Y; zeaxanthin, violaxanthin, antheraxanthin, âcryptoxanthin, âcarotene and cucurbitaxanthin A) carotenoid isochromic fractions were estimated following the protocol of spectrophotometric method (Hornero Mendez and Minguez Mosquera, 2001). Total colour value (ASTA American Spice Trade Association units) was estimated as per the procedure given by Roserbrook *et al.* (1968).

Phenotypic and genotypic correlations were worked out by using formula suggested by Falconer (1964). The direct and indirect effects were computed by using the procedure suggested by Wright (1921) and elaborated by Dewey and Lu (1959).

The estimates of phenotypic and genotypic correlation coefficient (Table 2) revealed that the genotypic correlations were higher than the corresponding phenotypic correlations for most of the characters indicating high heritability of the traits under study as suggested by earlier reports of Farhad *et al*. (2008), Kumar *et al*. (2012) and Janaki *et al.* (2016). The characters *viz.*, ascorbic acid and capsaicin were positively correlated with fruit yield per plant whereas, the rest of the characters were negatively associated with fruit yield per plant. The character oleoresin content was significantly and negatively correlated with fruit yield per plant at both phenotypic and genotypic levels. These findings suggested that selection for fruit yield per plant based on ascorbic acid content and capsaicin content is beneficial for further crop improvement programme. These results are in consonance with earlier reports of Gupta *et al.* (2009) and Sharma *et al.* (2010). Capsaicin content had significant and negative association with oleoresin and total colour value at both phenotypic and genotypic levels indicating a significant increase in capsaicin content leads to decrease in oleoresin and total colour value and *vice-versa.* The inter relationship among total colour value, red, yellow and total carotenoids were significant and positive indicating that simultaneous selection of these traits is possible and also suggested that total colour value increases significantly with increase in red, yellow and total carotenoids. These findings are supported by the earlier observations of Naresh *et al.* (2013) and Janaki *et al.* (2016).

The results of path analysis studies (Table 3) revealed that ascorbic acid, capsaicin, red carotenoids and yellow carotenoids at both phenotypic and genotypic levels had positive direct effect on fruit yield per plant indicating that direct selection based on these traits may be helpful in evolving high yielding varieties of chilli. These findings are in agreement with earlier reports of Kumar *et al.* (2012) and Janaki *et al.* (2016). The oleoresin, total colour value and total carotenoids had negative direct effect on fruit yield per plant. Arup *et al.* (2011) who had also reported the

negative direct effect of oleoresin content on fruit yield in chilli.

Lenka and Mishra (1973) have suggested scales for path coefficients with values 0.00 to 0.09 as negligible, 0.10 to 0.19 low, 0.20 to 0.29 moderate, 0.30 to 0.99 high and more than 1.00 as very high path coefficients. Accordingly, red carotenoids and yellow carotenoids at both levels had high positive direct effect whereas, total carotenoids had very high negative direct effect on fruit yield. Oleoresin had moderate negative direct effect while ascorbic acid had low positive direct effect on fruit yield. Capsaicin and total colour value were recorded negligible direct effects on fruit yield. Bijalwan and Mishra (2016) also reported low positive direct effect for ascorbic acid. Janaki *et al.* (2016) also observed high positive direct effect for red carotenoids. The red carotenoids indirectly influence the fruit yield through total colour value, yellow carotenoids and total carotenoids whereas, the yellow carotenoids indirectly influence the fruit yield via total colour value, red carotenoids and total carotenoids.

The results of correlation studies suggest that fruit yield per plant can be improved by selecting hybrids for ascorbic acid and capsaicin as they have recorded positive but non-significant association fruit yield per plant. As per path analysis, emphasis must be given to the characters like red carotenoids and yellow carotenoids in selection programme for yield improvement as they have observed high positive direct effects.

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Table 1. Salient features of parents used in Line × Tester analysis of chilli

S.No	Parents	Features
Lines		
1	LCA504	Drought resistant, highly pungent
2	LCA615	High yielding line with parrot green fruits
3	LCA446	Bold pod, high colour and oleoresin
4	LCA466	Bold and long pod, high colour and oleoresin
5	LCA442	Bold and long pod, high colour and mild pungent
6	LCA654	Medium bold, shiny fruit surface, light green in colour
7	LCA607	Light green pod, profuse branching
8	LCA655	Dual purpose variety, bold light green pod
9	LCA355	High colour with wrinkled surface
Testers		
1	G4	Dark green (olive green) fruits, virus resistant
2	LCA678	More primary branches, semi erect plant habit
3	LCA453	Bold pod, erect growth habit
4	LCA7032	Virus resistant, dark green fruits
5	LCA7052	More no. of fruits, shiny dry pod
6	LCA315	Virus resistant, fruits are long and dark green
Checks		
1	Indam5	IndoAmerican Hybrid Seeds (India) Pvt.Ltd. (IAHS)
2	Tejaswini	Maharashta Hybrid Seeds Co.Ltd. (MAHYCO)

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Table 2. Phenotypic (P) and Genotypic (G) correlation coefficients among seven biochemical characters and fruit yield in chilli (*Capsicum annuum* L.)

Character		Ascorbic acid (mg/100g)	Capsaicin (%)	Oleoresin (%)	Total Colour Value (ASTA Units)	Red Carotenoids (mg/100 g)	Yellow Carotenoids (mg/100 g)	Total Carotenoids (mg/100 g)	Dry Fruit Yield/ Plant (g)
Ascorbic acid (mg/100g)	P	**1.0000**	-0.0988	0.0983	0.0597	-0.0167	0.0913	0.0366	0.0732
	G	**1.0000**	-0.1122	0.0748	0.0516	-0.0249	0.0946	0.0368	0.1053
Capsaicin (%)	P		**1.0000**	-0.1977**	-0.1377*	-0.0395	-0.1835	-0.1258	0.0741
	G		**1.0000**	-0.2315**	-0.1430*	-0.0403	-0.1891	-0.1256	0.0914
Oleoresin (%)	P			**1.0000**	0.0443	-0.0262	-0.0051	-0.0202	-0.2107**
	G			**1.0000**	0.0471	-0.0348	-0.0068	-0.0244	-0.2592**
Total Colour Value (ASTA Units)	P				**1.0000**	0.7732**	0.5852**	0.7975**	-0.1118
	G				**1.0000**	0.7867**	0.6118**	0.8139**	-0.0954
Red Carotenoids (mg/100 g)	P					**1.0000**	0.4691**	0.8751**	-0.0718
	G					**1.0000**	0.5028**	0.8871**	-0.0291
Yellow Carotenoids (mg/100 g)	P						**1.0000**	0.8294**	-0.1071
	G						**1.0000**	0.8497**	-0.1271
Total Carotenoids (mg/100 g)	P							**1.0000**	-0.1120
	G							**1.0000**	-0.0805
Dry Fruit Yield/ Plant (g)	P								**1.0000**
	G								**1.0000**

*: Significant at 5 per cent level; **: Significant at 1 per cent level

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Table 3. Phenotypic (P) and Genotypic (G) path analysis showing direct (diagonal) and indirect effects of biochemical traits on fruit yield in chilli (*Capsicumannuum* L.)

Character		Ascorbic acid (mg/100g)	Capsaicin (%)	Oleoresin (%)	Total Colour Value (ASTA Units)	Red Carotenoids (mg/100 g)	Yellow Carotenoids (mg/100 g)	Total Carotenoids mg/100 g)
Ascorbic acid (mg/100g)	P	**0.1059**	-0.0105	0.0104	0.0063	-0.0018	0.0097	0.0039
	G	**0.1480**	-0.0166	0.0111	0.0076	-0.0037	0.0140	0.0054
Capsaicin (%)	P	-0.0015	**0.0150**	-0.0030	-0.0021	-0.0006	-0.0027	-0.0019
	G	-0.0017	**0.0151**	-0.0035	-0.0022	-0.0006	-0.0029	-0.0019
Oleoresin (%)	P	-0.0212	0.0427	**-0.2161**	-0.0096	0.0057	0.0011	0.0044
	G	-0.0194	0.0600	**-0.2593**	-0.0122	0.0090	0.0018	0.0063
Total Colour Value (ASTA Units)	P	-0.0043	0.0099	-0.0032	**-0.0716**	-0.0554	-0.0419	-0.0571
	G	-0.0044	0.0123	-0.0040	**-0.0858**	-0.0675	-0.0525	-0.0698
Red Carotenoids (mg/100 g)	P	-0.0112	-0.0264	-0.0175	0.5159	**0.6673**	0.3130	0.5839
	G	-0.0211	-0.0341	-0.0295	0.6667	**0.8475**	0.4262	0.7518
Yellow Carotenoids (mg/100 g)	P	0.0435	-0.0875	-0.0024	0.2791	0.2237	**0.4770**	0.3956
	G	0.0485	-0.0970	-0.0035	0.3138	0.2579	**0.5129**	0.4358
Total Carotenoids (mg/100 g)	P	-0.0381	0.1309	0.0210	-0.8299	-0.9107	-0.8632	**-1.0407**
	G	-0.0445	0.1517	0.0295	-0.9834	-1.0718	-1.0266	**-1.2082**
Dry Fruit Yield/ Plant (g)	**P**	**0.0732**	**0.0741**	**-0.2107****	**-0.1118**	**-0.0718**	**-0.1071**	**-0.1120**
	G	**0.1053**	**0.0914**	**-0.2592****	**-0.0954**	**-0.0291**	**-0.1271**	**-0.0805**
Partial R^2	P	0.0078	0.0011	0.0456	0.0080	-0.0479	-0.0511	0.1165
	G	0.0156	0.0014	0.0672	0.0082	-0.0247	-0.0652	0.0973

'r' – Correlation coefficient , *: Significant at 5 per cent level; **: Significant at 1 per cent level