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Variability, correlation and path analysis in F_2 population of cross between hot pepper and bell pepper

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Abstract
The extent of genetic variability, heritability, genetic advance as percent of mean and correlation coefficients in respect of 12 quantitative characters in the population of cross between Byadgi chilli and bell pepper were studied. High phenotypic and genotypic coefficient of variations for number of fruits per plant (68.02 and 52.16) reported, followed by dry fruit yield per plant, fruit volume, number of primary branches, number of secondary branches, plant height and fruit surface area. High heritability and genetic advance as percent of mean was observed for fruit yield per plant, average fruit weight, pericarp weight per fruit, seed weight per fruit, which could be improved by simple selection. A significant positive correlation of economic traits like number of fruits per plant, fruit weight and fruit lengths with fruit yield per plant was recorded suggesting that selection for these characters could lead to improvement in yield. Path analysis revealed that number of fruits per plant had maximum direct effects on fruit yield followed by fruit length, fruit diameter and pericarp weight. Thus emphasis should be given on these characters to improve yield potential. The traits such as fruit yield per plant, number of fruits per plant, fruit weight are important yield contributing characters and deserve due weightage, while formulating selection strategies for improvement of chilli. As high genetic variability revealed in F_2 population studied, this can be effectively utilized for improving yield and component traits.

Keywords: Bell pepper, chilli, GCV, PCV, heritability, correlation, path analysis

Introduction
Chilli (*Capsicum annuum* L.) is an important vegetable specially liked for its pungency, aroma and spicy taste. The productivity of the crop is low in view of coverage of large area under low yielding genotypes. Hence, there is need for development of new varieties and hybrids with high productivity. Lack of sufficient genetic variability for economically important characters is one of the reasons attributed for failure in yield improvement of chillies. The success in crop improvement programme chiefly depends on the extent of genetic variability for characters of interest. By keeping the objective of increasing variability in the crop we need to generate variability by making crosses between hot pepper and bell pepper which provide progenies having wide range of genetic and morphological variability of fruits compare to both the parents with sufficient viability and fertility.

Material and methods
Field experiment was conducted on black soil in Botany Garden, Department of Genetics and Plant Breeding, College of Agriculture, Dharwad, University of Agricultural Sciences, Dharwad. F2 population derived from cross between bell pepper and chilli (BPR-2 x Byadgi Kaddi) was evaluated. The experiment was laid down in randomized block design with two replications during Kharif 2011-12. Each entry was represented by a two unprotected rows of twenty plants with a spacing of 60 cm x 60 cm. The crop was managed as per recommended package of practices. Five plants were randomly selected for each genotype from each replication and observations were recorded on 12 quantitative characters, viz., plant height, number of primary branches per plant, number of secondary branches per pant, number of fruits per plant, fruit length, fruit diameter, fruit surface area, fruit volume, seed weight per fruit, pericarp weight per fruit and average fruit weight and dry fruit yield per plant.
The variability for different quantitative characters in cross genotypes were estimated as per procedures for analysis of variance suggested by Panse (1957) [20] and, GCV and PCV by Burton and De Vane (1953) [7] and heritability (Hanson *et al*., 1956) [11] and genetic advance by Johnson *et al*. (1955) [16].

Results and discussion

Variability and genetic components of variation

The extent of variability present in the genotypes was measured in terms of range, coefficient of variation, genotypic coefficient of variation (GCV), phenotypic coefficient of variation (PCV), broad sense heritability and genetic advance (GA). A wide range of variability was recorded in fruit yield (25.57 - 311.00 g/plant), number of fruits per plant (3 - 60), plant height (25.00 - 90.00 cm), fruit length (4.40 - 12.00), fruit diameter (0.90 - 3.50), fruit surface area (9.90 - 40.70 cm^2), fruit volume (1.49 - 23.74 cm^3), pericarp weight (3.46 - 7.41), average fruit weight (6.20 - 11.60), number of primary branches (2 - 11 per plant) and number of secondary branches (4 - 24 per plant).

A perusal of the data revealed that the magnitude of PCV was higher than GCV for all the characters. GCV and PCV estimates were close in plant height, number of secondary branches, fruit length, seed weight, pericarp weight and average fruit weight; in others it differed slightly, altogether suggesting low to medium influence of environment in the expression. Higher PCV and GCV values were recorded in number of fruits/plant, fruit volume and fruit yield per plant. Higher magnitude of PCV and GCV indicate the existence of substantial variability that could be potently exploited through direct selection. These results further confirmed the findings of researchers as Krishnamurthy *et al*., 2013 [17], Amit *et al*., 2014 [17], Bijalwan and Madhvi, 2015 [5] and Janaki *et al*., 2015 [15] reported high phenotypic and genotypic coefficient of variations, for fruit number per plant and fruit yield per plant. Aklilu *et al*., 2016 [2] recorded high GCV (fruit diameter, fruit weight, number of fruits per plant and fruit yield per plant) and, Krishnamurthy *et al*., 2013 [17] and Aklilu *et al*., 2016 [2] reported high PCV for plant height. For fruit yield per plant (Vani *et al*., 2007; Ukkund *et al*., 2007) [33, 32], for number of fruits per plant (Chattopadhyay *et al*., 2011, Patel *et al*., 2015 and Sahu *et al*., 2016) [8, 21, 24], for average fruit weight, fruit length (Patel *et al*., 2015 and Razzak *et al*., 2016) [21, 22], fruit length (Meena *et al*., 2016) [19], plant height (Razzak *et al*., 2016) [22]. Although GCV helps to measure the genetic variability in a character, it is not enough to permit partition the heritable variation. High GCV values were noted in the number of fruits/plant and fruit yield/plant. However, GCV alone provides insufficient evidence to indicate that the majority of variation is inheritable. Moderate GCV values were recorded for fruit length, fruit width, fruit surface area, seed weight, pericarp weight and average fruit weight.

Most of the traits studied had high heritability estimates. The heritability of the highest magnitude was noticed for average fruit weight (90.00%) and the lowest for fruit length (55.00%). Thus, it indicated that larger proportion of phenotypic variance has been attributed to genotypic variance and reliable selection could be made for almost all the traits on the basis of phenotypic expression. High estimates of heritability in broad sense indicate that substantial improvement can be made using standard selection procedures.

High heritability estimates were also recorded by researchers, as for fruit yield per plant, average fruit weight and number of fruits per plant by Amit *et al*. (2014) [17] and, Bijalwan and Madhvi, (2015) [5], for fruit length (Amit *et al*., 2014, Bijalwan and Madhvi, 2015, Aklilu *et al*., 2016 and Meena *et al*., 2016) [3, 5, 2, 19], for plant height (Krishnamurthy *et al*., 2013, Amit *et al*., 2014 and, Bijalwan and Madhvi, 2015 and Meena *et al*., 2016) [17, 3, 5, 19], for fruit diameter (Bijalwan and Madhvi, 2015, Aklilu *et al*., 2016 and, Meena *et al*., 2016) [5, 6, 2, 19] in consonance with the present study.

High heritability and high estimates of genetic advance as percent of mean were observed for maximum traits except fruit length where genetic advance was moderate (15.93%) with moderate heritability of 55%. This suggested the presence of additive gene action (Panse, 1957) [20] and hence these characters are likely to respond better to selection. High heritability and high genetic advance as percent of mean have also been obtained by many workers, as for fruit yield per plant and for average fruit weight (Amit *et al*., 2014, Bijalwan and Madhvi, 2015, Patel *et al*., 2015 and Rosmaina *et al*., 2016) [3, 5, 21, 23], for average fruit length (Patel *et al*., 2015 and Rosmaina *et al*., 2016) [21, 23], for fruit diameter (Rosmaina *et al*., 2016) [23], for plant height (Krishnamurthy *et al*., 2013 [17] and Rosmaina *et al*., 2016) [23] and, for all the these characters by Sandeep *et al*. (2013) [25] and Janaki *et al*. (2015) [15]. Moderate heritability along with high genetic advance was observed for number of fruits per plant.

Character association

Dry chilli yield per plant showed significant positive association with all yield related traits except for fruit length and fruit diameter. Highest correlation was observed for fruits per plant (0.7368) followed by plant height (0.4039), average fruit weight (0.3008), pericarp weight (0.2216), seed weight (0.2120), fruit surface area (0.1930), number of secondary branches (0.1911), fruit volume (0.1797), fruit length (0.1581) and number of primary branches (0.1572). The fruit characters viz., fruit length, average fruit weight, fruit diameter, fruit surface area and fruit volume showed significant positive association among themselves except fruit length and fruit diameter which were found negatively associated to each other. Plant height, number of primary branches and number of secondary branches showed significant positive association with yield. Number of primary branches in turn showed significant positive association with number of secondary branches (0.5260) and with plant height (0.3800). Number of secondary branches was associated significant positively with plant height (0.3400). Thus, in this F2 population, plant growth characters viz., plant height, number of primary branches and number of secondary branches, showed positive significant association with yield, thus suggesting that these characters are important yield components and the effective improvement in yield can be achieved through selection based on these characters. Similar results of positive association of plant growth character with yield have been reported by Yadwad (2005) [34], and Vaishnavi *et al*. (2017) [30] for plant height and number of primary branches.

Sink number and sink size are the two important traits in any species. In sweet pepper, number of fruits per plant and average fruit weight are the corresponding characters. In the present study also both the characters showed the significant positive association with yield. However, number of fruits per plant exhibited highest correlation. Afroza *et al*. (2013) [1], Krishnamurthy *et al*. (2013) [17], Aklilu *et al*. (2016) [2] and Srividhya *et al*. (2017) [28] reported high positive significant correlation of number fruits per plant with fruit yield per plant. Similar results of positive association of both fruit weight and fruits per plant with yield have been reported by Depestre *et al*. (1981) [10], Depestre and Gomez (1992) [9], Mishra *et al*. (1998) [18], Bhojaraja (2009) [4] in sweet pepper, and Yadwad (2005) [34], Chattopadhyay *et al*. (2011) [8], Hasanuzzaman and Golam (2011) [13], Patel *et al*. (2015) [21],

Bijalwan and Mishra (2016) [6] and Vaishnavi *et al*, (2017) [30] in chilli. Fruit length is another important criterion in chilli which decides consumer preference. Fruit length showed positive significant association with yield indicating that simple phenotypic selection based on fruit length in these F2 populations will help in yield improvement. Positive association of fruit length with the yield is in confirmity with the reports of Sood *et al*. (2007) [27], Yadwad *et al*. (2008) [35], Bhojaraja (2009) [4], Chattopadhyay *et al*. (2011) [8], Hasanuzzaman and Golam (2011) [13], Vikram *et al*. (2014) [31] and, Bijalwan and Mishra (2016) [6]. Fruit weight is also an important trait which showed significant positive association with yield in the population as also reported in studies of Yadwad *et al*. (2008) [35] and Bhojaraja (2009) [4], Vikram *et al*. (2014) [31], Vaishnavi *et al*. (2017) [30]. Hence, selection strategy involving this trait would help in yield improvement. Other fruit characters like fruit diameter, fruit surface area, fruit volume, pericarp weight and seed weight showed positive significant association, with yield and also among themselves indicating that selection for a trait will help in improving associated trait in turn leading to high productivity. Vikram *et al*. (2014) [31] reported significant positive correlation fruit breadth with green fruit yield. Correlation studies indicated that number of fruits per plant, fruit weight, fruit length and pest parameters deserve greater weightage during selection for fruit yield in chilli.

Path analysis

The correlation values decide only the nature and degree of association existing between pairs of characters. A character like plant yield is dependent on several mutually associated component characters. The knowledge of correlation alone, however is often misleading as the correlation observed may not reflect true nature of association, since two characters may show correlation just because they are correlated with a common third one (Jaiswal and Gupta, 1967) [14]. In such cases it becomes necessary to study a method which takes into account the causal relationship. The direct and indirect effect of different characters on dry chilli yield per plant in F_2 population of the cross between hot pepper and bell pepper are presented below.

Plant height exhibited low positive direct effects (0.0639) and indirectly via number of fruits per plant (0.0581), number of primary branches (0.1443) and number of secondary branches (0.0718) on yield. Number of primary branches showed low positive direct effects (0.0014) and indirectly low positive via number of fruits per plant, all the fruit characteristics except fruit length. Secondary branches number exhibited negatively direct effects (-0.0113) and but influenced yield positive indirectly via fruits per plants (0.1230) and number of primary branches (0.0500). Fruits per plant contributed directly (0.6945) and indirectly via fruit and seed weight for its high significant association with yield (0.7368). Among the fruit characters high positive direct effect of fruits per plant (0.6945), fruit length (0.1509), fruit diameter (0.1126) contributed for high significant association of corresponding characters with yield. Fruit diameter also influenced yield indirectly via fruits per plant (0.0407) and seed weight (0.0251). Pericarp weight exhibited high positive direct effect (0.1238) and low positive indirect via average fruit weight (0.0393), fruit diameter (0.0264) and fruit surface area (0.0123). Average fruit weight affects yield direct positive (0.0679) and indirectly via pericarp weight (0.0435) and seed weight (0.0324). Fruit surface area and fruit volume exhibited negative direct effect (-0.0290) and (-0.0247) respectively. Residual effect was low (0.2957) for this cross, indicated that the traits included accounted for most of the variation present in the fruit yield per plant.

Results obtained from the path analysis revealed that yield was primarily influenced by number of fruits per plant. Number of fruits per plant showed maximum direct effect on yield per plant in the population. Hence, it would be rewarding to lay emphasis on fruits per plant while developing selection strategies in the population. The results are in conformity with reports of Suryakumari *et al*. (2011) [29], Afroza *et al*. (2013) [1], Krishnamurthy *et al*. (2013) [17], Vikram *et al*. (2014) [31], Patel *et al*. (2015) [21], Aklilu *et al*. (2016) [2], Sahu *et al*. (2016) [24], Srividhya *et al*. (2017) [28] and Vaishnavi *et al*. (2017) [30].

Another character which showed high direct effect on yield followed by number of fruits per plant were fruit length, pericarp weight and fruit diameter. Hence, selection would also be effective in improving yield through these traits beside fruits per plant. Positive association of fruit length with yield is also evident from the reports of Yadwad *et al*. (2008) [35], Krishnamurthy *et al*. (2013) [17], Vikram *et al*. (2014) [31] and Vaishnavi *et al*. (2017) [30] Fruit diameter will be helpful for improving the yield and consumer preference of shape and size in the crop. Though very low direct effects of plant height, number of primary branches and number of secondary branches was observed on yield, these traits contributed indirectly via fruits per plant. Hence, while selecting the plants in F_2, one should not neglect the above traits. Similar results have been reported by Hiremath (1997), Smitha and Basavaraja (2007) and Yadwad *et al.* (2008) [35].

This study on path coefficient analysis suggested that selection for number of fruits per plant, fruit length, fruit weight would be effective for improving yield per plant in chilli. Low magnitude of residual effects in the population indicated that the traits included in the present investigation accounted for most of the variation present in the dependent variable that is fruit yield per plant.

Table 1: Genetic variability parameters for different quantitative traits in F_2 populations of BPR-2 x Byadgi Kaddi

Characters	Mean	Min	Max	Vp	Vg	PCV	GCV	h^2 (%)	GA	GAM
Plant height (cm)	45.65	25.00	90.00	115.40	96.66	23.53	21.54	84.00	18.54	40.62
No. of primary branches	4.73	2	11	2.77	2.14	35.25	30.96	77.00	2.65	56.00
No. of secondary branches	13.79	4	24	13.80	11.94	26.93	25.05	87.00	6.62	48.02
Fruits No./ plant	12.94	3	60	77.51	45.57	68.02	52.16	59.00	10.66	82.39
Fruit length (cm)	8.45	4.40	12.00	1.42	0.78	14.09	10.44	55.00	1.35	15.93
Fruit diameter (cm)	1.71	0.90	3.50	0.12	0.07	20.46	15.50	57.00	0.41	24.20
Fruit surface area (cm^2)	22.42	9.90	40.70	26.76	16.29	23.07	18.00	61.00	6.49	28.93
Fruit volume (cm^3)	6.61	1.49	23.74	8.33	6.08	43.66	37.30	73.00	4.34	65.66
Seed weight (g)	3.58	2.40	4.72	0.28	0.24	14.84	13.71	85.00	0.93	26.09
Pericarp weight (g)	5.30	3.46	7.41	0.65	0.59	15.16	14.50	91.00	1.51	28.56
Avg. fruit weight (g)	9.02	6.20	11.60	1.07	0.97	11.49	10.90	90.00	1.92	21.32
Fruit yield/ plant (g)	119.20	25.57	311.00	4350.00	2756.00	53.67	43.63	64.00	86.35	72.84

Table 2: Correlation between different quantitative characters in F_2 generation of BPR-2 x Byadgi Kaddi

	Plant height (cm)	No. of primary branches	No. of secondary branches	Fruits No./plant	Fruit length (cm)	Fruit diameter (cm)	Fruit surface area (cm^2)	Fruit volume (cm^3)	Seed weight (g)	Pericarp weight (g)	Avg. fruit weight (g)	Fruit yield/ plant (g)
Plant height (cm)	1.0000	0.3800**	0.3400**	0.4390**	0.0120	0.0640	0.0390	0.0420	0.0450	0.1450	0.1640*	0.4039**
No. of primary branches		1.0000	0.5260**	0.1560*	-0.0540	0.0800	0.0580	0.0320	0.0080	0.1570*	0.1600*	0.1572*
No. of secondary branches			1.0000	0.1990**	-0.0770	0.1380	0.0610	0.0900	0.0250	0.2210**	0.1850*	0.1911*
Fruits No./plant				1.0000	0.0100	-0.0060	0.0100	0.0150	0.1270	0.0060	0.1140	0.7368**
Fruit length (cm)					1.0000	-0.0880	0.4850**	0.2100**	0.0120	0.1230	0.1790*	0.1581*
Fruit diameter (cm)						1.000	0.7260**	0.8960**	0.3120**	0.3180**	0.3660**	0.1375
Fruit surface area (cm^2)							1.0000	0.8920**	0.2170**	0.3420**	0.3620**	0.1930*
Fruit volume (cm^3)								1.000	0.2900**	0.3430**	0.3740**	0.1797*
Seed weight (g)									1.0000	0.0600	0.4770**	0.2120**
Pericarp weight (g)										1.000	0.6410**	0.2216**
Avg. fruit weight (g)											1.0000	0.3008**

*, ** indicates significant at 5 percent and 1 percent level of probability, respectively

Table 3: Direct and indirect effect of different quantitative characters on yield in F_2 generation of BPR-2 x Byadgi Kaddi

	Plant height (cm)	No. of primary branches	No. of secondary branches	Fruits No./ plant	Fruit length (cm)	Fruit diameter (cm)	Fruit surface area (cm^2)	Fruit volume (cm^3)	Seed weight (g)	Pericarp weight (g)	Avg. fruit weight (g)	r (Fruit yield/ plant in g)
Plant height (cm)	0.0639	0.1443	0.0718	0.0581	0.0007	0.0041	-0.0025	0.0065	0.0093	0.0293	0.0185	0.4039**
No. of primary branches	0.0355	0.0014	0.0570	0.0140	-0.0001	0.0062	0.0018	-0.0047	0.0110	0.0196	0.0153	0.1572*
No. of secondary branches	-0.0039	0.0500	-0.0113	0.1230	0.0290	0.0076	-0.0007	0.0016	0.0003	-0.0025	-0.0021	0.1911*
Fruits No./plant	0.0070	-0.0820	0.0127	0.6945	0.0067	-0.0081	0.0069	0.0148	0.0275	0.0043	0.0525	0.7368**
Fruit length (cm)	0.0018	0.0082	-0.0115	0.0310	0.1509	-0.0033	-0.0732	0.0117	0.0018	0.0136	0.0270	0.1581*
Fruit diameter (cm)	0.0172	-0.0090	0.0095	0.0407	0.0118	0.1126	0.0118	-0.1009	0.0246	0.0080	0.0112	0.1375
Fruit surface area (cm^2)	-0.0011	0.0047	-0.0018	-0.0003	0.1141	0.0531	-0.0290	0.0259	-0.0063	0.0199	0.0138	0.1930*
Fruit volume (cm^3)	0.0100	0.0038	-0.0022	0.0255	-0.0052	0.1621	-0.0020	-0.0247	0.0125	0.0094	-0.0092	0.1797*
Seed weight (g)	0.0027	0.0005	0.0015	0.0428	0.0270	0.0188	-0.0031	0.0185	0.0602	0.0136	0.0295	0.2120**
Pericarp weight (g)	0.0180	0.0096	0.0074	0.0008	0.0153	0.0264	0.0123	-0.0387	0.0074	0.1238	0.0393	0.2216**
Avg. fruit weight (g)	0.0032	0.0109	-0.0126	0.1156	0.0122	0.0249	-0.0046	0.0074	0.0324	0.0435	0.0679	0.3008**

*, ** indicates significant at 5 percent and 1 percent level of probability, respectively, Residual effect - 0.2957.

Conclusion

It was aimed to assess the magnitude of variability for different quantitative traits and to determine the nature and magnitude of correlation among different traits and their direct and indirect effect on fruit yield in early segregating generation (F_2) of the cross made between two diverse parents, hot pepper and bell pepper.

In view, considerable variation was observed in all the F2 population for yield and its component traits. Wide range of variability was recorded in fruit yield, number of fruits per plant, plant height, fruit length, fruit diameter, fruit surface area, fruit volume, pericarp weight, average fruit weight, number of primary branches and number of secondary branches.

All the component traits of yield were found to be governed mainly by genetic factors than non-genetic factors and revealed through the high PCV and PCV for maximum traits and moderate PCV were found for fruit length, seed weight, pericarp weight and average fruit weight and moderate GCV for fruit length, fruit diameter, fruit surface area, seed weight, pericarp weight and average fruit weight. Moderate GCV and PCV showed by population but heritability coupled with high genetic advance over mean for all the traits studied except fruit length, where high heritability coupled with moderate genetic advance over mean was found. Hence, population is potential population for further selection for yield due to predominance of additive gene action in governing the yield.

Character association studies revealed positive significant association of number of fruits per plant with yield indicating that there is a need to lay emphasis on number of fruits per plant while selecting for yield. Fruit characters like fruit weight and fruit length also showed positive significant association with yield indicating that one should also include these characters while selecting for yield. Number of fruits per plant is the most important character contributing to yield through high positive direct effect and also indirectly through other component traits. Fruit length, fruit diameter and pericarp weight also contributed towards yield due to positive direct effects. Growth parameters also influence yield indirectly through number of fruits per plant. As high genetic variability revealed in F_2 population studied, this can be effectively utilized for improving yield and component traits.

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