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Research Note

Genetic Associations and Path-coefficient Analysis of the Economic Traits in the Chili (*Capsicum annuum* L.)

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Abstract :
Genetic associations and path-coefficient analysis was performed for the 15 economic traits affecting capsaicin content (%) in 38 elite genetic stocks/accessions of chili (*Capsicum annuum*). The capsaicin content was significantly associated with number of primary branches per plant and days to first flowering followed by weak positive association with days to fruit initiation and negative association with fruit weight dry and fruit weight fresh . In path-coefficient analysis, the number of primary branches per plant was found to be the premium direct contributor to the capsaicin content followed by fruit length . Fruit diameter exhibited the third highest direct effects. The fruit surface area added to the capsaicin content indirectly via fruit length and fruit weight. Primary branches per plant and days to first flowering emerged as a reliable component in selection criterion in breeding high capsaicin content yielding chili (*Capsicum annuum*).

Key words:
Capsaicin content, Capsaicinoids, *Capsicum annuum,* Genetic associations, Genetic stocks, Path-coefficient.

Pepper *(Capsicum* spp.) or chili is the second most important Solanaceous crop after tomato throughout the world (Souvanalat, 1999). There are five major species namely *Capsicum annuum, C. frutescens*, C. *chinense, C. pubescens* and *C. baccatum* but *C. annuum* is the most widely cultivated species in India and word-wide. Both hot and sweet peppers originated from *C. annuum* (Singh, 1993).The pungency in *Capsicum* is due to presence of a crystalline volatile compound capsaicin, a compound that represents an extensively investigated group of compounds called capsaicinoids (Palevitch and Craker, 1995). Capsaicin preparations are used as counter irritant in lumbago, neuralgia and rheumatic disorders (Wealth of India, 1950). As one of the richest sources of carotenoids, the red pepper has considerable commercial significance as a colorant in the food and cosmetic industries (Palevitch and Craker, 1995).

Genetic associations provides basic criteria for selection and leads to directional model based on yield and its components in the field experiments (Fraser and Eaton, 1983). Path coefficient analysis on the other hand, is an efficient statistical technique specially designed to quantify the inter-relationships of different components and their indirect effects on capsaicin yield (Rao *et al*., 1997). The information on nature of associations and path-coefficient analysis are meager in this crop. An investigation was therefore undertaken to examine the magnitude of the contributions/genetic associations of various economic traits to capsaicin content and its components.

The experimental material comprised 38 accessions of *Capsicum annuum* collected from various geographical locations of India. The plants were grown in randomized block design at the research farm of CIMAP, Lucknow, India during 1998, 1999, and 2000 with five replications (5-blocks). The plant-to-plant and row-to-row distances were kept as 45 cm and 60 cm, respectively. The recommended crop production practices (Singh, 1993) were adopted to raise the crop. Ten competitive plants per replication, of each genotype were chosen randomly for recording data. Observations were recorded for the 15 characters viz., plant height (cm), number of primary branches per plant, number of secondary branches per primary branch, number of tertiary branches per secondary branch, days of first flowering, days of second flowering, days of fruit initiation, leaf surface area (cm^2), fruit length (cm), fruit diameter (cm), fruit surface area (cm^2), fruit weight (fresh and dry) (g), capsaicin and capsanthin content in per cent. The genetic associations and path analysis were worked out according to Dewey and Lu

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(1959). Testing the significance of correlation was done following Fisher and Yates (1938).

The chemotypic trait with economic as well as the therapeutic value is mainly the capsaicin content in chilies. Capsaicin is expressed as a complex character in the *Capsicum annuum* contributed by number of components. It is influenced considerably by the interaction of several factors that are directly or indirectly related to it. In the present study, the capsaicin content (%) was significantly and positively associated with number of primary branches per plant (0.679) and days to first flowering (0.344) (Table 1), followed by positive association with days to fruit initiation (0.288), although that was weakly associated. Farhad *et al.,* 2008 also found significant positive correlation of yield per plant with number of secondary branches per plant, fruit girth and number of fruits per plant on 42 genotypes of *C. annuum*. Balasubramanian *et al.*, 1982 reported the positive significant correlation of capsaicin content with leaf length, leaf breadth, leaf area, number of fruits per plant, weight of fruits per plant and pericarp thickness in *Capsicum* plant.

The negative association was observed with fruit weight fresh (-0.225) and dry (-0.239) in the above trait. The significant and positive genetic associations were also noted between the traits fruit weight fresh and dry (0.968) with leaf surface area (0.493, 0.496); fruit diameter (0.762, 0.798); fruit surface area (0.658, 0.744), respectively. The results are in conformity with the findings of Sahoo *et al.,* 1990, Souvanalat, 1999, Munshi *et al.,* 2000 and Krishna *et* al., 2007 in *Capsicum* plant. The significant and negative genetic association was also noticed between number of primary branches and fruit weight fresh (-0.336) and fruit weight dry (-0.397).

The character, days to first flowering is highly positively associated with days to fruit initiation (0.685) (Mini and Vahab, 2002) followed by leaf surface area (0.524), fruit length (0.463), fruit surface area (0.499) and days to second flowering (0.362) in order (Table-1). The highly and strong positive genetic associations were also recorded between the traits: plant height with days of first flowering (0.417), days of second flowering (0.615), days to fruit initiation (0.595) and leaf surface area (0.358). This situation resembles widespread positive correlation between plant height and days to flowering in sunflower (Mogali and Virupakashappa, 1994) and *Capsicum* (Gyemtsho, 1996).

The highly significant and strong positive correlations were also observed between the characters, days to second flowering with days to fruit initiation (0.763); days to fruit initiation with leaf surface area (0.550); leaf surface area with fruit diameter (0.458), fruit surface area (0.454); fruit length with fruit surface area (0.759); fruit diameter with fruit surface area (0.691), fruit weight fresh (0.493) and fruit weight dry (0.496); fruit length with fruit surface area (0.759); fruit diameter with fruit surface area (0.691). The purpose of present work was not only to assess the possibilities of selection for agro-morphological traits examined, but also to examine their impacts upon *Capsicum* plant efficiency. In this respect, the correlation coefficients between capsaicin and other morphological traits and all other possible traits with other possible combinations must be taken into account.

Path coefficient analysis was developed to assess the magnitude of the contributions of various agro-morphological characters to capsaicin content in the form of cause and effects. The identification of the plant traits contributing positively, negatively, directly and/or indirectly to plant growth, with the aim of selecting high yielding varieties/genotypes, remains a major challenge to the plant breeders. The estimation of cause and effect relationship of capsaicin content (%) and other agronomic traits by genetic association and path-coefficient analysis has the scope of identifying such characters in the *C. annuum*.

The path-coefficient and genetic associations among the genotypes and traits revealing direct and indirect effects of *C. annuum* are presented in Table 2. The traits number of primary branches ($r = 0.679$) and days to first flowering ($r = 0.344$), showed a significant ($p < 0.01$ and $p < 0.05$) and positive genetic associations with capsaicin content. The positive direct effect of days to first flowering on capsaicin content is in accordance with the findings of Mini and Vahab, 2002. The number of primary branches per plant was found to be the premary direct contributor to the capsaicin content (%) followed by fruit length, the value of the path-coefficient being 0.870 and 0.814. Raiker *et al.* (2005) and Farhad *et al*. (2008) were also found similar results. Number of primary branches per plant and fruit weight showed high positive direct effect on fruit yield. Fruit diameter had the third highest direct effect (0.687) followed by days to fruit initiation (0.629) and fruit weight dry (0.621). Direct effects of days to first flowering (0.402) and capsanthin content (0.024) were relatively low but were positive.

Fruit surface area had the highest negative direct impact (-1.502) followed by days to second flowering (-0.672) on capsaicin content (%). The direct contribution of plant height, number of secondary branches per primary branch, number of tertiary branches per secondary branch, leaf surface area, fruit weight were also negative but small with the residual effect (0.184).

The fruit surface area added to the capsaicin content indirectly via fruit length (0.626), fruit weight (0.462) and the fruit weight added to the capsaicin indirectly via fruit weight dry (0.602), respectively. The primary branches per plant was an important parameter for selection of improved capsaicin containing plant in *C. annuum*. The identification of number of primary branches per plant as the highest direct and indirect contributor of capsaicin content is encouraging and the genotype selected for high primary branches per plant are likely to possess high capsaicin content and a great promise of increased capsaicin yield per hectare in *C. annuum* crop.

The present study indicated that the number of primary branches and days to first flowering should be considered during selection process in *C. annuum* crop, as these characters are going to contribute directly towards the high capsaicin yield.

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Table 1. Correlation coefficient among morphological and chemical characters of *Capsicum annuum)*

Characters	Pri. branches/ plant	Sec. branches/pri. branch	Tert. branches/sec. branch	Days to I[st] flowering	Days to II[nd] flower-ing	Days to fruit initia-tion	Leaf surface area	Fruit length	Fruit diameter	Fruit surface area	Fruit wt. (fresh)	Fruit wt.(dry)	Capsaicin content (%)	Capsanthin content (%)
Plant height	0.164	0.183	-0.011	0.417**	0.615**	0.595**	0.358*	-0.029	0.261	0.109	0.313	0.24	0.044	-0.031
Pri branches/ plant		0.315	0.197	0.116	0.093	0.162	-0.054	-0.116	-0.215	-0.211	-0.336*	-0.397*	0.679**	-0.05
Sec. branches / pri. branch			0.143	0.016	0.023	0.169	0.001	0.023	0.026	0.032	0.028	0.004	0.035	-0.043
Tert. branches/ sec/ branch				0.225	-0.108	-0.034	0.151	0.281	0.08	0.32	0.261	0.259	-0..078	0.127
Days to I[st] flowering					0.362*	0.685**	0.524**	0.463**	0.165	0.499**	0.248	0.279	0..344*	-0.166
Days to II[nd] flowering						0.763**	0.288	-0.218	0.05	-0.152	0.138	0.073	-0.005	-0.073
Days to fruit initiation							0.550**	0.053	0.263	0.221	0.278	0.239	0.288	-0.04
Leaf surface area								0.211	0.458**	0.454**	0.493**	0.496**	0.085	0.1
Fruit length									0.125	0.759**	0.245	0.321	0.036	-0.1
Fruit diameter										0.691**	0.762**	0.798**	-0.067	0.22
Fruit surface area											0.658**	0.744**	-0.016	0.129
Fruit wt. (fresh)												0.968**	-0.225	0.108
Fruit wt. (dry)													-0.239	0.167
Capsaicin content (%)														-0.148

* - $p< 0.05$ and ** - $p< 0.01$, respectively

Table 2. Path coefficient analysis to determine direct (bold) and indirect effects of different plant traits on capsaicin content in *Capsicum annuum*.

Characters	Plant height	Pri. branches/ plant	Sec. branches/ pri. branch	Tert. branches/ sec. branch	Days to 1ST flowering	Days to IInd flowering	Days to fruit initiation	Leaf surface area	Fruit length	Fruit diameter	Fruit surface area	Fruit wt. (fresh)	Fruit wt.(dry)	Capsanthin content (%)	Genotypic correlation (r) with capsaicin content (%)
Plant height	**-0.202**	0.147	-0.053	0.001	0.168	-0.414	0.374	-0.039	-0.023	0.179	-0.165	-0.079	0.149	-0.0007	0.044
Pri branches/ plant	-0.034	**0.870**	-0.102	-0.051	0.049	-0.064	0.105	0.006	-0.105	-0.154	0.328	0.088	-0.255	-0.001	0.679**
Sec. branches / pri branch	-0.038	0.319	**-0.279**	-0.061	0.006	-0.016	0.111	-0.001	0.028	0.019	-0.050	-0.007	0.005	-0.001	0.035
Ttertiary branches/ sec. branch	-0.001	0.188	-0.073	**-0.237**	0.102	0.080	-0.024	-0.018	0.271	0.060	-0.537	-0.073	0.177	0.003	-0.078
Days to Ist flowering	-0.084	0.107	-0.004	-0.060	**0.402**	-0.243	0.431	-0.057	0.382	0.113	-0.750	-0.062	0.174	-0.004	0.344*
Days to IInd flowering	-0.124	0.083	-0.006	0.028	0.146	**-0.672**	0.480	-0.031	-0.179	0.034	0.228	-0.035	0.045	-0.001	-0.005
Days to fruit initiation	-0.120	0.146	-0.049	0.009	0.275	-0.513	**0.629**	-0.059	0.044	0.181	0.332	-0.069	0.148	-0.001	0.288
Leaf surface area	-0.007	-0.049	-0.004	-0.040	0.120	-0.194	0.346	**-0.109**	0.174	0.314	-0.683	-0.124	0.308	0.002	0.085
Fruit length	0.005	-0.113	-0.009	-0.079	0.189	0.149	0.034	-0.023	**0.814**	0.087	-1.155	-0.063	0.202	-0.002	0.036
Fruit diameter	-0.052	-0.195	-0.007	-0.020	0.066	-0.033	0.166	-0.049	0.103	**0.687**	-1.038	-0.192	0.496	0.005	-0.067
Fruit surface area	-0.022	-0.190	-0.009	-0.084	0.200	0.102	0.139	-0.049	0.626	0.475	**-1.502**	-0.165	0.462	0.003	-0.016
Fruit wt. fresh)	-0.063	-0.303	-0.008	-0.069	0.099	-0.093	0.175	-0.053	0.202	0.523	-0.988	**-0.251**	0.602	0.002	-0.225
Fruit wt. (dry)	-0.048	-0.358	-0.002	-0.067	0.122	-0.049	0.151	-0.054	0.265	0.548	-1.118	-0.254	**0.621**	0.004	-0.239
Capsanthin content (%)	0.006	-0.038	0.012	-0.036	-0.069	0.051	-0.027	-0.011	-0.093	0.157	-0.202	-0.028	0.106	**0.024**	-0.148

Residual effect = 0.184

Note- Pri. = Primary, Sec.= Secondary, Tert.= Tertiary