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Research Note

Correlation and path co-efficient analysis for yield and its attributing traits in Chilli (*Capsicum annuum* L.)

G. Pruthviraj[1], B. V. Tembhurne[1*], G. Y. Lokesh[1], B. Rajanna[2] and M. K. Meena[3]

[1]Department of Genetics and Plant Breeding, College of Agriculture, UAS, Raichur (Karnataka), India.
[2]MARS, Raichur (Department of Genetics and Plant Breeding) UAS, Raichur (Karnataka), India.
[3] Department of Crop Physiology, DR Office, UAS, Raichur, (Karnataka), India.
*E-Mail: bvtembhurne@gmail.com

Abstract
The present investigation was conducted to find the correlation and path-coefficient analysis for yield and its attributing traits in chilli (*Capsicum annuum* L.) genotypes during summer 2022. The experiment was conducted by selecting twenty four chilli genotypes grown under the shade house for 15 characters. The experiment was laid out in Randomized Complete Block Design with two replications. Correlation studies revealed that average dry fruit yield per plant showed highly significant and positive correlation with plant height, plant spread, number of primary branches, pollen viability, fruit weight, total leaf area, stomatal conductance and total chlorophyll content at both phenotypic and genotypic levels. Path coefficient analysis for average dry fruit yield per plant revealed that, plant height, plant spread, number of primary branches, pollen viability, days to first fruit picking, fruit weight and total chlorophyll content showed positive direct effects at both phenotypic and genotypic levels. Hence, direct selection based on these characters would be effective in genetic improvement of chilli for developing high temperature tolerant genotypes in chilli.

Keywords: *Capsicum annuum* L., Correlation, Path co-efficient, Association, High temperature

Chilli (*Capsicum annuum* L.) is one of the most important commercial cum spice crop. It belongs to family Solanaceae, grown for its pungent fruits and are known for acidic flavour and colour which are used as both green and red ripe. The Capsicum species are members of the Solanaceae family, which includes tomato, potato, tobacco and petunia. This genus contains about 31 species of which five are domesticated, namely *Capsicum annuum* L., *Capsicum frutescens* L., *Capsicum chinense Jacq*., *Capsicum baccatum* L., *and Capsicum pubescens* R. It was first introduced to India by Portuguese towards the end of 15th century (Basu and Amit, 2003). Within the genus, species can be distinguished into two groups, according to the basic number of chromosomes: one with n = x = 12 chromosomes and another with n = x = 13 chromosomes. Chilli is often cross-pollinated crop and frequency of cross pollination in the field can range from just 7 per cent to as high as 36 per cent.

High temperature stress is one of the major limiting factors in pepper production. The optimum day temperature for growth and productivity of hot pepper plants has been found to be 20-30 °C and yields are significantly decreased when temperature rises above 30 °C. Yield is a complex character determined by several component characters. Improvement in yield is possible only through selection for the desired component characters. However, yield is complex polygenic trait that is indirectly or directly dependent on a number of traits called yield components (Elewanya *et al*., 2005). For evaluating the yield potential of any variety, it is necessary to give attention to all the yield contributing characters. It is essential to

assess the degree of association of various quantitative characters with yield for effective selection programme. Hence, the knowledge of association of the various plant characters with yield and among themselves is required so that a rational choice of characters for selection can be exercised.

The correlation coefficient analysis measures the mutual relationship between various characters and it 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 reliable characters contributing to yield. Erudition of correlation alone is often deceptive as the correlation observed may not be always accurate. Two traits may show association just because they are correlated with a common third one (Khan and Dar, 2010). In such cases, path analysis aids in segregating correlation coefficients into direct and indirect effects *via* alternative pathways. Keeping in a view the present experiment was conducted to study the correlation and path analysis for high temperature tolerant genotypes in chilli.

Twenty four diverse chilli genotypes (comprising of hybrids and advanced breeding lines) with different genetic background were selected and grown in a randomized block design with two replications on a plot size of 100 sq ft (50 ft x 2.0 ft) and spacing of 60 x 45 cm arranged as raised beds under shade house. This experiment was conducted at experimental farm, Department of Genetics and Plant Breeding and Laboratory, College of Agriculture Raichur, during the year 2021-22. Raichur is situated in North Eastern dry zone (Zone-II) of Karnataka state. The chilli seedlings were transplanted on February first week 2022 and subjected to hot summer in the shade house. The data was recorded on four plants per genotype and was averaged to use in statistical analysis for the traits *viz*., plant height, plant spread, number of primary branches, number of secondary branches, days to first flower bud initiation, days to 50 per cent flowering, pollen viability, days to first fruit picking, average dry fruit yield per plant, fruit length, fruit weight, total leaf area, relative water content, total dry matter, stomatal conductance, total chlorophyll content and leaf proline content. The collected data was statistically analyzed to estimate phenotypic and genotypic correlations, as well as to perform path-coefficient analysis using INDOSTAT software.

Correlation co-efficient analysis: Correlation co-efficients were calculated at both genotypic and phenotypic levels for all the possible combinations of yield and its attributing traits. The correlation coefficient at both phenotypic and genotypic levels indicated that the average dry fruit yield per plant was significantly and positively correlated with pollen viability (0.866, 0.871), fruit weight

(0.761, 0.764) total chlorophyll content (0.731, 0.730), stomatal conductance (0.676, 0.676), number of primary branches (0.667, 0.662), total leaf area (0.576, 0.586), plant spread (0.538, 0.529), plant height (0.478, 0.472), total dry matter (0.360, 0.345) and fruit length (0.310, 0.302). These findings were in congruent with the results of Bijalwan and Mishra (2016), Gupta *et al*. (2009), Ullah *et al*. (2011), Chattopadhyay *et al*. (2011), Kumar *et al*. (2012) and Yatung *et al*. (2014) for significant and positive association of average dry fruit yield per plant with plant height, plant spread, number of primary branches and fruit weight, Bundela *et al*. (2019) for fruit length, Khurana *et al*. (1993) for total leaf area, Mahantesh *et al*. (2013) for positive significant association of total chlorophyll content with average fruit yield per plant in chilli. The positive and highly significant correlation indicates that these traits are strongly correlated with average dry fruit yield in chilli (Demewez *et al*., 2014) (**Table 1.1 and 1.2**)

Pollen viability depicted highly significant and positive association with fruit weight (0.733, 0.748), total chlorophyll content (0.716, 0.714) and stomatal conductance (0.677, 0.673) also fruit weight showed significant positive association with pollen viability (0.733, 0.747), fruit length (0.562, 0.561) and total leaf area (0.631, 0.648). The result is in line with the work of other scholars namely Munshi *et al*. (2000) and Sreelathakumary and Rajamony (2003) in chilli. The total chlorophyll content showed significant and positive association at both phenotypic and genotypic levels with plant height (0.426, 0.422), number of primary branches (0.630, 0.629), plant spread (0.555, 0.550), pollen viability (0.716, 0.714), fruit weight (0.593, 0.594), total leaf area (0.491, 0.495), stomatal conductance (0.635, 0.628) and leaf proline content (0.315, 0.307). Similar findings were noticed by Dutta *et al*. (2017) and Reddy *et al*. (2013) for significant positive association with pollen viability in birds eye chilli. Since total chlorophyll content was found to have a positive and significant relationship with fruit yield it indicates that fruit yield increases with increase in total chlorophyll content. Stomatal conductance exhibited significant positive association with plant height (0.510, 0.511), number of primary branches (0.722, 0.725) and plant spread (0.609, 0.609). These results were in conformity with the results of Hernandez *et al*. (1989) which reports that increasing of stomatal conductance was affected by plant height and shade, which means that solar radiation affects diffusive resistance stomata or stomatal conductance which influences the CO_2 fixation resulting in the decreased photosynthesis rate. Number of primary branches exhibited significant positive association at both phenotypic and genotypic levels with plant spread (0.549, 0.535), pollen viability (0.581, 0.583), fruit weight (0.520, 0.503), total leaf area (0.690, 0.706), stomatal conductance (0.722, 0.725) and total chlorophyll

Table 1.1. Phenotypic correlations between fruit yield and its attributing traits in chilli grown under shade house condition

	PH	PB	PS	DFBI	DF	PV	DFP	FL	FW	TLA	SC	RWC	TDM	CC	LP$_R$C	FY
PH	1.000	0.471**	0.578**	0.216	-0.203	0.282	0.186	-0.114	0.367*	0.562**	0.511**	0.206	0.479**	0.426**	0.209	0.478**
PB		1.000	0.549**	0.126	-0.2740	0.581**	-0.110	0.393**	0.520**	0.690**	0.722**	0.009	0.402**	0.630**	0.286*	0.667**
PS			1.000	0.204	-0.162	0.384**	0.053	0.067	0.518**	0.540**	0.610**	0.106	0.510**	0.555**	0.035	0.538**
DFBI				1.000	0.418**	0.247	0.085	0.086	0.050	-0.064	0.264	0.002	0.101	0.185	0.225	-0.144*
DF					1.000	-0.240	-0.028	0.053	-0.125	-0.334*	-0.134	0.157	-0.467**	-0.323*	-0.106	-0.328*
PV						1.000	-0.087	0.410**	0.733**	0.550**	0.677**	-0.014	0.352*	0.716**	0.365*	0.866**
DFP							1.000	-0.450**	-0.043	-0.185	-0.035	0.109	-0.156	0.135	-0.058	0.089
FL								1.000	0.562**	0.296*	0.269	-0.103	-0.064	0.244	0.050	0.310*
FW									1.000	0.631**	0.624**	0.100	0.305*	0.593**	0.191	0.761**
TLA										1.000	0.667**	0.109	0.543**	0.491**	0.09	0.576**
SC											1.000	0.091	0.509**	0.635**	0.303*	0.676**
RWC												1.000	-0.094	0.030	0.226	-0.086
TDM													1.000	0.460**	0.319*	0.360*
CC														1.000	0.316*	0.731**
LP$_R$C															1.000	0.199

* = significant at 5 per cent probability level ** = significant at 1 per cent probability level

Table 1.2. Genotypic correlations between fruit yield and different characters in chilli grown under shade house condition

	PH	PB	PS	DFBI	DF	PV	DFP	FL	FW	TLA	SC	RWC	TDM	CC	LP$_R$C	FY
PH	1.000	0.463*	0.562**	0.246	-0.204	0.280	0.176	-0.132	0.350*	0.566**	0.511*	0.183	0.479**	0.422**	0.201	0.472*
PB		1.000	0.535**	0.150	-0.277	0.583**	-0.198	0.385**	0.503**	0.706**	0.725**	-0.054	0.398**	0.630**	0.281	0.662**
PS			1.000	0.240	-0.146	0.378**	-0.025	0.047	0.495**	0.549**	0.609**	0.017	0.507**	0.551**	0.016	0.529**
DFBI				1.000	0.440**	0.268	0.091	0.097	0.072	-0.081	0.286*	0.004	0.111	0.197	0.246	-0.165*
DF					1.000	-0.275	-0.038	0.084	-0.093	-0.392**	-0.149	0.209	-0.533**	-0.367*	-0.117	-0.346*
PV						1.000	-0.155	0.410**	0.748**	0.560**	0.673**	-0.086	0.343*	0.714**	0.358*	0.871**
DFP							1.000	-0.644**	-0.157	-0.443**	-0.095	-0.025	-0.242	0.142	-0.134	0.090
FL								1.000	0.561**	0.300*	0.265	-0.152	-0.072	0.238	0.045	0.302*
FW									1.000	0.648**	0.629**	0.022	0.297*	0.594**	0.183	0.764**
TLA										1.000	0.673**	0.093	0.552**	0.495**	0.090	0.586**
SC											1.000	0.027	0.501**	0.629**	0.293*	0.676**
RWC												1.000	-0.175	-0.037	0.206	-0.151
TDM													1.000	0.452**	0.311*	0.354*
CC														1.000	0.308*	0.730**
LP$_R$C															1.000	0.193

* = significant at 5 per cent probability level ** = significant at 1 per cent probability level

PH: Plant height; PB: Number of primary branches; PS: Plant spread; DFBI: Days to first flower bud initiation;DF: Days to 50 per cent flowering; PV: Pollen viability; DFP: Days to first fruit picking; FY: Average dry fruit yield/plant; FL: Fruit length; FW: Fruit weight; TLA: Total leaf area; SC: Stomatal conductance; RWC: Relative water content; TDM: Total dry matter;CC: Total chlorophyllcontent; LP$_R$C: Leaf proline content

Table 2.1. Phenotypic path analysis for fruit yield and its attributing traits in chilli grown under shade house condition

	PH	PB	PS	DFBI	DF	PV	DFP	FL	FW	TLA	SC	RWC	TDM	CC	LP$_R$C
PH	**0.220**	0.104	0.127	0.047	-0.045	0.062	0.041	-0.025	0.081	0.124	0.113	0.045	0.106	0.094	0.046
PB	0.137	**0.290**	0.159	0.037	-0.080	0.168	-0.032	0.114	0.151	0.200	0.209	0.003	0.117	0.183	0.083
PS	0.016	0.015	**0.028**	0.006	-0.005	0.011	0.001	0.002	0.014	0.015	0.017	0.003	0.014	0.015	0.001
DFBI	-0.010	-0.006	-0.010	**-0.047**	-0.020	-0.012	-0.004	-0.004	-0.002	0.003	-0.012	0.000	-0.005	-0.009	-0.011
DF	0.017	0.023	0.013	-0.035	**-0.083**	0.020	0.002	-0.004	0.010	0.028	0.011	-0.013	0.039	0.027	0.009
PV	0.187	0.385	0.255	0.164	-0.159	**0.664**	-0.057	0.272	0.487	0.365	0.449	-0.009	0.234	0.475	0.242
DFP	0.007	-0.004	0.002	0.003	-0.001	-0.003	**0.037**	-0.017	-0.002	-0.007	-0.001	0.004	-0.006	0.005	-0.002
FL	0.017	-0.057	-0.010	-0.013	-0.008	-0.060	0.066	**-0.146**	-0.082	-0.043	-0.039	0.015	0.009	-0.036	-0.007
FW	0.122	0.173	0.173	0.017	-0.042	0.244	-0.014	0.187	**0.333**	0.210	0.208	0.033	0.102	0.197	0.064
TLA	-0.128	-0.157	-0.123	0.015	0.076	-0.125	0.042	-0.067	-0.143	**-0.227**	-0.150	-0.025	-0.124	-0.112	-0.023
SC	-0.017	-0.024	-0.020	-0.009	0.004	-0.022	0.001	-0.009	-0.021	-0.022	**-0.033**	-0.003	-0.017	-0.021	-0.010
RWC	-0.023	-0.001	-0.012	0.000	-0.018	0.002	-0.012	0.012	-0.011	-0.012	-0.010	**-0.114**	0.011	-0.003	-0.026
TDM	-0.034	-0.028	-0.036	-0.007	0.033	-0.025	0.011	0.005	-0.022	-0.038	-0.036	0.007	**-0.071**	-0.033	-0.023
CC	-0.003	-0.005	-0.005	-0.002	0.003	-0.006	-0.001	-0.002	-0.005	-0.004	-0.005	0.000	-0.004	**0.008**	-0.003
LP$_R$C	-0.030	-0.041	-0.005	-0.032	0.015	-0.052	0.008	-0.007	-0.027	-0.014	-0.043	-0.032	-0.045	-0.045	**-0.142**
FY	0.478**	0.667**	0.537**	-0.144*	-0.328*	0.866**	0.089	0.310*	0.761**	0.576**	0.676**	-0.087	0.360*	0.731**	0.199

R^2 = 0.9170 and Residual Effect = 0.2880

Table 2.2. Genotypic Path analysis for fruit yield and its attributing traits in chilli grown under shade house condition

	PH	PB	PS	DFBI	DF	PV	DFP	FL	FW	TLA	SC	RWC	TDM	CC	LP$_R$C
PH	**0.217**	0.100	0.122	0.053	-0.044	0.061	0.038	-0.029	0.076	0.123	0.111	0.040	0.104	0.092	0.044
PB	0.139	**0.301**	0.161	0.045	-0.083	0.176	-0.060	0.116	0.152	0.213	0.219	-0.016	0.120	0.189	0.085
PS	0.040	0.038	**0.071**	0.017	-0.010	0.027	-0.002	0.003	0.035	0.039	0.043	0.001	0.036	0.039	0.001
DFBI	-0.016	-0.010	-0.016	**-0.065**	-0.029	-0.018	-0.006	-0.006	-0.005	0.005	-0.019	0.000	-0.007	-0.013	-0.016
DF	0.022	0.030	0.016	-0.048	**-0.108**	0.030	0.004	-0.009	0.010	0.042	0.016	-0.023	0.058	0.040	0.013
PV	0.195	0.406	0.263	0.187	-0.192	**0.696**	-0.108	0.286	0.521	0.390	0.469	-0.060	0.239	0.498	0.249
DFP	0.017	-0.019	-0.002	0.009	-0.004	-0.015	**0.094**	-0.060	-0.015	-0.042	-0.009	-0.002	-0.023	0.013	-0.013
FL	0.009	-0.027	-0.003	-0.007	-0.006	-0.029	0.046	**-0.071**	-0.040	-0.021	-0.019	0.011	0.005	-0.017	-0.003
FW	0.108	0.156	0.153	0.022	-0.029	0.231	-0.048	0.173	**0.309**	0.200	0.194	0.007	0.092	0.184	0.056
TLA	-0.141	-0.176	-0.137	0.020	0.098	-0.139	0.110	-0.075	-0.161	**-0.249**	-0.167	-0.023	-0.137	-0.123	-0.023
SC	-0.025	-0.035	-0.030	-0.014	0.007	-0.033	0.005	-0.013	-0.031	-0.033	**-0.049**	-0.001	-0.024	-0.031	-0.014
RWC	-0.012	0.004	-0.001	0.000	-0.014	0.006	0.002	0.010	-0.002	-0.006	-0.002	**-0.066**	0.012	0.002	-0.014
TDM	-0.019	-0.015	-0.020	-0.004	0.021	-0.013	0.009	0.003	-0.012	-0.021	-0.019	0.007	**-0.039**	-0.018	-0.012
CC	-0.035	-0.053	-0.046	-0.017	0.031	-0.060	-0.012	-0.020	-0.050	-0.042	-0.053	0.003	-0.038	**0.084**	-0.026
LP$_R$C	-0.027	-0.038	-0.002	-0.033	0.016	-0.048	0.018	-0.006	-0.025	-0.012	-0.040	-0.028	-0.042	-0.041	**-0.135**
FY	0.472**	0.662**	0.529**	-0.165*	-0.346*	0.871**	0.090	0.302*	0.764**	0.587**	0.676**	-0.151	0.354*	0.730**	0.193

R^2 = 0.9255 and Residual Effect = 0.2729

PH: Plant height; PB: Number of primary branches; PS: Plant spread; DFBI: Days to first flower bud initiation;DF: Days to 50 per cent flowering; PV: Pollen viability; DFP: Days to first fruit picking; FY: Average dry fruit yield/plant; FL: Fruit length; FW: Fruit weight; TLA: Total leaf area; SC: Stomatal conductance; RWC: Relative water content; TDM: Total dry matter;CC: Total chlorophyllcontent; LP$_R$C: Leaf proline content

content (0.630, 0.630). Similar results were reported by Kuruvilla *et al*. (1998) in *Capsicum annuum* and Robert and Terry (2008) in *Capsicum chinense*. Since number of primary branches was positively correlated with yield, this indicates that yield increases with more number of primary branches. Likewise, plant height (0.578, 0.562), pollen viability (0.384, 0.378), total leaf area (0.540, 0.549), stomatal conductance (0.610, 0.609), total dry matter (0.510, 0.507) and total chlorophyll content (0.555, 0.551) showed significant positive correlation with plant spread. Therefore, increase in plant spread will improve dry fruit yield per plant. Plant height showed significant and positive association with the number of primary branches (0.471, 0.463), plant spread (0.578, 0.562), total leaf area (0.562, 0.566), stomatal conductance (0.511, 0.511) and total chlorophyll content (0.426, 0.422). Similar results were found by Kumar *et al*. (2014), Rohini and Lakshmanan (2015) in Chilli.

Additionally, average dry fruit yield per plant showed negative non significant association with relative water content (-0.086, -0.151). However it registered significant and negative correlation with days to 50 per cent flowering (-0.328, 0.346). Similar results were found by Vidya *et al*. (2018) in chilli. Therefore, it can be inferred that selection based on the traits that demonstrated a positive correlation with fruit yield per plant will help to increase yield and discover genotypes that are high temperature tolerant.

Path co-efficient analysis - Direct effects: Path coefficient analysis at both phenotypic and genotypic levels indicated that pollen viability (0.664, 0.696) had the highest direct effect on average dry fruit yield per plant which ensures effective pollination, leading to better seed and fruit development. Thus, it serves as an important reproductive trait directly contributing to yield improvement in chilli, followed by fruit weight (0.333, 0.309), number of primary branches (0.290, 0.301), plant height (0.220, 0.217), days to first fruit picking (0.037, 0.094), plant spread (0.028, 0.071) and total chlorophyll content (0.008, 0.084). Therefore emphasis on these characters which showed direct influence on fruit yield per plant helps in improvement of yield and also to identify high temperature tolerant genotypes. Similar results were obtained by Bekele *et al*. (2022), Devi *et al*. (2018), Pujar *et al*. (2017) and Gajanayake *et al*. (2011) in chilli (**Table 2.1 and 2.2**).

Indirect effects: Pollen viability was reported to have positive indirect effect on fruit weight (0.487, 0.521), total leaf area (0.365, 0.390), stomatal conductance (0.449, 0.469), total dry matter (0.234, 0.239) and total chlorophyll content (0.475, 0.498). While, negative indirect effect *via*., days to 50 per cent flowering (-0.159, -0.192), days to first fruit picking (-0.057, -0.108) and relative water

content (-0.009, -0.060) on average fruit yield per plant. These associations suggest that pollen viability indirectly enhances yield by improving physiological efficiency and plant growth. Similar results were obtained by Prasath *et al*. (2011), Bhalekar *et al*. (2004) and Gajanayake *et al*. (2011) in chilli.

The residual effect was found to be 0.2880 at phenotypic level and 0.2729 at the genotypic level. These relatively low residual values indicate that the majority of the variation in average dry fruit yield per plant was well explained by the characters included in the study. It suggests that the selected traits had a strong contribution towards yield determination. However, a small proportion of variation remains unexplained, which may be due to other minor or unmeasured factors. Overall, the model showed good reliability in explaining yield variability.

The results revealed that the characters *viz*., plant height, plant spread, number of primary branches, pollen viability, fruit weight, total leaf area, stomatal conductance and total chlorophyll content showed highly significant and positive association with average dry fruit yield per plant at both phenotypic and genotypic levels. Hence, selection towards these characters can aid us in breeding high temperature tolerant genotypes. Likewise, path coefficient analysis at both the levels for dry fruit yield per plant revealed that, plant height, plant spread, number of primary branches, pollen viability, days to first fruit picking, fruit weight and total chlorophyll content showed positive direct effects. Therefore emphasis on these characters which showed direct influence on fruit yield per plant helps in improvement of yield and identification of high temperature tolerant genotypes in chilli.

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