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**Research Article**

# Character association and path co-efficient analysis studies on yield and yield attributing characters in chilli (*Capsicum annuum* L.)

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**Abstract**
Seventy one genotypes (54 $F_1$ hybrids, 15 parents and two commercial checks) of chilli (*Capsicum annuum* L.) were evaluated at Horticultural Research Station, Lam, Guntur, Andhra Pradesh to carry out the correlation studies between twelve quantitative traits and to estimate the direct and indirect effects of yield attributing traits on yield per plant. The phenotypic and genotypic association of fruit yield per plant was significant and positive with plant height, plant spread, number of fruits per plant and days to fruit maturity indicating the importance of these traits in selection for yield. The path analysis revealed that the direct contribution of number of fruits per plant and average dry fruit weight was high and positive on yield per plant. Whereas, it was moderate, positive for days to fruit maturity and low, positive for fruit length indicated that its true relationship with yield and direct selection based on these traits may be helpful in evolving high yielding genotypes of chilli.

**Keywords**
Chilli, Capsicum annuum, correlation, path analysis, yield

## Introduction

Chilli, known as the universal spice of India has its unique place in the diet as a vegetable cum spice crop along with additional importance of offering outstanding job and income generating opportunities for enormous small farmers in the country. It is an indispensable spice due to its pungency, taste, appealing colour and flavour. India is the largest producer (1.492 million tonnes from 0.775 million hectares), consumer and exporter of chilli in the world with productivity of 1.9 metric t/ha (National Horticulture Board, 2014). Even though India ranks first in area and production of chilli, its productivity is very low as compared to other countries like Japan (3.6 t/ha) and Korea (2 t/ha), USA and Indonesia (Patil *et al.*, 2012). Hence, there is a need to develop high yielding varieties and hybrids. Yield is a complex character determined by several component characters (Singh, 2005). Improvement in yield is possible only through selection for the desired component characters. 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 in order to 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. Studies on this aspect in chilli were made by several earlier workers *viz.* Jogi *et al*. (2013), Vikram *et al*. (2014) and Rohini & Lakshmanan (2015). Therefore the investigation was carried out to determine the nature and degree of association among the characters and their direct and indirect effects on chilli yield.

## Materials and Methods

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. The resulting 54 $F_1$ hybrids along with their 15 parents and 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 observations were recorded on five randomly selected plants for twelve characters *viz.*, plant height (cm), plant spread (cm), number of primary branches, days to 50% flowering, days to fruit maturity, number of fruits per plant, fruit length (cm), fruit diameter (cm), average dry

fruit weight (g), dry fruit yield per plant (g), number of seeds per fruit and seed weight (g/1000 seed).

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).

**Results and Discussion**

In the present study, the estimates of phenotypic and genotypic correlation coefficients (Table 2) depicted that the genotypic correlations were higher than the corresponding phenotypic correlations for most of the traits indicated presence of high heritability for that respective traits. Moreover, it may be due to masking effect of environment causing differential genotypic and phenotypic expression of these traits. These studies are in conformity with the earlier observations of Krishnamurthy *et al.* (2013), Janaki *et al.* (2016) and Sharma and Sridevi (2016).

The fruit yield per plant exhibited significant and positive phenotypic and genotypic association with plant height ($r_p$0.2604, $r_g$0.3625), plant spread ($r_p$0.2159, $r_g$0.3003) , number of fruits per plant ($r_p$0.6566, $r_g$0.6454) and days to fruit maturity ($r_p$0.2192, $r_g$0.3040) indicating the usefulness of these traits upon improvement of fruit yield in chilli, whereas its association with no. of primary branches per plant ($r_g$0.2973) and seed weight ($r_g$0.1511) was significant and positive only at genotypic level (Table 2). Hence, fruit yield can be improved by selecting the lines with maximum plant height & plant spread, more number of fruits per plant & maximum days to fruit maturity. Similar results have been reported in chillies by Hasanuzzaman and Golam (2011) and Rohini & Lakshmanan (2015) who have also observed significant positive correlation of various yield attributing traits with fruit yield.

The inter relationship among the plant height, plant spread, no. of primary branches per plant and no. of fruits per plant was positive and significant at both phenotypic and genotypic levels (Table 2). These results are in conformity with earlier findings of Reddy *et al*. (2008) and Jogi *et al.* (2013). Similarly the inter relationship among the fruit diameter, average dry fruit weight, number of seeds per fruit and 1000 seed weight was positive and significant at both phenotypic and genotypic levels (Table 2). These results indicated that increase in one trait leads to increase in other correlated traits. These results are in agreement with reports of Hasanuzzaman and Golam (2011) and Kumar *et al*. (2012).

Fruit length and fruit diameter showed negative and significant association with plant height, plant spread, no. of primary branches per plant, days to 50% flowering and no. of fruits per plant (Table 2). Similar findings were reported by Tembhurne *et al.* (2008). Similarly average dry fruit weight and 1000 seed weight exhibited negative and significant association with plant height, plant spread, no. of primary branches per plant and no. of fruits per plant (Table 2). These results are supported by earlier findings of Tembhurne *et al.* (2008) and Sharma *et al.* (2010) in chilli. These results indicated that increase in fruit length/fruit diameter/average dry fruit weight/1000 seed weight/all leads to decrease in other negatively correlated traits and *vice-versa*. No. of seeds per fruit showed negative, significant correlation with plant spread, no. of primary branches per plant and fruit length at genotypic level while with no. of fruits per plant at both phenotypic and genotypic levels (Table 2). These results indicated that increase in no. of seeds per fruit leads to decrease in other negatively correlated traits and *vice-versa*. Kumar *et al*. (2012) has also reported similar findings in chilli.

Fruit length exhibited significant, positive association with average dry fruit weight ($r_p$0.1923, $r_g$0.3012) whereas it showed significant, negative association ($r_g$-0.2305) with no. of seeds per fruit which revealed that increase in fruit length associated with increase in average fruit weight and decrease in no. of seeds per fruit and *vice-verse* (Table 2). These results are in conformity with earlier findings of Berhanu *et al.* (2011). Days to 50% flowering showed positive and significant association with plant spread, no. of primary branches per plant and fruit diameter while its association with fruit length is significant and negative. Days to fruit maturity exhibited significant and positive association with plant height ($r_p$, $r_g$), plant spread ($r_p$) and 1000 seed weight ($r_g$) (Table 2). These results are in line with earlier reports of Tembhurne *et al.* (2008) and Sharma *et al.* (2010).

The path coefficient analysis provides an effective means of finding out direct and indirect effect of association and permits a critical examination of specific forces acting to produce given correlation and measure the relative importance of each factor. The direct and indirect effects of different characters on yield are presented in Table 3.

The path analysis studies (Table 3) revealed that plant height, fruit diameter and 1000 seed weight at phenotypic level, no. of primary branches per plant at genotypic level, number of fruits per plant, days to fruit maturity, fruit length, average dry fruit weight, number of seeds per fruit at both phenotypic and genotypic levels exhibited positive direct effect indicating that direct selection based on these traits may be helpful in evolving high yielding varieties of chilli. These results are in agreement with reports made by Kumar *et al*. (2012).

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, no. of fruits per plant exhibited very high and positive direct contribution at genotypic level (1.0583), whereas at phenotypic level it was high and positive (0.9636) and indirectly influence the fruit yield through plant height, plant spread, no. of primary branches per plant and days to 50 % flowering. The direct effect of average dry fruit weight was also high and positive (p0.4448 and g0.6692) and indirectly influence the fruit yield through days to 50 %

flowering, days to fruit maturity, fruit length, fruit diameter, no. of seeds per fruit and 1000 seed weight. The high direct effect of these traits and its pronounced association with yield per plant reveals its true relationship with yield and direct selection for these traits will be rewarding. The direct effect of days to fruit maturity was moderate and positive, whereas it was low and positive in case of fruit length (Table 3). These results are in conformity with earlier reports of Sharma *et al.* (2010), Rohini & Lakshmanan (2015) and Hasan *et al.* (2016).

Studies on character association indicated that plant height, plant spread, number of fruits per plant and days to fruit maturity had positive significant association with yield per plant indicating the importance of these traits in selection for yield and were identified as yield attributing characters on which selection can be relied upon for the genetic improvement of fruit yield in chilli. The path analysis revealed that the direct contribution of number of fruits per plant and average dry fruit weight was high and positive on yield per plant. Whereas, it was moderate, positive for days to fruit maturity and low, positive for fruit length indicated that direct selection based on these traits may be helpful in evolving high yielding hybrids of chilli.

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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 twelve quantitative characters in chilli (*Capsicum annuum* L.)**

| Character | | Plant Height (cm) | Plant Spread (cm) | No. of Primary Branches/ Plant | Days to 50% Flowering | No. of Fruits/ Plant | Days to Fruit Maturity (red) | Fruit Length (cm) | Fruit Diameter (cm) | Average Dry Fruit Weight (g) | No. of Seeds/ Fruit | 1000 Seed Weight (g) | Dry Fruit Yield/ Plant (g) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Plant Height (cm) | **P** | **1.0000** | 0.4598** | 0.3053** | -0.0175 | 0.3846** | 0.1771** | -0.3748** | -0.2307** | -0.2559** | 0.0022 | -0.1714* | 0.2604** |
| | G | **1.0000** | 0.6171** | 0.4323** | -0.0672 | 0.5069** | 0.2466** | -0.4506** | -0.3104** | -0.3313** | -0.1034 | -0.1813** | 0.3625** |
| Plant Spread (cm) | P | | **1.0000** | 0.3161** | 0.1403* | 0.3850** | 0.1420* | -0.3207** | -0.1759* | -0.2248** | -0.0783 | -0.1539* | 0.2159** |
| | G | | **1.0000** | 0.2838** | 0.1528* | 0.5103** | 0.0803 | -0.4693** | -0.2239** | -0.3031** | -0.1983** | -0.1367* | 0.3003** |
| No. of Primary Branches/ Plant | P | | | **1.0000** | 0.2587** | 0.3037** | 0.0903 | -0.2887** | -0.1753* | -0.2624** | -0.1294 | -0.2038** | 0.1285 |
| | G | | | **1.0000** | 0.2925** | 0.5575** | -0.1233 | -0.4301** | -0.2174** | -0.4574** | -0.2448** | -0.1614* | 0.2973** |
| Days to 50% Flowering | P | | | | **1.0000** | 0.0229 | -0.0755 | -0.2365** | 0.2104** | 0.0109 | 0.0223 | 0.0333 | -0.0494 |
| | G | | | | **1.0000** | 0.0542 | -0.1276 | -0.2468** | 0.2454** | 0.0138 | 0.0191 | 0.0990 | -0.0170 |
| No. of Fruits/ Plant | P | | | | | **1.0000** | -0.0303 | -0.1745* | -0.4749** | -0.5295** | -0.3156** | -0.1832** | 0.6566** |
| | G | | | | | **1.0000** | -0.0128 | -0.2743** | -0.5927** | -0.6428** | -0.4919** | -0.3132** | 0.6454** |
| Days to Fruit Maturity (red) | P | | | | | | **1.0000** | -0.0914 | -0.0005 | 0.0919 | 0.0565 | 0.0825 | 0.2192** |
| | G | | | | | | **1.0000** | -0.1172 | 0.0610 | 0.1289 | 0.1196 | 0.2846** | 0.3040** |
| Fruit Length (cm) | P | | | | | | | **1.0000** | -0.0209 | 0.1923** | -0.1204 | 0.0756 | 0.0221 |
| | G | | | | | | | **1.0000** | -0.0365 | 0.3012** | -0.2305** | 0.0636 | -0.0131 |
| Fruit Diameter (cm) | P | | | | | | | | **1.0000** | 0.5479** | 0.3851** | 0.2088** | -0.1563* |
| | G | | | | | | | | **1.0000** | 0.7143** | 0.4387** | 0.1935** | -0.1965** |
| Average Dry Fruit Weight (g) | P | | | | | | | | | **1.0000** | 0.3097** | 0.3654** | 0.0257 |
| | G | | | | | | | | | **1.0000** | 0.4675** | 0.5992** | 0.0057 |
| No. of Seeds/ Fruit | P | | | | | | | | | | **1.0000** | 0.1846** | -0.0883 |
| | G | | | | | | | | | | **1.0000** | 0.5106** | -0.2064** |
| 1000 Seed Weight (g) | P | | | | | | | | | | | **1.0000** | 0.0526 |
| | G | | | | | | | | | | | **1.0000** | 0.1511* |
| 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 yield attributing characters on yield per plant in chilli (*Capsicum annuum* L.)**

| Character | | Plant Height (cm) | Plant Spread (cm) | No. of Primary Branches/ Plant | Days to 50% Flowering | No. of Fruits/ Plant | Days to Fruit Maturity (red) | Fruit Length (cm) | Fruit Diameter (cm) | Average Dry Fruit Weight (g) | No. of Seeds/ Fruit | 1000 Seed Weight (g) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Plant Height (cm) | P | **0.0480** | 0.0221 | 0.0147 | -0.0008 | 0.0185 | 0.0085 | -0.0180 | -0.0111 | -0.0123 | 0.0001 | -0.0082 |
| | G | **-0.0105** | -0.0065 | -0.0046 | 0.0007 | -0.0053 | -0.0026 | 0.0048 | 0.0033 | 0.0035 | 0.0011 | 0.0019 |
| Plant Spread (cm) | P | -0.0212 | **-0.0461** | -0.0146 | -0.0065 | -0.0177 | -0.0065 | 0.0148 | 0.0081 | 0.0103 | 0.0036 | 0.0071 |
| | G | -0.0057 | **-0.0092** | -0.0026 | -0.0014 | -0.0047 | -0.0007 | 0.0043 | 0.0021 | 0.0028 | 0.0018 | 0.0013 |
| No. of Primary Branches/ Plant | P | -0.0007 | -0.0007 | **-0.0022** | -0.0006 | -0.0007 | -0.0002 | 0.0006 | 0.0004 | 0.0006 | 0.0003 | 0.0004 |
| | G | 0.0588 | 0.0386 | **0.1360** | 0.0398 | 0.0758 | -0.0168 | -0.0585 | -0.0295 | -0.0622 | -0.0333 | -0.0219 |
| Days to 50% Flowering | P | 0.0006 | -0.0048 | -0.0089 | **-0.0343** | -0.0008 | 0.0026 | 0.0081 | -0.0072 | -0.0004 | -0.0008 | -0.0011 |
| | G | 0.0026 | -0.0060 | -0.0114 | **-0.0391** | -0.0021 | 0.0050 | 0.0096 | -0.0096 | -0.0005 | -0.0007 | -0.0039 |
| No. of Fruits/ Plant | P | 0.3706 | 0.3709 | 0.2926 | 0.0221 | **0.9636** | -0.0292 | -0.1681 | -0.4575 | -0.5101 | -0.3040 | -0.1764 |
| | G | 0.5364 | 0.5400 | 0.5899 | 0.0573 | **1.0583** | -0.0135 | -0.2903 | -0.6272 | -0.6802 | -0.5205 | -0.3314 |
| Days to Fruit Maturity (red) | P | 0.0371 | 0.0297 | 0.0189 | -0.0158 | -0.0063 | **0.2094** | -0.0191 | -0.0001 | 0.0192 | 0.0118 | 0.0173 |
| | G | 0.0644 | 0.0210 | -0.0322 | -0.0333 | -0.0033 | **0.2611** | -0.0306 | 0.0159 | 0.0336 | 0.0312 | 0.0743 |
| Fruit Length (cm) | P | -0.0466 | -0.0399 | -0.0359 | -0.0294 | -0.0217 | -0.0114 | **0.1243** | -0.0026 | 0.0239 | -0.0150 | 0.0094 |
| | G | -0.0713 | -0.0742 | -0.0680 | -0.0390 | -0.0434 | -0.0185 | **0.1582** | -0.0058 | 0.0476 | -0.0364 | 0.0101 |
| Fruit Diameter (cm) | P | -0.0101 | -0.0077 | -0.0076 | 0.0092 | -0.0207 | 0.0000 | -0.0009 | **0.0436** | 0.0239 | 0.0168 | 0.0091 |
| | G | 0.0154 | 0.0111 | 0.0108 | -0.0122 | 0.0295 | -0.0030 | 0.0018 | **-0.0497** | -0.0355 | -0.0218 | -0.0096 |
| Average Dry Fruit Weight (g) | P | -0.1138 | -0.0999 | -0.1167 | 0.0048 | -0.2355 | 0.0409 | 0.0855 | 0.2436 | **0.4448** | 0.1377 | 0.1625 |
| | G | -0.2217 | -0.2028 | -0.3061 | 0.0092 | -0.4301 | 0.0862 | 0.2015 | 0.4780 | **0.6692** | 0.3128 | 0.4009 |
| No. of Seeds/ Fruit | P | 0.0001 | -0.0045 | -0.0074 | 0.0013 | -0.0180 | 0.0032 | -0.0069 | 0.0220 | 0.0177 | **0.0571** | 0.0105 |
| | G | -0.0062 | -0.0119 | -0.0147 | 0.0011 | -0.0296 | 0.0072 | -0.0139 | 0.0264 | 0.0281 | **0.0602** | 0.0307 |
| 1000 Seed Weight (g) | P | -0.0038 | -0.0034 | -0.0045 | 0.0007 | -0.0040 | 0.0018 | 0.0017 | 0.0046 | 0.0081 | 0.0041 | **0.0220** |
| | G | 0.0002 | 0.0002 | 0.0002 | -0.0001 | 0.0004 | -0.0004 | -0.0001 | -0.0002 | -0.0008 | -0.0006 | **-0.0013** |
| Dry Fruit Yield/ Plant (g) | P | **0.2603**** | **0.2158**** | **0.1284** | **-0.0494** | **0.6566**** | **0.2191**** | **0.0221** | **-0.1562*** | **0.0256** | **-0.0883** | **0.0526** |
| | G | **0.3625**** | **0.3003**** | **0.2973**** | **-0.0170** | **0.6454**** | **0.3040**** | **-0.0131** | **-0.1964**** | **0.0056** | **-0.2063** | **0.1511*** |
| Partial $R^2$ | P | 0.0125 | -0.0099 | -0.0003 | 0.0017 | 0.6327 | 0.0459 | 0.0027 | -0.0068 | 0.0114 | -0.0050 | 0.0012 |
| | G | -0.0038 | -0.0028 | 0.0404 | 0.0007 | 0.6830 | 0.0794 | -0.0021 | 0.0098 | 0.0038 | -0.0124 | -0.0002 |

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