Research Note

Association studies for yield and some yield contributing morpho-physiological components in cauliflower (Brassica oleracea L. var. botrytis L.)

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Abstract
Twenty five genotypes of cauliflower along with one check Madhuri were evaluated for yield and some yield contributing morpho-physiological components in cauliflower. Further, the investigation was done to find out interrelationships among different characters and their direct and indirect contribution towards yield. Estimates of phenotypic and genotypic correlation coefficient revealed that marketable yield per plant was significantly and positively correlated with curd size index, gross weight per plant, curd solidity, curd compactness, curd diameter, stalk length, number of leaves per plant and harvest index. The high positive direct effect on marketable yield per plant was exhibited by curd size index, gross weight per plant, days to marketable curd maturity from date of transplanting, curd solidity, stalk length and per cent marketable curds. Therefore, these traits should be considered as the selection criterion to improve the marketable yield per plant.

Key words
Cauliflower, Correlation, path analysis, marketable yield per plant

Cauliflower (Brassica oleracea L. var. botrytis; 2n=2x=18) is an important cruciferae vegetable belonging to Brassicaceae family and grown throughout world. It is good source of proteins, carbohydrates, minerals and vitamins. Being a member of Cole group, cauliflower can contribute immensely in improving the human health and have been classified as ‘Super Food’ as it possess robust oxidative defence systems i.e. antioxidants and polyphenols (Miean and Mohamed, 2001). It is low in fat but high in dietary fiber, foliate and water, possessing a high nutritional density. It contains several phytochemicals, common in the cabbage family that may be beneficial to human health. A high intake of cauliflower has been associated with reduced risk of aggressive prostate cancer (Kushwaha et al., 2013).

In Himachal Pradesh, snowball group (late maturing) is the major cauliflower group both in terms of off-season as well as seed crop and provides ideal genotypes both to farmers and consumers. Owing to the different agroclimatic conditions, cauliflower is grown throughout the year in one or other part of the state. In cauliflower, growing of commercial hybrids in contrast to other Brassica vegetables picked up late and it is only since about 1985 they attained commercial reality. The reasons may be thermosensitivity of the crop and unavailability of good performing hybrids. But now almost all the cauliflower grown in the developed countries are F₁ hybrids, mainly because of economical interest and not for agronomical reasons. In India, the share of cauliflower hybrid cultivars is still less than 11 per cent (Muthukumar and Selvakumar, 2014) and the picture of many other developing countries is no way better than this. Further research on F₁ hybrid cultivars would also increase the use of hybrid seeds. In Himachal Pradesh, to increase the production and productivity of cauliflower and elevate the income of farmers, it would be advisable to grow hybrids. For this reason, it is necessary to identify the environment specific best performing hybrids.

Yield is a complex character determined by several component characters. So selection for yield should take into account related characters as well (Selvi et al., 2016). Keeping this in view, the present study was conducted to study correlation and path analysis of economically important characters in cauliflower genotypes. Singh et al. (2006) and Sheemar et al. (2012), in their studies reported that marketable yield per plant had significant positive correlation with curd size index, gross weight per plant, number of leaves per plant, stalk length, curd solidity, curd compactness, curd diameter and harvest index. Knowledge about association between horticultural traits viz., gross weight per plant, marketable yield per plant, plant height etc., is of great value in planning a breeding programme. Coefficients of correlation between different important traits and their path analysis help cauliflower breeders to decide suitable selection criteria to improve yield and other component traits.

The present investigation was carried out at the Research Farm of the Department of Vegetable Science and Floriculture, CSK Himachal Pradesh Krishi Vishvavidyalaya, Palampur, (H.P.), during rabi, 2014-2015 to study the performance of various cauliflower hybrids and to identify the promising ones. Twenty five genotypes along with one check Madhuri were evaluated in Randomized Complete Block Design with three replications. Details and source of genotypes are presented in
Significant differences were observed among all the genotypes for all the traits under study (Table 2). Knowledge of correlation and path analysis help plant breeder to ascertain the real components of yield and provide an effective basis of phenotypic selection (Gudmewad et al., 2016). Correlation among different traits is of vital importance to know their association, as yield is an important outcome of many correlated characters.

An understanding of inter-character correlation is essential to successful selection of useful genotypes from the whole population but intensive selection for any characteristic might result in losses in others. The magnitude of the genotypic and phenotypic correlations and their utilization in the selection had been stated by a number of researchers (Ali et al., 2008). Correlation coefficients have been worked out at genotypic and phenotypic levels. The data pertaining to correlation coefficient are presented in Table 3.

The end product, yield has often been described as the product of its components under the influence of the environment and is known to show interdependence. The component traits have indirect effect towards yield apart from their direct contribution towards yield. It is quite likely that the contribution of a component showing significant association with yield may get diluted due to interaction with other components. The path coefficient analysis allows partitioning of correlation coefficients into direct and indirect effects of various traits towards dependent variable and thus, helps in assessing the cause-effect relationship as well as effective selection (Dewey and Lu, 1959). It plays an important role in determining the degree of relationship between yield and its component effects and also permits critical examination of specific factors that provide a given correlation. As depicted by Table 4, curd size index (0.663), gross weight per plant (0.301), days to marketable curd maturity from date of transplanting (0.298), curd solidity (0.266), stalk length (0.225), curd diameter (0.216), per cent marketable curds (0.178), and harvest index (0.105) had high positive direct effects on marketable yield per plant at phenotypic level and traits such as days to marketable curd maturity from date of transplanting (1.392), curd diameter (0.956), curd size index (0.820), dry matter content (0.668), per cent marketable curds (0.631) and number of leaves per plant (0.590) also had appreciable positive direct contribution to the total association with marketable yield per plant at genotypic level. The direct effects of remaining traits were low.

Earlier researchers have also reported direct and positive effects of gross weight per plant (Singh et al., 2006), harvest index and curd depth (Sheemar et al., 2012), on the total association with marketable yield per plant.

**References**

Ali Jibouri, H.A., Miller, P.A. and Robinson, H.F. 1958. Genotypic and environmental variance and covariance in upland cotton crops of inter-specific origin. *Agron. J.*, 50: 633-636.

Ali, Y., Atta, B.M., Akhter, J., Monneveux, P., and Lateef, Z. 2008. Genetic variability, association and diversity studies in wheat (*Triticum aestivum* L.) germplasm. *Pak. J. Bot.*, 40(5): 2087-2097.

Dewey, D.R. and Lu, K.H. 1959. A correlation and path analysis of components of crested wheat-grass seed production. *Agron. J.*, 51: 515-518.

Gudmewad, R.B., Khandagale, S.G., Kumara Swamy, R.V, and Swati. 2016. Character association and path analysis studies for yield and its components in pea (*Pisum sativum* L.). *Electron. J. Plant Breed.*, 7(2): 427-433

Kushwaha, A., Baily, S.B., Maxton, A. and Baily Ram, G.D. 2013. Isolation and characterization of PGPR associated with cauliflower roots and its effect on plant growth. *The Bioscan*, 8: 95-99.
Miean, K.H. and Mohamed, S. 2001. Flavonoid (Myricetin, Quercetin, Kaempferol, Luteolin and Apigenin) content of edible tropical plants. *Journal of Agriculture and Food Chemistry*, **49**: 106-112.

Muthukumar, P. and Selvakumar, R. 2014. Seed Production in Vegetable Crops. In: Glausdtas Horticulture, New Vishal Publications, New Delhi P. 335.

Selvi, S.B., Rajangam J., Suresh, J. and Muthuselvi, R. 2016. Character association and path analysis studies for yield and its components in pea (*Pisum sativum* L.). *Electron. J. Plant Breed.*, **7**(3): 750-757.

Sheemar, G., Singh, D., Malik, A. and Kumar, A. 2012. Correlation and path analysis studies of economic traits in cauliflower (*Brassica oleracea* L. var. *botrytis*). *J. Agri. Tech.*, **85**: 1791-1799.

Singh, B., Pandey, A.K., Verma, A. and Rai, M. 2006. Genetic variability in aghani group of Indian cauliflower (*Brassica oleracea* L. var. *botrytis*). *Indian J. Plant Gen. Res.*, **19**: 113-117.
Table 1. List of genotypes and their sources

| Hybrids | Sources       | Hybrids | Sources               |
|---------|---------------|---------|-----------------------|
| H 1     | Rasi Seeds    | H 13    | US Agri Seeds         |
| H 2     | Rasi Seeds    | H 14    | Tokita Seeds          |
| H 3     | Noble Seeds   | H 15    | Seminis               |
| H 4     | Sungro        | H 16    | Indo-American Hybrid Seeds |
| H 5     | Taki Seeds    | H 17    | US Agri Seeds         |
| H 6     | Rasi Seeds    | H 18    | Team Seeds            |
| H 7     | Noble Seeds   | H 19    | Pahuja Seeds          |
| H 8     | Rasi Seeds    | H 20    | Vigro Seeds           |
| H 9     | Rasi Seeds    | H 21    | US Agri Seeds         |
| H 10    | Seminis Seeds | H 22    | Sakata Seeds          |
| H 11    | Team seeds    | H 23    | Noble Seeds           |
| H 12    | Suttind Seeds | H 24    | Seminis               |
| Standard Check | Claus Seeds   |         |                       |
| Madhuri |               |         |                       |

Table 2. Analysis of variance for different traits in cauliflower hybrids

| Sources of variation          | Mean squares |         |         |
|-------------------------------|--------------|---------|---------|
|                               | Replications | Genotypes | Error   |
| df                            | 2            | 24       | 48      |
| Days to initiation of curd from transplanting | 19.36       | 100.86** | 0.40    |
| Days to marketable curd maturity from date of transplanting | 32.21       | 97.83**  | 1.66    |
| Gross weight per plant (g)    | 11799.84     | 45477.00** | 972.34 |
| Marketable yield per plant (g)| 1258.56      | 33255.67** | 565.14 |
| Curd depth (cm)               | 0.11         | 1.40**   | 0.02    |
| Curd diameter (cm)            | 0.07         | 2.40**   | 0.10    |
| Curd size index (cm²)         | 1.37         | 455.70** | 2.58    |
| Curd compactness (³)          | 7.91         | 21.22**  | 17.82   |
| Curd solidity (g/cm)          | 72.07        | 1223.75** | 206.56 |
| % Marketable curds            | 1.49         | 60.80**  | 1.71    |
| Stalk length (cm)             | 0.01         | 0.71**   | 0.02    |
| Number of leaves per plant    | 3.36         | 2.00**   | 0.82    |
| Plant height (cm)             | 9.82         | 17.00**  | 1.12    |
| Dry matter content (%)        | 1.72         | 3.11**   | 1.00    |
| Ascorbic acid content (mg/100g)| 18.66       | 207.01** | 0.76    |
| Total soluble solids (°Brix)  | 0.81         | 0.77**   | 0.05    |
| Harvest index (%)             | 1.50         | 169.91** | 1.60    |

** Significant at 1% level
Table 3. Estimates of phenotypic (P) and genotypic (G) correlation coefficients among different horticultural traits in cauliflower hybrids

| Days to marketable curd maturity from d.o.t. | Gross weight per plant (g) | Curd size index (cm²) | Curd depth (cm) | Curd diameter (cm) | Curd compacitence (degrees) | Curd solidity (g/cm) | Per cent marketable curds | Stalk Length (cm) | Number of leaves per plant | Plant height (cm) | Dry matter content (%) | Ascorbic acid content (mg/100g) | Total soluble solids | Harvest index (%) | Correlation with marketable yield per plant (r) |
|-------------------------------------------|---------------------------|----------------------|-----------------|-------------------|---------------------------|----------------------|--------------------------|---------------------|-----------------------------|-----------------|------------------------|--------------------------|---------------------|------------------|----------------------------------|
| Days to initiation of curd from transplanting | G | 0.865** | -0.473** | -0.503** | -0.013 | -0.545** | -0.197 | -0.092 | 0.133 | -0.067 | -0.183 | 0.218 | 0.128 | -0.156 | 0.171 | 0.099 | -0.379** |
| Days to marketable curd maturity from d.o.t. | G | 0.888** | -0.500** | -0.512** | -0.016 | -0.590** | -0.875** | -0.134 | 0.141 | -0.076 | -0.332** | 0.224 | 0.194 | -0.157 | 0.176 | 0.099 | -0.393** |
| Gross weight per plant | P | 0.282* | -0.376** | 0.112 | -0.268* | -0.133 | -0.051 | 0.249* | -0.007 | -0.074 | -0.059 | 0.172 | -0.144 | 0.203 | 0.250* | -0.169 |
| Ascorbic acid content (mg/100g) | G | -0.293* | -0.386** | 0.116 | -0.303** | -0.614** | -0.086 | 0.278* | -0.012 | -0.104 | -0.058 | 0.253* | -0.161 | 0.228 | 0.259* | -0.177 |
| Per cent marketable curds | P | 0.459** | 0.005 | 0.422** | 0.089 | 0.145 | 0.057 | 0.114 | 0.230* | -0.053 | -0.294* | 0.044 | 0.052 | -0.288* | 0.509** |
| Stalk Length (cm) | G | 0.482** | -0.004 | 0.443** | 0.575** | 0.201 | 0.067 | 0.122 | 0.404** | -0.090 | -0.407** | 0.051 | 0.063 | -0.302** | 0.538** |
| Number of leaves per plant | G | 0.086 | 0.339** | 0.280 | 0.462** | 0.194 | 0.323** | 0.408** | -0.170 | 0.266* | -0.111 | -0.219 | 0.154 | 0.817** |
| Plant height (cm) | G | 0.088 | 0.378** | 0.083 | 0.582** | 0.200 | 0.338** | 0.701** | -0.185 | 0.428** | -0.112 | -0.243* | 0.151 | 0.841** |
| Dry matter content (%) | G | 0.051 | 0.007 | 0.016 | 0.196 | 0.135 | -0.009 | -0.268* | 0.179 | -0.083 | -0.151 | 0.263* | 0.041 |
| Ascorbic acid content (mg/100g) | G | 0.048 | 0.050 | 0.020 | 0.200 | 0.135 | -0.034 | -0.300** | 0.299** | -0.090 | -0.169 | 0.278* | 0.044 |
| Total soluble solids | G | 0.639** | 0.141 | -0.254* | 0.114 | 0.618** | -0.295* | 0.220 | 0.036 | -0.333* | -0.090 | 0.326** |
| Harvest index (%) | G | 0.638** | 0.058 | 0.206 | 0.143 | -0.281* | 0.074 | -0.066 | 0.058 | 0.267* | 0.267* |
| Correlation with marketable yield per plant (r) | G | 0.877** | 0.190 | 0.941** | 0.877** | -0.789** | 0.175 | -0.377** | 0.049 | 0.675** | 0.437** |
| ** Significant at P ≤ 0.01; * Significant at P ≤ 0.05

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Table 4. Estimates of direct and indirect effects of different traits on marketable yield per plant at phenotypic (P) and genotypic (G) levels of cauliflower hybrids

| Traits                                      | Days to initiation of curd from transplanting | Days to marketable curd maturity from d.o.t. | Gross weight per plant (g) | Soluble solids | Total soluble solids (g) | Harvest index (%) | Correlation With marketable yield per plant (r) |
|---------------------------------------------|-----------------------------------------------|---------------------------------------------|---------------------------|-----------------|-------------------------|-------------------|-----------------------------------------------|
| Days to initiation of curd from transplanting | P -0.241                                      | G -1.533                                    | 0.258                     | -0.143          | -0.334                  | 0.030             | 0.011                                         |
| Days to marketable curd maturity from d.o.t | P -0.208                                      | G -1.360                                    | 0.298                     | -0.084          | -0.249                  | -0.003            | -0.057                                        |
| Number of市场able curd                      | P -0.307                                      | G -0.358                                    | 0.270                     | 0.027            | 0.086                   | 0.009             | 0.039                                         |
| Total soluble solids                         | P -0.041                                      | G -0.270                                    | 0.016                     | 0.115            | 0.039                   | 0.007             | -0.001                                        |
| Harvest index                                | P -0.203                                      | G -0.151                                    | 0.074                     | -0.087          | 0.102                   | -0.006            | -0.001                                        |

**Significant at P ≤ 0.01; *Significant at P ≤ 0.05 level; Residual effect (P): 0.152; (G): -0.044; The bold values indicate direct effect with marketable yield per plant**

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