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CAUSE AND EFFECT RELATIONSHIP TO IDENTIFY IMPORTANT YIELD CONRIBUTING TRAITS IN SAFFRON (*Crocus sativus* L.)

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ABSTRACT: The present investigation was carried out at Saffron Research Station Pampore, SKUAST-Kashmir during 2010. Fifty clones were planted in a randomized bock design with three replications. Observations were recorded on 10 randomly selected and tagged competitive plants for 11 morphological, physiological, floral and corm attributes.viz, plant height (cm), number of radical leaves per plant, stomatal frequency, stomatal size (microns), chlorophyll content (%), number of flowers per corm, fresh pistil weight per corm (mg), pistil length (cm), stigma length (cm), number of daughter corms/ mother corm, and average weight of daughter corms per mother corm (g). The path analysis revealed that pistil length recorded highest direct effect towards fresh pistil weight followed by plant height and stigma length. Rest of the traits as number of flowers recorded weak positive direct effects and the negative direct effect of number of radical leaves plant^{-1} on the dependant variable. However in case of corm attributes in saffron (*Crocus sativus* L.), average weight of daughter corms/ mother corm exerted negative direct effect on number of daughter corms/mother corm, while as size of stomata showed strong positive direct effect on number of daughter corms/mother corm.

Keywords: *Saffron, yield, path coefficient analysis, direct effect, indirect effect.*

Saffron is sterile autumn-flowering specie, which propagates vegetatively by means of a tuberous bulb, known as a corm (Gresta *et al.,* 6; Moraga *et al.,* 9). The name saffron is commonly used to refer both to the spice and the plant itself. The major components of saffron are crocins, picro-crocin and safranal. Crocins is responsible for the colour of saffron, where as picro-crocin and saffranil are responsible for its bitter taste and aroma (De Juan *et al.,* 4). Despite such desirable characteristics saffron production suffers from certain major problems including requirement for large input of manual work (Agayey *et al.,* 2). Most importantly, saffron is subject to strong genetic erosion (Fernandez, 5). Nowadays, saffron is used almost exclusively for cooking purposes to give colour, flavour and aroma to the food. Interest in the impact of saffron carotenoids on human health is growing due to their high antioxidant capacity (Gresta *et al.,* 6; Lage and Cantrell, 8). The golden spice as it is known for its use as a colouring and flavouring agent, is used in preparation of saffronic *kahawa*, a traditional Kashmiri beverage and is also used in Kashmiri wazwan. More specifically it has been recognized as an anticancer medicinal herb (Abdullah, 1).

Saffron, the world's famous low volume high value spice is the legendry crop of Jammu and Kashmir being under cultivation since 500BC. More than 1600 farm families of district Pulwama, Budgam, Srinagar and Doda are involved in saffron trade directly or indirectly. The agro-based industry is contributing 3crores to the state exchequer which is second highest after horticultural industry. Presently the industry is running at the loss of 30 per cent on account of low returns (Nehvi *et al.,* 11). Several reasons account for low saffron productivity of J&K, but lack of high yielding varieties is one of the most important reason that has not been addressed so far.

Urgent measures are required to prevent a sharp curtailment in the production of saffron worldwide. It is therefore, essential that the cultivation and processing of saffron becomes more profitable. A major step towards achieving this goal of increasing productivity of saffron, through specific plant breeding programmes are to be initiated, thereby improving its cultivation and reduce the manual work involved. Such breeding programmes are in the infant stage, with as yet no visible results, as there is only one known cultivar of saffron worldwide, named simply as saffron.

With an aim to harness local diversity of saffron, in Kashmir pragmatic studies on variability, genetic divergence and identification of elite clones through clonal selection was started by SKUAST-K in 2004 and large number of clones were identified. Efforts were also made to induce variability through physical and chemical mutagenesis. As a result of these efforts 50 clones are available at Saffron Research Substation

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(Dossu) Konibal and warrants further investigation for morphological, economic and physiologic characters.

The knowledge on the extent of variation and identification of a good number of genotypes as potential donors in yield improvement programme is essential. Equally important is the information on indirect (correlation and path coefficients) selection parameters so as to formulate a coherent breeding programme for future use. For the most efficient mobilization of available germplasm resources, it is vital to have better understanding of the nature and magnitude of genetic variability, character association and their direct and indirect effect on yield and other traits. Consequently, the more we know of the true relationship among the variables, the more meaningful will be the result of path analysis. The technique has been employed to study the direct and indirect effect of various traits on the ultimate product of economic importance in several crops.

MATERIALS AND METHODS

The present investigation was carried out at Saffron Research Sub-Station (Dassu) Konibal Pampore a constituent Research Sub-station of Sher-e-Kashmir University of Agricultural Sciences and Technology Kashmir. The experimental site is located at 34.1°N latitude, 74.89°E longitude and about 1650 m m.s.l and 14 kms away from main campus of the University at Shalimar, Srinagar.

Fifty clones available at Saffron Research Substation (Dossu) Konibal were selected for study. The clones were planted in a randomized block design with three replications with intra/interspacing of 10 and 20 cm respectively at Saffron Research Substation (Dossu) Konibal during September, 2010. Observations were recorded on 10 randomly selected and tagged competitive plants during 2010 for the characters, *viz, Floral attributes* : number of flowers per corm, fresh pistil weight per corm (mg), pistil length (cm), and stigma length (cm): *Corm attributes* : number of daughter corms/ mother corm, average weight of daughter corms per mother corm (g); and *Morpho-physiological* attributes : plant height (cm), number of radical leaves per plant, stomatal frequency, stomatal size (microns) and chlorophyll content (%).

RESULTS AND DISCUSSION

Table 1: Direct (diagonal) and Indirect (off-diagonal) effects of important traits on Number of daughter corms/mother corm in saffron (*Crocus sativus* L.)

Characters	Stomatal frequency	Av. weight of daughter corms /mother corm (g)	Size of stomata (microns)	Chlorophyll content (%)	Genotypic correlation coefficient with number of daughter corms/ mother corm
Stomatal frequency	**0.2286**	-0.0672	0.2247	0.0586	0.4446**
Average weight of daughter corms mother corm^{-1}(g)	0.1049	**-0.1464**	0.0582	-0.0103	0.0065
Size of stomata (microns)	0.1333	-0.0221	**0.3851**	0.0179	0.5142**
Chlorophyll content (%)	0.0562	0.0063	0.0289	**0.2382**	0.3296**

*, **, Significant at 5% and 1%, respectively; R Square =0.4685; Residual Effect=0.299

Table 2: Direct (diagonal) and Indirect (off-diagonal) effects of important traits on Fresh pistil weight (mg) in saffron (*Crocus sativus* L.)

Characters	Number of radical leaves plant^{-1}	Plant height (cm)	Number of flowers corm^{-}	Pistil length (cm)	Stigma length(cm)	Genotypic correlation coefficient with fresh pistil weight (mg)
Number of radical leaves plant $^{-1}$	**-0.2493**	0.0726	0.0343**	0.0277	0.0411	-0.0735
plant height (cm)	-0.0702	**0.2578**	0.0259	-0.0035	0.0101	0.2201*
Number of flowers corm^{-1}	-0.0863	0.0673	**0.0992**	0.0091	0.0237	0.1130
Pistil length (cm)	-0.0181	-0.0024	0.0024	**0.3805**	0.0443	0.4067**
Stigma length(cm)	-0.0685	0.0175	0.0157	0.1126	**0.1495**	0.2268*

***,**,** Significant at 5% and 1%, respectively; R Square=0.4685; Residual effect=0.2998

The present investigation was carried out to generate information on cause and effect relationship for 11 floral, corm and physio- morphological attributes. The results obtained through various biometrical/statistical procedures and the inferences drawn regarding various parameters are described in respect of cause and effect relationship.

Cause and effect relationship

If the cause and effect relation is well defined, it is possible to represent the whole system of variables in the form of a diagram as depicted in Figure1. Here direct and indirect effect of five different yield attributing traits towards fresh pistil weight were estimated through partitioning of their genotypic correlation coefficients using path coefficient analysis. At genotypic level, results are presented in Table 1 and depicted in Figure 1. Maximum positive direct effect of pistil length (0.3805) to fresh pistil weight was observed which contributed to the strong association. Plant height and stigma length also have positive direct effect on fresh pistil weight. The number of radical leaves/plant has a strong indirect negative effect on fresh pistil weight.

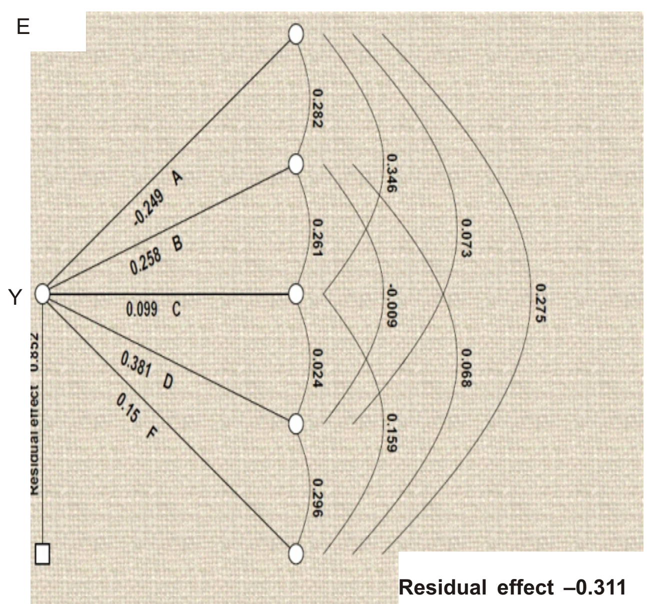

Fig.1 : An outline of path diagram depicting inference of various factors on fresh pistil weight.

Legend :

1. Number of radical leaves plant^{-1}
2. Plant height (cm)
3. Number of flowers corm^{-1}
4. Pistil length (cm)
5. Stigma length(cm)

Direct and indirect effect of four different corm attributing traits towards number of daughter corms/ mother corm were estimated through partitioning of their genotypic correlation coefficients using path coefficient analysis at genotypic level, results are presented in Table 2 and depicted in Figure 2. Maximum positive direct effect of stomata size (microns) (0.3821) to number of daughter corms/ mother corm was observed which contributed to the strong association. Chlorophyll content and stomatal frequency also have positive direct effect on number of daughter corms/ mother corm, respectively. The Average weight of daughter corms/ mother corm has a

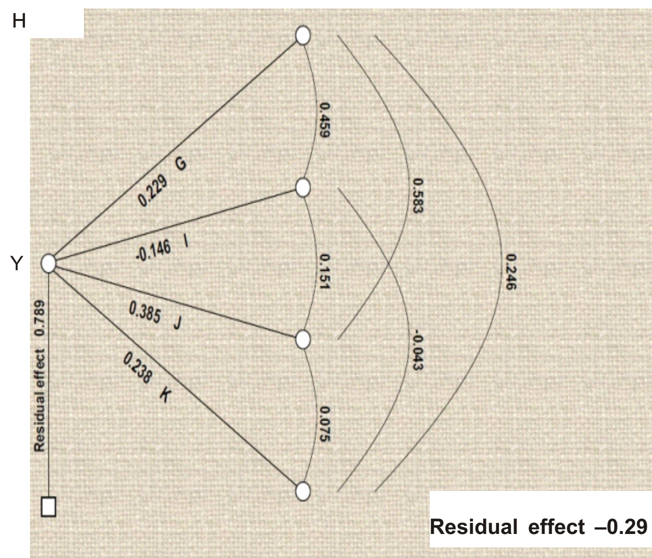

Fig.2 : An outline of path diagram depicting inference of various factors on number of daughter corms/mother corm.

Legend :

1. Stomatal frequency
2. Average weight of daughter corms mother corm^{-1} (g)
3. Size of stomata (microns)
4. Chlorophyll content (%)

Y- Number of daughter corms/ mother corm.

strong indirect negative effect on number of daughter corms/ mother corm.

From the above, it is evident that correlation between effect on one hand and the various characters (cause) on the other, have been partitioned into direct and indirect effect. As a guideline for interpretation of path analysis results, the following points need to be kept in mind.

1. If correlation coefficient between a causal factor and the effect is almost equal to its direct effect, then the correlation explain true relationship and a direct selection through the trait will be effective.
2. If correlation coefficient is positive, but the direct effect is negative or negligible, the indirect effect seem to be cause of correlation. Under such situations, the indirect cause factor are to be considered simultaneously.
3. Correlation coefficient may be negative, but the direct effect is positive and high. Under such circumstances, a restricted simultaneous selection model is to be followed. i,e. restrictions are to be imposed to nullify the undesirable indirect effects to make use of direct effect.

Path coefficient analysis in the first case (fresh pistil weight) revealed residual variance of 0.311,indicating thereby that 69% variance was accounted for by path analysis, where as in 22nd case (number of daughter corms/ mother corm) a residual variance of 0.29 indicating thereby, that 71% variance was accounted for by path analysis.

Based on the prior knowledge of casual relationship between independent and dependent variables a casual scheme was formulated. In one scheme number of radical leaves/plant, plant height, number of flowers/corm, pistil length and stigma length were taken as independent variables and their contribution towards fresh pistil weight per corm (dependent trait) was determined. Whereas, in another scheme stomatal frequency, average weight of daughter corms mother corm, size of stomata and chlorophyll content were taken as independent variables with number of daughter corms/mother corm as a dependent variable. The analysis revealed that pistil length recorded highest direct effect towards fresh pistil weight followed by plant height and stigma length. Rest of the traits as number of flowers recorded weak positive direct effects and the negative direct effect of number of radical leaves/plant on the dependent variable. The weak direct effect of number of flowers/corm was nullified on account of strong indirect effect via pistil length and stigma length. In the 2nd case size of stomata recorded highest direct effect towards number of daughter corms/mother corm followed by chlorophyll content and stomatal frequency. The average weight of daughter corms/mother corm indicates –ive direct effect on the number of daughter corms (dependant trait). The negative direct effect was nullified by the positive effect of morphological independent traits.

Degree of relationship through the estimation of correlation coefficient simply measures the nature of symmetrical association between various characters. It does not provide any valid information regarding the magnitude of direct contribution of a particular trait to the ultimate economic product. In order to determine efficient criteria for selection of various floral, morphological and corm attributes to improve yield, it is essential to have information regarding the direct and indirect contribution of these traits towards the yield through study of cause and effect relationship .In this context, an attempt was made to generate information on direct and indirect effect of various attributes on saffron yield and corm yield.

The estimates of residual variability measured in terms of residual effect indicated that most of the traits were considered in the evaluation of selective potential of present set of materials and explain the relationship of these traits with saffron yield and corm number. Path coefficient analysis in gladiolas by Sadhu *et al.* (12) revealed that flower size and duration of flowering recorded maximum direct effect on yield whereas Hedge *et al.* (7); Anuradha *et al.* (3) and Neraj *et al.* (10) recorded maximum positive direct effect by plant height in various crops.

CONCLUSION

Based on findings of present investigation possibility of saffron improvement is indicated through clonal selection from the available germplasm resources. Identification of five elite genotypes with distinct superiority in yield and corm attribute can act as a source for further improvement and development of high yielding varieties which can be beneficial for saffron industry in Jammu and Kashmir, particularly to the marginal and small farmers associated with saffron cultivation by increasing their net returns from saffron and encourage farmers from nontraditional areas to take up saffron cultivation. Development of varieties from the identified germplasm resources, exhibiting high yielding potential and quality will boost the production and productivity of saffron in Jammu and Kashmir State and improve the socio-economic well being of the people associated with this important commercial crop.

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