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Path coefficient and Exploratory Factor Analysis in Rose (*Rosa × hybrida* L.) Genotypes

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ABSTRACT: The present experiment was carried out to analyze the path coefficient and exploratory factors for vegetative and floral traits of ninety-six rose genotypes. The path coefficient analysis provided information about the direct and indirect effect of examined traits on flower weight per plant. Quantitative analysis was carried out for all the characters which are directly or indirectly associated with the yield and yield contributing traits. The highest direct positive effect on flower weight per plant was exhibited by the number of petals per flower followed by bud diameter, petal length, flower diameter, and neck length. The traits such as the number of buds per plant, prickle density, number of secondary branches, and number of primary branches had a direct negative effect on flower weight. Exploratory factor analysis revealed that the number of petals per flower, bud length, prickle density, stem girth, number of flowers per plant, petal length, and flower weight are major factors contributing to the genetic variation in different rose genotypes.

Keywords: Path analysis, Morphological traits, Exploratory factor analysis, Rose genotypes.

INTRODUCTION

The rose is a versatile flower crop that may be used as a cut flower, loose flower, and to make value-added and processed products including gulk and gulroghan, Pankhurst, potpourri, rose water, and essential oils for cosmetic and fragrance industries. It is grown all over the world for the production of numerous medicinal and nutritionally significant goods. Despite its widespread distribution worldwide, there has been not much investigation into its variety in India. Any plant breeding program's success depends on the germplasm's diversity. Because hybridization and allopolyploidization occur often in the genus *Rosa* (Zhang, 2003), understanding the genetic relationships between genotypes is essential. It is also required to efficiently use genetic variability to meet changing consumer and producer demands. A better understanding of the genetic relationship among diverse rose genotypes could be useful for rose breeders in near future. This information helps in giving proper weightage to various traits during selection or other breeding programs so that the improvement of desirable traits could be achieved effectively (Panwar *et al.*, 2012). Path analysis establishes the extent of association between yield and its components and also brings out the relative importance of their direct and indirect effects, thus giving an obvious understanding of their association with yield (Nikhil *et al.*, 2014). Selection of high-yielding varieties based only on the yield will not be much effective unless adequate information on genetic parameters is available to formulate a hybridization and selection program for further improvement because the estimate of the mean serves as a basis for eliminating the undesirable genotypes. Information on the association of characters, and direct and indirect effects contributed by each character towards yield will be an added advantage in aiding the selection process (Khadivi *et al.*, 2015). In order to separate the direct effects of one variable from the indirect effects of the other variables (while maintaining the other variables' constant values), correlation coefficients must first be partitioned according to their components. This provides a clear picture of the individual contributions made by each variable to the yield (Marinković, 1992). There is less information on direct and indirect path coefficients (genotypic and phenotypic) in rose genotypes. Path coefficients have been used to develop selection criteria for various traits in several flowering species of economic importance (Miano *et al*., 2015). Therefore, the objective of the current experiment was to learn more about the direct and indirect effects of morphological traits on flower weight per plant and also to learn about the major traits which contribute towards the genetic variation using exploratory factor analysis.

MATERIALS AND METHODS

Plant materials. The plant material utilized for conducting the experiment consisted of 96 genotypes of rose (Table 1). Germplasm maintained at the research farm of the division of Floriculture and Landscaping, ICAR-Indian Agricultural Research Institute was utilized in the study. The genotypes were planted in a randomized block design (RBD) with three replications. Recommended cultural practices were carried out in the experimental plots.

Morphological observations. Rose genotypes were characterized for 17 different morphological (Vegetative and floral)characteristics such as the number of petals per flower, number of flowers per plant, neck length (cm), number of buds per plant, stalk length (cm), bud length (cm), bud diameter (mm), intermodal length (cm), prickle density, stem girth (mm), flower diameter (cm), number of primary branches, number of secondary branches, petal length (cm), petal width (cm), flower weight (g), plant height (cm).

Statistical analysis. ANOVA for all the characters was done using SAS Software. Version 9.4. The path-coefficient analysis, a technique developed by Wright and implemented by Dewey and Lu (1959), was used to evaluate the direct and indirect effects of the growth and flower weight. Exploratory factor Analysis was done utilizing the "psych" package of R software.

Table 1: Rose genotypes representing hybrid tea and floribunda groups.

Rose types	Genotypes
Hybrid Tea (Class-I)	Pusa Sonora, Raktagandha, Pusa Mohit, Pusa Ajay, Dr. Bharat Ram, Raja Ram Mohan Roy, Mridula, Nehru Centenary, Surabhi, Dr. B.P. Pal, Priyadarshini, Soma, Sugandha, Dr. Benjamin Pal, Anurag, Ranjana, Pusa Priya, Pink Montezuma, Jawani, Haseena, Homage, Lalima, Raja Surendra Singh of Nalagarh, Raktima, Homage, Haseena, Jawani, Pink Montezuma,Sailoz Mukherjee, Mrinalini, Pusa Arun, Dr.M.S. Randhawa, Pusa Garima, Sahasradhara, Abhisarika, Madhosh,Preyasi, Bhim,Tajmahal, Jawahar, Aruna, Dulhan, Pusa Gaurav, Pusa Bahadur, Jogn, Arjun, Sylvia, Strong Prag, Melody Perfume, French Perfume, Midas Touch, Marcopolo
Floribunda (Class-II)	Pusa Virangana, Delhi Brightness, Pusa Muskan, Shabnam, Chingari, Lahar, Rose Sherbat, Sadabahar, PusaBaramasi, Pusa Abhishek, Surdas, Mansi, Madhura, Dr. S.S. Bhatnagar, Deepak, Anita, Suryakiran, PusaManhar, Pusa Shatabdi, Delhi Princess, Prema, Neelambri, Shola, Punchu, Jantar Mantar, Iceberg, Pusa Pitamber, Pusa Urmil, Oholala, Jiji, Loree, Pusa Komal, Arunima, Suchitra, Pusa Aradhana, Krishna, Charliston,Calcutta-300

RESULT AND DISCUSSION

An important method for dividing the correlation coefficients into the direct and indirect impacts of independent factors on a dependent variable is path coefficient analysis. The indirect relationship between the variables in correlation research gets increasingly complicated as additional factors are added. Simply because two characters are connected with a common third one, two characters may exhibit correlation. In such cases, Path coefficient analysis offers a useful method for a rigorous investigation of the actions of particular forces to form a given correlation and assess the relative weight of each factor. It must be performed in order to clearly illustrate the selection criterion. All of the data for the traits were averaged, and the flower weight was chosen as the dependent variable while the other traits were chosen as independent variables. The data indicated (Table 2) that the highest positive direct effect at the phenotypic level was *via* the number of petals per flower (0.3535) followed by bud diameter (0.23), petal length (0.20), flower diameter (0.17), and neck length (0.10), respectively. Thus, these traits turned out to be the major components of flower weight. It also revealed that there was a true relationship between these characters and flower weight and hence, the direct selection of these traits could be highly rewarding in crop improvement programs of rose genotypes. Similar observations were also reported in anthurium by Binodh *et al.* (2004); Shiva and Nair (2008). Whereas the highest negative direct effect was shown by the number of buds per plant (-0.1696) followed by prickle density (-0.0912), the number of secondary branches (-0.0729), and the number of primary branches (-0.0595). The maximum positive direct effect at the genotypic level (Table 3) is exhibited *via* the number of petals per flower (0.3611) followed by petal length (0.2413), bud diameter (0.2238), and flower diameter (0.1611), respectively. Whereas the highest negative direct effect of the number of primary branches (-0.1778) followed by prickle density (-0.0945), the number of primary branches (-0.0641), and the number of secondary branches (-0.0679). These outcomes are in line with those from studies on roses (Panwar *et al.*, 2012), marigold (Reena *et al.*, 2005; Namita *et al*., 2009; Panwar *et al.*, 2014), dahlia (Chowdhary, 1989); gladiolus (Deshraj *et al.*, 1997). The residual effect of phenotypic and genetic path analysis was 0.418 and 0.408, indicating that the characters considered for path analysis were appropriate. These findings are in line with those of Singh and Singh (2005) studies on marigold. The results corroborated the findings of Singh (2010); Kumar *et al.* (2010); Kumar *et al.* (2015); Lal *et al.* (2018) in garden peas.

Bartlett's test of sphericity was done to test the interdependencies among the traits. Bartlett's test of sphericity uncovered the significant interdependencies among the traits. However, from the KMO test, it was found that many characters have a KMO of less than 0.5, and overall KMO was less than 0.5. Hence, the characters which are having KMO less than 0.5 are removed.

Table 2: Phenotypic path coefficient analysis of different quantitative traits on flower weight (FW).

Chs	NL	SL	IL	PD	SG	NPB	NSB	PH	NPF	NFP	NBP	BL	BD	FD	PL	PW	R with flower weight (FW)
NL	**0.0929**	0.0084	0.0053	-0.0125	0.0029	0.0025	0.0044	0.0082	0.0413	-0.0032	0.0082	0.0166	0.1009	0.0616	0.1460	-0.0011	0.482**
SL	0.0091	**0.0859**	-0.0014	-0.0011	0.0030	-0.0380	-0.0105	0.0284	0.0491	-0.0005	0.0029	0.0226	0.0910	0.0494	0.0690	-0.0015	0.357**
IL	0.0314	-0.0075	**0.0158**	-0.0079	0.0002	0.0070	-0.0042	0.0033	0.0090	-0.0013	-0.0059	0.0106	0.0395	0.0186	0.0453	-0.0006	0.153**
PD	0.0122	0.0010	0.0013	**-0.0945**	0.0019	0.0036	-0.0036	0.0057	0.0251	0.0053	-0.0323	0.0039	0.0397	0.0248	0.0440	-0.0003	0.038
SG	0.0224	0.0210	0.0003	-0.0152	**0.0121**	-0.0123	-0.0119	0.0236	0.0210	0.0183	-0.0549	0.0093	0.0463	0.0455	0.0952	-0.0012	0.219**
NPB	-0.0036	0.0510	-0.0017	0.0053	0.0023	**-0.0641**	-0.0290	0.0229	0.0458	0.0104	-0.0208	0.0109	0.0539	0.0277	0.0309	-0.0011	0.141*
NSB	-0.0060	0.0132	0.0010	-0.0050	0.0021	-0.0274	**-0.0679**	0.0103	0.0412	0.0201	-0.0550	-0.0040	0.0245	-0.0061	-0.0050	0.0000	-0.064
PH	0.0180	0.0576	0.0012	-0.0128	0.0067	-0.0347	-0.0165	**0.0423**	0.0768	0.0142	-0.0320	0.0188	0.1012	0.0727	0.1109	-0.0018	0.423**
NPF	0.0106	0.0117	0.0004	-0.0066	0.0007	-0.0081	-0.0077	0.0090	**0.3611**	0.0017	-0.0200	-0.0086	0.0332	-0.0073	0.0044	0.0007	0.375**
NFP	-0.0057	-0.0008	-0.0004	-0.0095	0.0042	-0.0128	-0.0261	0.0115	0.0114	**0.0524**	-0.1007	-0.0004	-0.0155	-0.0176	-0.0044	0.0006	-0.114
NBP	-0.0043	-0.0014	0.0005	-0.0172	0.0037	-0.0075	-0.0210	0.0076	0.0406	0.0297	**-0.1778**	0.0020	0.0137	-0.0045	0.0279	-0.0005	-0.109
BL	0.0263	0.0330	0.0028	-0.0062	0.0019	-0.0119	0.0047	0.0135	-0.0530	-0.0003	-0.0061	**0.0588**	0.0706	0.0649	0.1141	-0.0017	0.311**
BD	0.0419	0.0349	0.0028	-0.0168	0.0025	-0.0154	-0.0074	0.0191	0.0535	-0.0036	-0.0109	0.0185	**0.2238**	0.0699	0.1267	-0.0016	0.538**
FD	0.0355	0.0264	0.0018	-0.0146	0.0034	-0.0110	0.0026	0.0191	-0.0163	-0.0057	0.0050	0.0237	0.0971	**0.1611**	0.1689	-0.0030	0.494**
PL	0.0562	0.0246	0.0030	-0.0172	0.0048	-0.0082	0.0014	0.0194	0.0065	-0.0010	-0.0205	0.0278	0.1175	0.1128	**0.2413**	-0.0035	0.565**
PW	0.0158	0.0197	0.0014	-0.0047	0.0023	-0.0108	-0.0001	0.0116	-0.0368	-0.0045	-0.0133	0.0150	0.0539	0.0743	0.1311	**-0.0065**	0.248**

Table 3: Genotypic path coefficient analysis of different quantitative traits on flower weight (FW).

Chs	NL	SL	IL	PD	SG	NPB	NSB	PH	NPF	NFP	NBP	BL	BD	FD	PL	PW	R with flower weight (FW)
NL	**0.1069**	0.0080	0.0054	-0.0118	0.0038	0.0021	0.0043	0.0087	0.0402	-0.0030	0.0078	0.0161	0.1023	0.0666	0.1184	0.0001	0.476**
SL	0.0102	**0.0840**	-0.0014	-0.0011	0.0039	-0.0339	-0.0110	0.0300	0.0472	-0.0004	0.0028	0.0221	0.0931	0.0538	0.0564	0.0002	0.356**
IL	0.0354	-0.0071	**0.0162**	-0.0075	0.0003	0.0063	-0.0042	0.0033	0.0077	-0.0011	-0.0055	0.0102	0.0404	0.0202	0.0367	0.0001	0.151*
PD	0.0138	0.0010	0.0013	**-0.0912**	0.0026	0.0030	-0.0037	0.0059	0.0235	0.0049	-0.0303	0.0036	0.0404	0.0269	0.0355	0.0000	0.037
SG	0.0253	0.0204	0.0003	-0.0146	**0.0161**	-0.0111	-0.0125	0.0249	0.0201	0.0169	-0.0517	0.0092	0.0474	0.0494	0.0778	0.0001	0.218**
NP B	-0.0037	0.0479	-0.0017	0.0046	0.0030	**-0.0595**	-0.0299	0.0232	0.0421	0.0095	-0.0194	0.0099	0.0534	0.0293	0.0256	0.0001	0.134*
NSB	-0.0063	0.0127	0.0009	-0.0046	0.0028	-0.0244	**-0.0729**	0.0108	0.0397	0.0184	-0.0519	-0.0038	0.0251	-0.0063	-0.0037	0.0000	-0.064
PH	0.0204	0.0554	0.0012	-0.0119	0.0088	-0.0304	-0.0172	**0.0455**	0.0742	0.0130	-0.0300	0.0183	0.1023	0.0782	0.0884	0.0002	0.416**
NPF	0.0122	0.0112	0.0004	-0.0061	0.0009	-0.0071	-0.0082	0.0096	**0.3535**	0.0013	-0.0189	-0.0081	0.0336	-0.0078	0.0035	-0.0001	0.370**
NFP	-0.0064	-0.0007	-0.0004	-0.0092	0.0055	-0.0115	-0.0274	0.0120	0.0091	**0.0491**	-0.0942	-0.0003	-0.0158	-0.0190	-0.0032	-0.0001	-0.112
NBP	-0.0050	-0.0014	0.0005	-0.0163	0.0049	-0.0068	-0.0223	0.0081	0.0393	0.0272	**-0.1696**	0.0021	0.0139	-0.0048	0.0218	0.0001	-0.108
BL	0.0295	0.0318	0.0028	-0.0056	0.0025	-0.0101	0.0048	0.0142	-0.0494	-0.0002	-0.0061	**0.0583**	0.0716	0.0700	0.0925	0.0002	0.307**
BD	0.0475	0.0340	0.0028	-0.0160	0.0033	-0.0138	-0.0079	0.0202	0.0516	-0.0034	-0.0102	0.0182	**0.2300**	0.0762	0.1036	0.0002	0.536**
FD	0.0404	0.0257	0.0019	-0.0139	0.0045	-0.0099	0.0026	0.0202	-0.0157	-0.0053	0.0047	0.0232	0.0995	**0.1761**	0.1379	0.0003	0.492**
PL	0.0621	0.0233	0.0029	-0.0159	0.0061	-0.0075	0.0013	0.0198	0.0061	-0.0008	-0.0182	0.0265	0.1170	0.1193	**0.2036**	0.0004	0.546**
PW	0.0181	0.0190	0.0015	-0.0045	0.0030	-0.0097	0.0000	0.0123	-0.0351	-0.0040	-0.0128	0.0146	0.0548	0.0804	0.1071	**0.0007**	0.245**

The characters which retained are the number of petals per flower, number of flowers per plant, bud length, prickle density, stem girth, petal length, flower weight, and plant height. Now considering the retained characters bartlett's test of sphericity was done which was found significant. KMO test was also significant as all the characters, as well as overall KMO, was more than 0.5. From the parallel analysis plot (Fig. 1), it can be inferred from the parallel analysis that the optimum number of factors contributing to variation is two. Firstly, factor loadings were computed without rotation but the problem of cross-loadings was observed. Hence, finally, factor loadings were computed employing Varimax rotation (Table 4). Pattanayak *et al.* (2019) also used varimax rotation to study the contribution of different factors to genetic variation in rice bean genotypes. From the factor analysis, it can be inferred that factor one consists of five characters such as the number of petals per flower, bud length, prickle density, stem girth, and plant height, and factor two consists of three characters such as the number of flowers per plant, petal length, and single flower weight. The results of factor analysis have been graphically displayed in the biplot (Fig. 2).

Table 4: Varimax Rotation for various vegetative and floral traits of rose genotypes.

Characters	Factor 1	Factor 2	Communality	Specificity	Complexity parameter
No. of petals per flower	**0.25**	0.04	0.06	0.94	1.0
No. of flowers per plant	0.15	**0.32**	0.12	0.88	1.4
Bud length	**0.93**	0.17	0.89	0.11	1.1
Prickle density	**0.96**	0.17	0.94	0.05	1.1
Stem girth	0.37	0.18	0.17	0.83	1.5
Petal length	0.21	**0.98**	0.99	0.01	1.1
Flower weight	0.13	**0.94**	0.90	0.09	1.0
Plant height	**0.61**	0.35	0.49	0.50	1.6

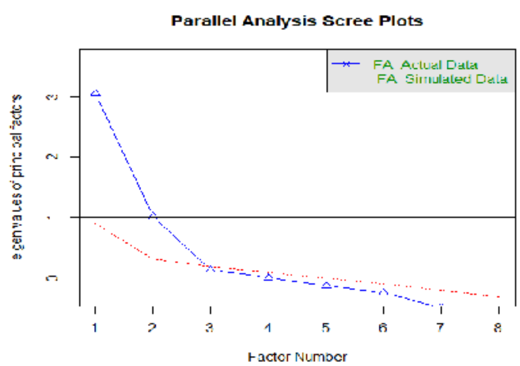

Fig. 1.

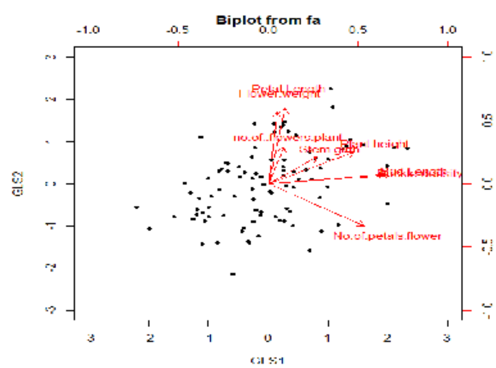

Fig. 2.

CONCLUSION

For a better understanding of the crop improvement, the path co-efficient analysis and exploratory factor estimate are crucial. It provides precise measurements of each component character's direct and indirect effects on flower weight. The conclusion that can be drawn from path coefficient analysis and factor analysis is that the number of petals per flower is the most significant trait for flower weight, followed by bud diameter, petals length, flower diameter, and neck length. Therefore, these traits should be taken into consideration as selection criteria for flower weight, helping to improve yield in rose genotypes.

FUTURE SCOPE

The relationship between different vegetative and floral traits has been considered a useful characteristic to distinguish variance among different rose genotypes. The genotypes used in this study showed a large amount of phenotypic diversity, these genotypes could be used in future rose breeding programs or they can be utilized for molecular breeding programme. With the aid of path coefficient analysis, numerous attributes can be properly weighed during selection or other breeding programs, resulting in the successful improvement of desired traits.

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Conflict of Interest: None.

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