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Path coefficient studies in marigold (*Tagetes* spp.)

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Abstract

Path analysis studies were carried out among twelve genotypes of marigold for twenty quality and yield attributing traits contributing towards total flower yield. The present study was conducted at Botanical Garden. Bihar Agricultural University, Sabour, Bhagalpur, Bihar, India during winter season, 2021-22. The experiment was laid out in Randomized Block Design with three replications. The results revealed that path coefficient result revealed that characters like number of flowers per plant (0.716, 0.715), number of leaves per plant (0.856, 0.858) and average fresh weight of flower (0.708, 0.708) showed direct positive effect towards flower yield per plant at both phenotypic and genotypic level, respectively through which the selection of superior marigold genotypes may be obtained.

Keywords: Marigold, correlation, path coefficient, germplasm, quality

Introduction

Marigold is a top-ranking loose flower in India followed by chrysanthemum, jasmine, tuberose, and crossandra. Marigold (*Tagetes* spp.) is one of the most important species grown commercially for loose flowers in different parts of India, especially in the tropical and sub-tropical regions. It symbolizes prosperity and is related to the renowned, strong and brave lion. It belongs to family Asteraceae and is originated from central and southern America specially Mexico. Its basic chromosome number is 12 and has diverse growth habit, size, floral colour along with types and utility. Besides commonly used as bedding and loose flowers, it is used for adding food flavour and as pharmaceutical, nutraceutical, industrial, pesticide and organic manure with a lot of opportunities in value added products. Marigold is the state flower of Bihar which covers an area of 1160 hectare with production of 10,600 MT of loose flower in 2019.

Growth, flowering and seed production of marigold is highly influenced by light and temperature. Among the existing 55 species of marigold, the main group of marigold is African marigold *(Tagetus erecta* L.) and French marigold (*Tagetus patula* L.). Since the performance of genotypes varies with region, season and growing conditions, hence selection is an important method for identifying marigold genotypes with desirable horticultural traits for specific purposes. Thus, the present study was taken to identify best genotypes in Bihar in terms of commercial cultivation. Many cultivars have been developed from local material collected from different parts of the country. Despite of varietal development, there is need to develop genotypes with stable and better yield, quality and their adaptation under different environment. A variety may perform well only in a particular environment and therefore the genetic potentiality of different genotypes and their interaction with environmental condition is to be established and according to their performance, selection of best growth and flowering traits genotype needs to be done. The wide range of groups and varieties of this flower made the workers research more complex. Its flower yield is a complex character and is the result of interrelationship of various components.

The climatic condition of north India is highly variable and being a photosensitive crop, light and temperature has an influential role on marigold vegetative growth and flowering. Hence, genotype performance varies with location and growing conditions. Thus, it is necessary to develop varieties adapted to specific climatic conditions, which can be used for further genetic improvement of marigold. Selection as an important method of breeding is opted for identifying marigold genotypes with desirable horticultural traits for specific purposes and maximizing production. Flower crop performance largely depends on Genotypic x Environment interaction which leads to varied performance of same genotype differently under varied environmental conditions. Correlation and path coefficient analysis furnishes information regarding the nature and magnitude of various associations and help in the measurement of direct influence of one variable on others. The type of association between flower yield and yield attributes to judge the direct and indirect influences of flower yield components through path coefficient analysis for selecting suitable genotypes for improving flower yield.

Materials and Methods

The present study was conducted at Botanical Garden. Bihar Agricultural University, Sabour, Bhagalpur, Bihar, India during winter season, 2021-22. The experiment was laid out in Randomized Block Design with three replications. Nursery preparation work was started on 14th October by mixing well rotten FYM at 10 kg/m^2. Raised beds of 15 cm were prepared with plot size 4 m × 4 m. The nursery was prepared on 16th October and approximately 5 g seeds of each germplasm were sown evenly for raising seedlings. Land was brought to a good tilth by 4-5 ploughings and levelled properly followed by incorporation of 30 kg farm yard manure per m^2. Farm yard manure was uniformly sprinkled and mixed thoroughly. Nitrogen @100kg/ ha, phosphorous @100kg/ha and potassium @100kg/ha were incorporated in the soil as basal dose in form of urea, single super phosphate and muriate of potash, respectively. Nitrogen at 200 kg/ ha was applied in two split doses at 30 and 60 days after transplanting. Plants were transplanted at four lesf stage at 50 × 50 cm spacing. The data on plant height (cm), stem diameter (cm), plant spread (cm), number of primary branches per plant, number of leaves per plant, leaf biomass (g), days taken to first flower opening, average fresh weight of flower (g), flower duration (days), flower diameter (cm), number of flowers per plant and flower yield per plant (g) were recorded. Correlation coefficient and path analysis were computed by the formula suggested by Al-Jibouri *et al*., 1958, Dewey and Lu, 1959, Lush, 1940 and Lenka and Mishra, 1973. Path coefficient analysis helps in understanding the cause of association between two variables. It determines the direct effect of various characters on flower yield per plant and also indirect effect via other trait component and facilitates the selection of superior genotypes.

Results and Discussion

As per genotypic path coefficient analysis number of leaves per plant (0.856), number of flowers per plant (0.716) and average fresh weight of flower (0.708) had high direct positive effect towards number of flower yield per plant, whereas average fresh weight of leaf (0.248) and weight of seeds per peduncle (0.258) had moderate direct positive effect on flower yield per plant, while plant height (0.061), plant spread (0.015), stem diameter (0.079), flower peduncle length (0.068), days taken to seed ripening (0.081) had negligible direct positive effect on flower yield per plant, whereas high direct negative effect was reported by leaf biomass (-0.979), whereas low direct negative effect via flower duration (-0.153), flower diameter (-0.169), 100 seed weight (-0.128) and seed yield per plant (-0.137) was recorded on flower yield per plant. Negligible direct negative effect via number of secondary branches per plant (-0.098), days taken to first bud initiation (-0.080), days taken to first flower opening (-0.019), and number of seeds per peduncle (-0.020) was observed on flower yield per plant. This might be due to the more regional adaptability and genetical growth habit of the genotypes resulting in higher proportion of morphological growth in terms of vigour and reproductive growth leading to increased flower yield. Similar results were found in chrysanthemum by Poulose *et al.* (2021), Srinivasan *et al.* (2018), Patel *et al.* (2018), Kumar *et al.* (2018), Giri *et al.* (2018), Sahu *et al.* (2018), Choudhary *et al.* (2015), Panwar *et al.*(2014), Karuppaiah and Kumar (2010), Singh and Singh (2009)) and Karuppaiah *et al.* (2004) in marigold.

Number of leaves per plant recorded high indirect positive effect on flower yield per plant via number of flowers per plant (0.679), whereas negligible indirect positive effect was analysed via plant height (0.008), plant spread (0.009), average fresh weight of leaf (0.036), stem diameter (0.009), days taken to flowering (0.001), average fresh weight of flower (0.034), days taken to seed ripening (0.008), number of seed per peduncle (0.001) and 100 seed weight (0.016), seed yield per plant (0.010), whereas high indirect negative effect via leaf biomass (-0.909) and negligible indirect negative effect via number of primary branches per plant (-0.030), number of secondary branches per plant (-0.069), days taken to first bud appearance (-0.004), flower duration (-0.007), flower diameter (-0.002), flower peduncle length (-0.011) and weight of seed per peduncle (-0.019) was analysed.

Number of primary branches per plant observed high indirect positive effect on flower yield per plant via number of leaves per plant (0.652), number of flower per plant (0.453) and negligible indirect positive effect via plant height (0.015), plant spread (0.008), average fresh weight of leaf (0.031), stem diameter (0.003), average fresh weight of flower (0.041), flower peduncle length (0.002), days taken to seed ripening (0.047) weight of seed per peduncle (0.012), 100 seed weight (0.006) was observed on flower yield per plant, whereas high indirect negative effect was seen via leaf biomass (-0.663), negligible indirect negative effect via number of secondary branches per plant (-0.040), days taken to bud initiation (-0.030), days taken to flowering (-0.005), flow-

Table 1. Path using genotypic path coefficient

	PH	L/P	PB	SB	PS	FFL	SD	LB	DBI	FD	FDU	FDI	F/P	FWF	PL	DSR	S/P	W/P	100Sw	SY/P	r
PH	0.061	0.110	-0.010	-0.039	0.011	0.136	0.035	-0.274	-0.046	-0.013	-0.070	-0.118	-0.032	-0.001	0.040	0.038	-0.017	0.226	0.020	-0.123	-0.065
L/P	0.008	0.856	-0.030	-0.069	0.009	0.036	0.009	-0.909	-0.004	0.001	-0.007	-0.002	0.679	0.034	-0.011	0.008	0.001	-0.019	0.016	0.010	0.616**
PB	0.015	0.652	-0.040	-0.040	0.008	0.031	0.003	-0.663	-0.030	-0.005	-0.003	-0.009	0.453	0.041	0.002	0.047	-0.003	0.012	0.006	-0.014	0.463**
SB	0.024	0.607	-0.016	-0.098	0.011	0.086	0.026	-0.741	0.009	0.004	-0.017	0.005	0.396	-0.067	-0.008	-0.013	-0.002	0.073	-0.002	-0.025	0.249
PS	0.046	0.534	-0.022	-0.072	0.015	0.128	0.025	-0.690	-0.037	-0.006	-0.005	-0.069	0.291	-0.020	0.015	0.022	-0.010	0.119	0.033	-0.068	0.227
FFL	0.033	0.124	-0.005	-0.034	0.008	0.248	0.017	-0.478	-0.041	-0.008	0.014	-0.058	0.022	-0.197	0.036	0.033	-0.010	0.064	0.050	-0.037	-0.221
SD	0.027	0.096	-0.001	-0.032	0.005	0.054	0.079	-0.118	0.004	-0.002	-0.086	-0.085	-0.007	0.369	0.044	0.000	-0.007	0.142	-0.031	-0.059	0.391*
LB	0.017	0.795	-0.027	-0.074	0.010	0.121	0.010	-0.979	-0.016	-0.001	0.001	-0.014	0.616	-0.079	0.000	0.016	-0.002	-0.004	0.036	-0.001	0.424**
DBI	0.035	0.039	-0.015	0.011	0.007	0.129	-0.004	-0.196	-0.080	-0.017	0.019	-0.089	-0.005	0.024	0.037	0.061	-0.012	0.071	0.044	-0.055	0.005
DF	0.041	-0.049	-0.011	0.018	0.004	0.099	0.008	-0.072	-0.069	-0.019	-0.048	-0.104	-0.053	0.096	0.045	0.067	-0.015	0.132	0.030	-0.087	0.015
FDU	0.028	0.038	-0.001	-0.011	0.000	-0.023	0.044	0.004	0.010	-0.006	-0.153	-0.085	0.058	0.110	0.033	0.011	-0.009	0.172	-0.019	-0.089	0.112
FDI	0.043	0.009	-0.002	0.003	0.006	0.086	0.040	-0.083	-0.042	-0.012	-0.077	-0.169	-0.011	0.106	0.050	0.026	-0.015	0.169	0.027	-0.100	0.053
F/P	-0.003	0.812	-0.025	-0.054	0.006	0.008	-0.001	-0.843	0.001	0.001	-0.012	0.003	0.716	0.018	-0.014	0.001	0.003	-0.054	0.018	0.028	0.608**
FWF	0.000	0.042	-0.002	0.009	0.000	-0.069	0.041	0.110	-0.003	-0.003	-0.024	-0.025	0.019	0.708	0.013	0.001	0.003	0.051	-0.077	0.008	0.801**
PL	0.036	-0.143	-0.001	0.012	0.003	0.130	0.052	-0.001	-0.043	-0.013	-0.073	-0.125	-0.144	0.133	0.068	0.042	-0.015	0.131	0.026	-0.080	-0.004
DSR	0.029	0.084	-0.023	0.016	0.004	0.101	0.000	-0.199	-0.060	-0.016	-0.022	-0.054	0.009	0.007	0.036	0.081	-0.011	0.064	0.035	-0.058	0.022
S/P	0.054	-0.035	-0.006	-0.011	0.008	0.125	0.028	-0.120	-0.051	-0.015	-0.073	-0.132	-0.105	-0.122	0.050	0.047	-0.020	0.179	0.059	-0.125	-0.264
W/P	0.054	-0.063	-0.002	-0.028	0.007	0.061	0.044	0.014	-0.022	-0.010	-0.102	-0.111	-0.151	0.139	0.034	0.020	-0.014	0.258	-0.032	-0.119	-0.023
100Sw	-0.009	-0.104	0.002	-0.001	-0.004	-0.096	0.019	0.275	0.027	0.005	-0.023	0.035	-0.098	0.425	-0.013	-0.022	0.009	0.065	-0.128	0.027	0.388*
SY/P	0.055	-0.064	-0.004	-0.018	0.007	0.068	0.034	-0.004	-0.032	-0.012	-0.099	-0.123	-0.148	-0.043	0.040	0.034	-0.018	0.225	0.025	-0.137	-0.215

ering duration (-0.003), flower diameter (-0.009), number of seeds per peduncle (-0.003) and seed yield per plant (-0.014) was displayed.

Days taken to seed ripening was recorded with low indirect positive effect towards flower yield per plant via average fresh weight of leaves (0.101), and negligible indirect positive effect via plant height (0.029), number of leaves per plant (0.084), number of secondary branches per plant (0.016), plant spread (0.004), stem diameter (0.000), number of flower per plant (0.009), average fresh weight of flower (0.007), flower peduncle length (0.036), weight of seed per peduncle (0.064), 100 seed weight (0.035) low indirect negative effect via leaf biomass (-0.199) and negligible indirect negative effect via number of primary branches per plant (-0.023), days taken to first bud appearance (-0.060), days taken to first flower opening (-0.016), flowering duration (-0.022), flower diameter (-0.054), number of seed per peduncle (-0.011) and seed yield per plant (-0.058) was also tabulated in Table 1.

Seed yield per plant was recorded with medium indirect positive effect towards flower yield per plant via weight of seeds per peduncle (0.225) and negligible indirect positive effect via plant height (0.055), plant spread (0.007), average fresh weight of leaf (0.068), stem diameter (0.034), flower peduncle length (0.040), days taken to seed ripening (0.034), 100 seed weight (0.025). Low indirect negative effect via flower diameter (-0.123), number of flower per plant (-0.148) and negligible indirect negative effect via number of leaves per plant (-0.064),number of secondary branches per plant (-0.018),leaf biomass (-0.004), days taken to first flower opening (-0.032), days taken to first flower opening (-0.012), flowering duration (-0.099), average fresh weight of flower (-0.043) and number of seeds per peduncle (-0.018) was also recorded. These indirect traits had a good relationship with dependent variable (flower yield per plant) and revealed that if direct selection for these traits is done, then it would be highly beneficial and rewarding for flower yield improvement. The results suggested that selection of traits that are indirectly associated with flower yield per plant, the correlation is mainly due to

Table 2. Path using phenotypic path coefficient

	PH	L/P	PB	SB	PS	FFL	SD	LB	DBI	FD	FDU	FDI	F/P	FWF	PL	DSR	S/P	W/P	100Sw	SY/P	r
PH	0.062	0.110	-0.010	-0.038	0.010	0.134	0.034	-0.270	-0.045	-0.013	-0.069	-0.117	-0.031	-0.001	0.040	0.037	-0.016	0.222	0.019	-0.120	-0.061
L/P	0.008	0.858	-0.031	-0.069	0.009	0.036	0.009	-0.910	-0.004	0.001	-0.007	-0.002	0.669	0.032	-0.011	0.007	0.001	-0.019	0.016	0.010	0.603**
PB	0.016	0.645	-0.041	-0.039	0.008	0.031	0.003	-0.655	-0.029	-0.005	-0.003	-0.009	0.447	0.039	0.002	0.045	-0.003	0.011	0.006	-0.014	0.455**
SB	0.024	0.598	-0.016	-0.099	0.010	0.083	0.024	-0.728	0.009	0.003	-0.016	0.005	0.385	-0.067	-0.008	-0.013	-0.002	0.071	-0.002	-0.025	0.238
PS	0.046	0.529	-0.023	-0.071	0.014	0.127	0.024	-0.683	-0.036	-0.006	-0.005	-0.069	0.288	-0.021	0.015	0.021	-0.010	0.118	0.033	-0.067	0.224
FFL	0.034	0.124	-0.005	-0.033	0.007	0.248	0.016	-0.476	-0.041	-0.007	0.014	-0.058	0.023	-0.197	0.035	0.032	-0.009	0.064	0.050	-0.037	-0.219
SD	0.027	0.096	-0.002	-0.032	0.004	0.054	0.076	-0.118	0.004	-0.002	-0.085	-0.084	-0.006	0.367	0.043	0.000	-0.007	0.142	-0.031	-0.059	0.390*
LB	0.017	0.797	-0.027	-0.073	0.010	0.120	0.009	-0.980	-0.016	-0.001	0.000	-0.015	0.608	-0.080	0.000	0.016	-0.002	-0.004	0.036	0.000	0.414*
DBI	0.036	0.038	-0.015	0.011	0.006	0.128	-0.003	-0.193	-0.079	-0.016	0.018	-0.087	-0.007	0.023	0.037	0.060	-0.012	0.071	0.043	-0.054	0.005
DF	0.041	-0.049	-0.011	0.017	0.004	0.098	0.008	-0.070	-0.068	-0.019	-0.047	-0.103	-0.054	0.094	0.044	0.065	-0.014	0.131	0.030	-0.086	0.013
FDU	0.028	0.039	-0.001	-0.011	0.000	-0.022	0.042	0.002	0.010	-0.006	-0.154	-0.083	0.056	0.108	0.032	0.011	-0.009	0.170	-0.019	-0.088	0.106
FDI	0.043	0.012	-0.002	0.003	0.006	0.086	0.038	-0.087	-0.041	-0.011	-0.076	-0.168	-0.012	0.104	0.049	0.025	-0.014	0.167	0.027	-0.098	0.048
F/P	-0.003	0.803	-0.025	-0.053	0.006	0.008	-0.001	-0.834	0.001	0.001	-0.012	0.003	0.715	0.019	-0.013	0.001	0.003	-0.054	0.017	0.028	0.609**
FWF	0.000	0.039	-0.002	0.009	0.000	-0.069	0.040	0.111	-0.003	-0.002	-0.023	-0.025	0.019	0.708	0.012	0.001	0.003	0.050	-0.077	0.008	0.799**
PL	0.037	-0.140	-0.001	0.012	0.003	0.128	0.049	-0.002	-0.043	-0.012	-0.072	-0.123	-0.143	0.130	0.067	0.041	-0.014	0.128	0.025	-0.079	-0.008
DSR	0.029	0.081	-0.023	0.016	0.004	0.100	0.000	-0.193	-0.060	-0.016	-0.022	-0.053	0.007	0.007	0.035	0.079	-0.011	0.063	0.035	-0.057	0.021
S/P	0.054	-0.036	-0.006	-0.011	0.007	0.124	0.027	-0.118	-0.050	-0.014	-0.073	-0.130	-0.102	-0.123	0.049	0.046	-0.019	0.179	0.059	-0.125	-0.261
W/P	0.054	-0.063	-0.002	-0.027	0.006	0.061	0.042	0.014	-0.022	-0.010	-0.101	-0.109	-0.149	0.138	0.033	0.019	-0.013	0.258	-0.032	-0.119	-0.022
100Sw	-0.009	-0.104	0.002	-0.001	-0.004	-0.096	0.018	0.273	0.027	0.004	-0.023	0.035	-0.097	0.424	-0.013	-0.022	0.009	0.065	-0.129	0.027	0.386*
SY/P	0.055	-0.064	-0.004	-0.018	0.007	0.068	0.033	-0.003	-0.032	-0.012	-0.099	-0.121	-0.146	-0.043	0.039	0.033	-0.017	0.225	0.025	-0.137	-0.212

indirect effect via other trait components. Under such a situation indirect selection through component character shall lead to desirable result. The contribution of residual effect was negligible (0.00052 and 0.11512) at genotypic and phenotypic level), which indicated that most of the variability could be explained through the characters under investigation. Similar results recorded by Singh and Singh (2009); Poulose *et al*. (2021), Srinivasan *et al.* (2018); Kumar *et al.* (2018) and Singh and Misra (2008) in marigold.

At genotypic and phenotypic combined level, maximum direct positive effect was seen towards flower yield per plant via stem diameter (0.079), (0.076) followed by number of flower (0.716), (0.715) and leaves per plant (0.856), (0.858) average fresh weight of leaves (0.248), (0.248) Flower diameter(-0.019),(-0.019). These indirect traits had a good relationship with dependent variable (flower yield per plant) and revealed that if direct selection for these traits is done, then it would be highly beneficial and rewarding for flower yield improvement. This might be due to the more regional adaptability and genetical growth habit of the genotypes resulting in higher proportion of morphological growth in terms of vigour and reproductive growth leading to increased flower yield. Similar results were finding in chrysanthemum by Poulose *et al.* (2021), Srinivasan *et al.* (2018), Patel *et al.* (2018), Kumar *et al.* (2018a), Giri *et al.*(2018), Sahu *et al.* (2018), Choudhary *et al.*(2015), Panwar *et al.*(2014), Karuppaiah and Kumar (2010), Singh and Singh (2009)) and Karuppaiah *et al.* (2004) in marigold.

Conclusion

Path coefficient analysis helps in understanding the cause of association between two variables. It determines the direct effect of various characters on flower yield per plant and also indirect effect via other trait component and facilitates the selection of superior genotypes. On the basis present investigation findings, it can be concluded that among overall performance of twelve genotypes of marigold, genotype Genotype Hisar Jafari-2, Inca Yellow and Inca Orange for flower and Crackerjack and Pusa Narangi Gainda for seed production were found suitable for Bihar conditions. In present investigation for path analysis, flower yield per plant was taken as dependent variable and all the other twenty traits were considered as independent variables.

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