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Genetic evaluation and variability studies on diverse marigold genotypes for vegetative and floral traits under Bihar conditions

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ABSTRACT

A study of fifteen marigold genotypes was conducted to assess vegetative, floral, and seed-related traits, examining genetic parameters including variability, heritability, GCV, PCV, traits association, and path coefficient analysis, revealing substantial genetic variations between the genotypes, affecting multiple aspects of growth and flowering traits. Genotypes Arka Bhanu, Arka Vibha, Arka Shubha, Arka Abhi, Bidhan Marigold 1, and Pusa Bahar having good vegetative, floral and seed yield attributes. A diverse array of mean values was observed across all the evaluated traits, *viz.* plant height (42.32-74.80 cm), plant spread (12.58-72.49 cm), leaf biomass (32.62-822.2 g), flowering duration (33.67-92.67 days), and flower yield/ plant (119.46-569.8 g). Traits including leaf biomass, total carotenoids content, seed yield/ plant, chlorophyll content, flower yield/ plant, primary and secondary branching exhibited higher genotypic and phenotypic coefficients of variation. Heritability estimates exceeding 90% were observed for most traits, whereas plant height, days taken to first flowering, flower diameter, and days taken to seed maturation showed relatively lower heritability values. The genetic advance as of percentage mean varied widely, ranging from 22.60 to 224.90%. It was observed maximum for leaf biomass, total carotenoids content, seed yield/plant, total chlorophyll content, and flower yield/plant. The results suggest that these traits with maximum heritability and genetic gain can be used in crop improvement programme through hybridization.

Key words: *Tagetes* spp., correlation, heritability, GCV, PCV, total carotenoids.

INTRODUCTION

Marigolds, the vibrant and visually striking economically profitable flowers, have long captivated the interest of farmers, gardeners and horticulturists. They exhibit traits such as low maintenance, quick crop rotation, and a wide range of eye-catching forms, sizes and shelf-life, making them highly sought after ornamental crop for commercial cultivation. Marigolds are the extremely popular choice for making floral garlands and arrangements used as decorations for various social and religious occasions including offering to deities. These flowers have become the subject of in-depth study and exploration, particularly with regard to their genetic diversity and the complex interplay between their morphological and floral traits (Kumari *et al*., 6).

Marigold is a prominent loose flower crop in India especially for states like Madhya Pradesh, Karnataka, Gujarat, Andhra Pradesh, Maharashtra, Tamil Nadu, Haryana, West Bengal and Bihar. Marigolds, belonging to the Asteraceae family, are among the most commercially important loose-flower crops produced in India. These plants have their origins in South and Central America, with a notable concentration in Mexico. Of the 33 known *Tagetes* species, African marigold (*T. erecta*) and French marigold (*T. patula*) are the two most extensively cultivated species. Its basic chromosome number is x = 12. The evaluation of marigold genotypes for morphological and floral traits in Bihar, has garnered significant attention, since this flower holds immense cultural, religious and economic significance (Namita *et al*., 7). As researchers have sought to unravel the underlying factors that contribute to the diverse phenotypes observed in marigolds, a multi-faceted approach has been employed, examining expression of a wide array of morphological and floral traits.

MATERIALS AND METHODS

The study was carried out at the Floriculture Research Farm, Bihar Agricultural College, Sabour, Bhagalpur, during the 2023-2024 growing season. The experimental material consisted of 15 genotypes, namely, Pusa Narangi Gainda, Pusa Arpita, Pusa Deep, Pusa Bahar, Pusa Basanti Gainda, Arka Abhi, Arka Bhanu, Arka Shubha, Arka Vibha, BM1, Garland Orange, Inca Orange, Marvel Gold, Marvel Yellow, and Marvel Orange procured from the public and private institutions. The experiment was employed in RBD design with three replications. Seedlings of different genotypes were grown in a raised nursery bed and transplanted to the prepared field after

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25 days, at the four-leaf stage, at a spacing of 45 cm × 45 cm between rows and planting within rows. The trial was carried out under open field conditions. Data was taken on five randomly chosen plants, within each replication, leaving the border plants to minimize edge effects. The main attributes of the genotypes employed in this research are presented in Table 1. The genotypes were evaluated for a range of vegetative growth, floral, and seed traits, *viz.*, plant height, plant spread, number of primary and secondary branches/plant, leaf biomass, days taken to flowering, flowering duration, flower diameter, flower yield/plant, days taken to seed maturation, seed yield/plant and biochemical attributes like total chlorophylls and total carotenoids content. The data were subjected to analysis of variance (Panse and Sukhatme, 9) and further calculations included phenotypic and genotypic coefficients of variation, heritability (broad sense), and genetic advance as percent mean (Burton and Devane, 4). Fresh tender leaves were used to estimate total chlorophylls (Arnon, 2). For biochemical analysis, fresh marigold flowers at full bloom stage were harvested to examine the colour and total carotenoids contents using Ranganna (13) method.

RESULTS AND DISCUSSION

The statistical analysis of variance uncovered substantial genetic diversity among the 15 marigold genotypes cultivars for various vegetative, flowering, and seed traits. However, no single genotype excelled in all the parameters. Instead, different genotypes demonstrated superiority for distinct growth, flowering, seed, and quality traits. The observed variability in genotype performance can be attributed to differences in genetic composition and adaptation to specific environmental conditions.

The data presented in Table 2 summarizes the mean performance matrics for 15 distinct marigold genotypes across an assortment of growth, flowering, and seed-related traits. The genotype Pusa Arpita exhibited the maximum plant height (74.80 cm), which was statistically on par to Arka Abhi (73.23 cm) and Arka Bhanu (72.30 cm), but significantly differed with Pusa Bahar (66.20 cm) and other 11 genotypes. However, genotype Marvel Gold showed the shortest plants height (42.32 cm). Similar observations were reported earlier by Singh and Misra (15). The maximum plant spread (72.49 cm) was recorded in Pusa Arpita followed by Arka Vibha (71.63 cm) and Arka Abhi (68.34 cm). Pusa Arpita was recorded the highest number of primary branches/ plant (20.41) with Arka Abhi (10.52) and Pusa Basanti Gainda (10.33) having the lower branches. Genotype Arka Vibha recorded the maximum number of secondary branches/ plant (63.70) followed by Arka Shubha (61.1) and Arka Abhi (59.9). Genotype Garland Orange (23.5) recorded the lower number of secondary branches/ plant followed by Marvel Orange (23.7) and Pusa Narangi Gainda (24.4). It was found that differences present in number

Table 1. Salient features of the marigold genotypes used in the study.

Genotype	Plant species	Plant height	Flower type	Flower form	Flower compactness	Flower colour
Pusa Basanti Gainda	*Tagetes erecta* L.	Medium	Carnation type	Semi double	+	Lemon Yellow
Pusa Narangi Gainda	*Tagetes erecta* L.	Medium	Carnation type	Semi double	+	Orange
Pusa Bahar	*Tagetes erecta* L.	Tall	Carnation type	Semi double	+	Bright Yellow
Pusa Arpita	*Tagetes patula* L.	Tall	Carnation type	Semi double	++	Light Orange
Pusa Deep	*Tagetes patula* L.	Medium	Carnation type	Semi double	++	Mahogany red
Arka Abhi	*Tagetes erecta* L.	Tall	Carnation type	Double	+++	Yellow
Arka Bhanu	*Tagetes erecta* L.	Tall	Carnation type	Double	++	Yellow
Arka Shubha	*Tagetes erecta* L	Medium	Carnation type	Double	++	Orange
Arka Vibha	*Tagetes erecta* L.	Medium	Carnation type	Double	+++	Orange
Bidhan Marigold 1	*Tagetes erecta* L.	Medium	Carnation type	Semi double	++	Light yellow
Garland Orange	*Tagetes erecta* L.	Medium	Carnation type	Semi double	+	Orange
Inca Orange	*Tagetes erecta* L.	Medium	Carnation type	Double	++	Orange
Marvel Orange	*Tagetes erecta* L.	Medium	Carnation type	Double	++	Orange
Marvel Yellow	*Tagetes erecta* L.	Medium	Carnation type	Double	++	Yellow
Marvel Gold	*Tagetes erecta* L.	Small	Carnation type	Double	++	Golden orange

Plant height (Small: 0-45 cm; medium: 46-60 cm; Tall: > 60 cm); Flower compactness (+: loose, ++: Less compact, +++: Highly compact)

Table 2. Mean performance of genotypes for growth, flowering and seed attributes.

Genotype	Plant height (cm)	Plant spread (cm)	No. primary branches	No. secondary branches	Leaf biomass (g)	Days taken to flowering (days)	Flowering duration (days)	Flower diameter (cm)	Flower yield / plant (g)	Days taken to seed maturation (days)	Seed yield/ plant (g)
Pusa Basanti Gainda	54.57	61.43	10.33	41.9	287.81	74.00	33.67	5.27	337.93	45.33	134.77
Pusa Narangi Gainda	54.37	55.05	7.61	24.4	162.21	67.00	42.00	5.29	303.61	40.00	231.39
Pusa Bahar	66.20	56.92	9.80	37.7	185.34	66.33	59.00	5.43	382.24	40.67	437.45
Pusa Arpita	74.80	72.49	20.41	53.3	822.25	96.00	61.07	4.45	119.46	37.67	36.64
Pusa Deep	52.90	49.28	5.36	31.8	58.33	53.00	92.67	4.08	288.56	40.33	21.29
Arka Abhi	73.23	68.34	10.52	59.9	278.17	78.00	58.22	6.85	484.44	38.00	375.16
Arka Bhanu	72.30	63.16	9.33	57.9	126.34	69.33	65.00	6.14	569.81	35.33	291.49
Arka Shubha	56.23	62.57	7.91	61.1	173.94	72.67	64.67	6.70	491.75	35.33	231.26
Arka Vibha	54.23	71.63	8.72	63.7	324.90	69.67	63.00	6.48	552.16	33.67	227.17
Bidhan Marigold 1	47.97	49.31	9.50	56.0	90.59	81.33	46.67	5.31	393.42	29.67	83.45
Garland Orange	50.37	39.58	7.53	23.5	59.60	72.33	47.04	5.32	162.64	24.67	128.21
Inca Orange	49.35	14.82	9.33	36.2	76.90	74.00	51.11	6.77	259.22	31.33	290.27
Marvel Orange	50.61	16.32	7.80	23.7	35.45	77.00	43.33	6.10	128.92	28.33	60.69
Marvel Yellow	52.71	19.45	6.33	29.5	41.28	76.00	43.74	5.43	135.36	28.67	106.93
Marvel Gold	42.32	12.58	8.04	28.2	32.62	79.00	45.00	5.14	120.64	30.00	68.74
Mean	56.81	47.53	9.24	42.04	183.72	73.71	54.41	5.65	315.34	34.60	181.66
Range (L- H)	42.32 -74.80	12.58-72.49	5.36-20.41	23.5-63.7	32.62-822.2	53.00-96.00	33.67-92.67	4.45-6.85	119.46-569.81	24.67 - 45.33	21.29-437.45
SEm (±)	1.97	1.68	0.37	1.48	8.83	2.35	1.85	0.17	12.38	1.17	9.35
CD at 5%	5.71	4.86	1.06	4.29	25.58	6.81	5.37	0.51	35.85	3.37	27.09
CV (%)	6.01	6.11	6.88	6.12	8.32	5.52	5.90	5.35	6.80	5.83	8.92

of branches may be due to the influence of height and plant spread, *i.e.* direct relationship between the traits, which is governed by genetic makeup of the genotypes of different genetic composition. The duration from planting to flowering represents a pivotal trait in commercial marigold cultivation, as it directly influences the timing of floral product availability in the market, with premature or delayed flowering impacting the market supply. However, earliness is profitable to the farmers as it reduces the crop duration and facilitate to catch early market. Genotype Pusa Deep was found most early (53.00 days) significantly followed by Pusa Bahar (66.33 days), and Pusa Narangi Gainda (67 days). However, Pusa Arpita had the most delayed flowering (96.00 days), which was significantly followed by Bidhan Marigold 1 (81.33 days). The singly flower size and weight are the important traits as marigold is sold based on individual flower weight basis. Optimum flower size is good for garland making. Bigger flower size was noted in Arka Abhi (6.85 cm), followed by Inca Orange (6.77 cm), Arka Shubha (6.70 cm) and Arka Vibha (6.48 cm). Smaller flowers were noted in Pusa Deep (4.08 cm) and Pusa Arpita (4.45 cm). Early flowering was seen in Pusa Deep (94.87 days), significantly followed by Arka Vibha (55.43 days), Arka Shubha (48.33 days) and Arka Bhanu (43.50 days). Flower yield/ plant was found maximum in Arka Bhanu (569.81 g), which was statistically at par with Arka Vibha (552.16 g), followed by Arka Shubha (491.75 g) and Arka Abhi (484.44 g). On the other hand, the lowest flower yield per plant (119.46 g) was observed in Pusa Arpita, which was statistically at par with Marvel Gold (120.64 g), Marvel Orange (128.92 g), and Marvel Yellow (135.36 g). This result could be due to the vigorous plant stature, enhanced branching, increased flower production, higher flower weight, environmental conditions and also cultural practices which collectively enhanced productivity. Similar findings were earlier reported by Kumari and

Singh (6). The earliest seed maturation was recorded in Garland Orange (24.67 days), followed by Marvel Orange (28.33 days), and Marvel Yellow (28.67 days). Conversely, delayed seed maturation (45.33 days) was recorded in Pusa Basanti Gainda followed by Pusa Bahar (40.67 days), Pusa Deep (40.33 days), and Pusa Narangi Gainda (40.00 days). Maximum seed yield per plant was noted in genotype Pusa Bahar (437.45 g), followed by Arka Abhi (375.16 g), Arka Bhanu (291.49 g) and Inca Orange (290.27 g).

The genotypes exhibited substantial variability in biochemical traits, with significant differences in total chlorophylls and total carotenoids contents (Fig. 1). The genotype Arka Abhi (32.07 mg/100 g) contained the maximum total chlorophyll content and significantly followed by Pusa Narangi Gainda (27.98 mg/100 g), followed by Arka Bhanu (27.80 mg/100g), Arka Shubha (25.31mg/100 g), Pusa Bahar (23.50 mg/100 g), and Pusa Basanti Gainda (22.55 mg/100 g). However, the lower total chlorophyll content (2.02 mg/100 g) was recorded in genotype Bidhan Marigold 1, which was at par with Marvel Orange (2.69 mg/100 g). Pusa Deep showed the highest total carotenoids content (746.87 mg/100 g) which was significantly followed by Arka Shubha (410.37 mg/100 g), Arka Vibha (405.69 mg/100 g), whereas the lowest value was recorded in Pusa Basanti Gainda (69.20 mg/100 g) followed by Arka Bhanu (96.35 mg/100 g) and Pusa Bahar (96.44 mg/100 g). The floret colour, which is a heritable trait and such differences in the pigments might be due to gene action and can be used for varietal identification.

The various marigold genotypes exhibited differential performance for the different quantitative traits, showcasing the desirable traits. These traits can be leveraged in breeding programmes to combine favourable attributes into a single, elite genotype. The data showed considerable variation in the mean performance of genotypes across various evaluated traits like plant height (42.32-74.80 cm), plant spread (12.58-72.49 cm), number of primary branches (5.36-20.41), days to flowering (53.00- 96.00), flower size (4.45-6.85 cm), and average flower weight (3.04-13.10 g). Similar observations were recorded by Raghuvanshi and Sharma (12) and Singh and Misra (15). These variations could be attributed to the unique genotypic effect and pedigree of the genotype.

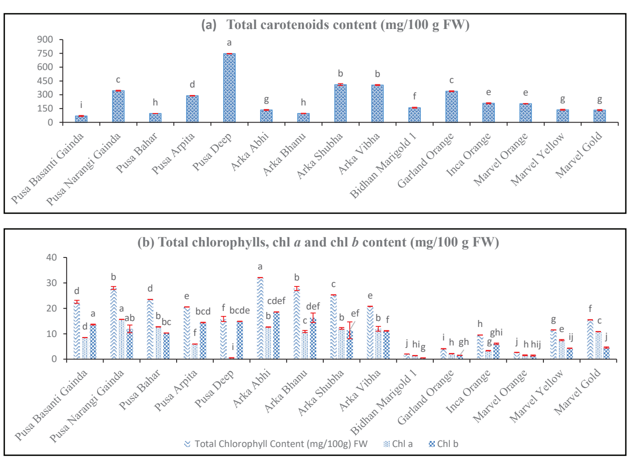


Fig. 1. Biochemical traits, namely, total carotenoids content (a), total chlorophyll, chl *a* and chl *b* content (b) of marigold genotypes.

The colour of any product significantly influences consumer enjoyment, and marigold flowers exhibit wide variation in floret colouration across different genotypes, impacting their pigment composition and bioactive content. Colour parameters were assessed by using the Hunter Colour Lab, and the average values obtained are listed in Table 3. Colorimetric analysis revealed significant genotypic variations in '*L*', '*a*', and '*b*' parameters for 15 marigold genotypes. Notably, the '*L*' value, indicative of colour lightness or darkness that differed significantly among the genotypes. Lower '*L*'value exhibited in Pusa Deep means darkest colour ('*L*' = 34.91) followed by Pusa Arpita (53.41), Arka Vibha (55.26), and Garland Orange (55.33), in the flower, whereas other genotypes exhibited brighter colours due to higher '*L*' values. Red undertones were associated with positive and higher '*a*' values in genotypes. Most of the genotypes displayed intense yellowness (high positive '*b*' values), except Pusa Deep (57.88),

Table 3. Flower colour attributes of different marigold genotypes.

Genotype	*L*	*a*	*b*
Pusa Basanti Gainda	82.65	3.74	106.80
Pusa Narangi Gainda	66.09	44.79	108.10
Pusa Bahar	76.22	6.92	93.56
Pusa Arpita	53.41	41.55	90.73
Pusa Deep	34.91	39.99	57.88
Arka Abhi	82.00	9.08	106.12
Arka Bhanu	73.54	13.32	91.27
Arka Shubha	61.58	38.06	97.91
Arka Vibha	55.26	42.96	95.69
Bidhan Marigold 1	73.56	34.61	78.63
Garland Orange	55.33	40.59	91.64
Inca Orange	65.28	38.33	98.77
Marvel Orange	67.31	35.62	96.54
Marvel Yellow	75.64	8.24	90.63
Marvel Gold	70.63	28.36	94.51

which had minimal yellowness. This genetic diversity provides opportunities for developing novel colour combinations, and its relationships with other traits. These results are consistent with findings obtained by Akshaya *et al.* (1) and Deepika *et al.* (5).

The genetic diversity inherent to the germplasm was quantified through the utilization of diverse statistical analyses, comprising the assessment of range, genotypic coefficient of variation, phenotypic coefficient of variation, heritability, and genetic advance as a percentage of the mean. The results showed that PCV values were found consistently higher than the GCV values across all quantitative traits, implying that environmental factors played a more significant role in shaping phenotypes than genetic factors (Pandey *et al.*, 8). The consideration of genetic factors is crucial when implementing selection programs. Maximum genotypic coefficient of variation (Table 4) was observed for leaf biomass (109.49) followed by total carotenoids content (71.07), seed yield per plant (70.08), total chlorophyll content (63.99), while lower GCV values were calculated for days taken to first flowering (12.06%) and flower size (14.41%). The PCV was highest for leaf biomass (109.81%) followed by total carotenoids (71.15%), seed yield per plant (70.65%), total chlorophyll content (64.16%), while lower PCV levels were recorded for days taken to first flowering (13.27%) followed by for flower size (15.37%). Highest levels of GCV and PCV (>30%) for different traits is desirable, which indicate selection for these traits would be more beneficial. These results are in conformity of the earlier report of Pandey *et al.* (8).

Solely relying on the genotypic coefficient of variation provides limited insight into the heritable component of the observed variation, underscoring the importance of estimating heritability for a thorough assessment. The value of heritability exceeded 90% was recorded for all traits except plant height, days taken to first flowering, flower diameter, days taken to seed maturation. Total carotenoids content and total chlorophylls exhibited the highest heritability estimate of 99.73 and 99.49%, respectively. Among the floral traits, the maximum heritability (98.25%) was recorded for flower yield per plant. These findings of substantial genetic influence are consistent with previous results. (Savadi *et al*., 14; Bhusaraddi *et al.*, 3). Genetic advance as percentage of the mean was notably elevated for leaf biomass (224.9%), followed by total carotenoids content (146.25%) and other 10 traits including flower yield per plant (103.87%), highlighting opportunities for genetic improvement. However, a lower rate of genetic improvement relative to the mean was observed in the number of days until first flowering. (22.59%) followed by flower diameter (27.84%), days taken to seed maturation (31.69%), and plant height (33.51%). Comparable outcomes were documented by Singh *et al.* (16). Heritability and genetic advance together provided more reliable predictions of the effects of selecting the best marigold genotypes compared to either trait alone. To ensure effective selection in marigold breeding, this study took a comprehensive approach by considering both heritability and genetic advance. A desirable combination of high heritability and high genetic advance were calculated for six

Table 4. Estimates of phenotypic and genotypic coefficients of variation, heritability and genetic advance for different traits of marigold.

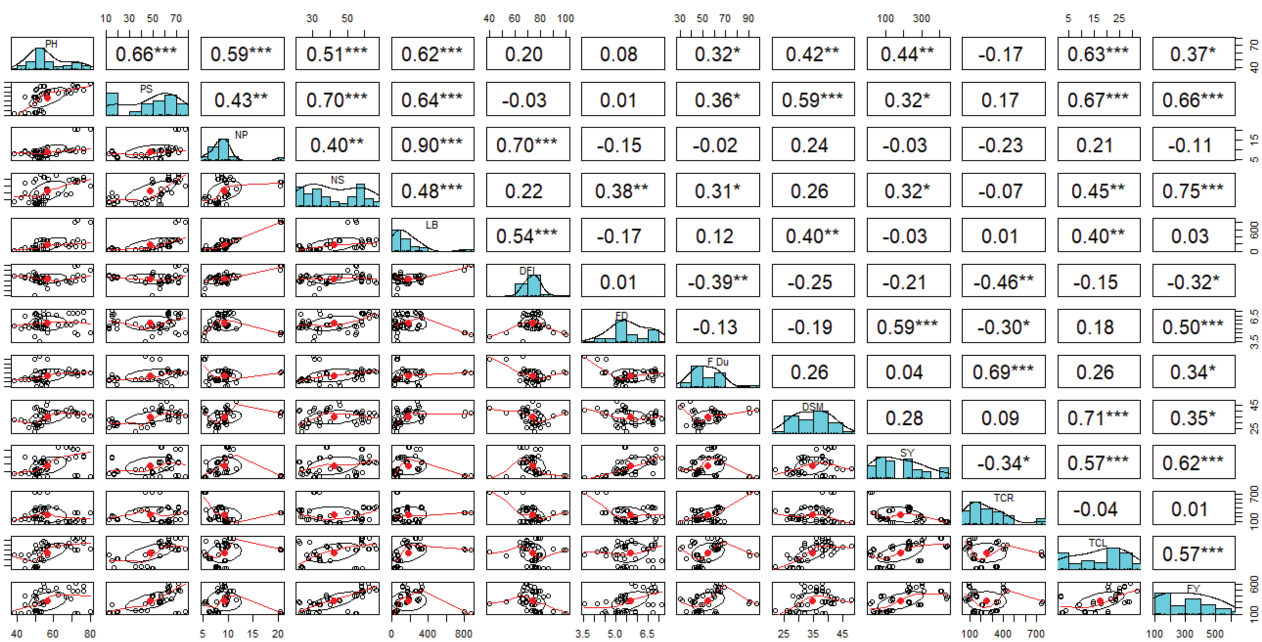
Parameter	Range	GCV	PCV	Heritability	Genetic advance % mean
Plant height (cm)	42.32 -74.80	17.228	18.245	89.165	33.512
Plant spread (cm)	12.58- 72.49	45.437	45.846	98.225	92.766
No. of primary branches/ plant	5.36-20.41	36.664	37.297	96.632	74.244
No. of secondary branches/ plant	23.5- 63.7	35.928	36.445	97.184	72.962
Leaf biomass (g)	32.62-822.25	109.49	109.81	99.425	224.9
Days taken to first flowering	53.00- 96.00	12.064	13.268	82.676	22.597
Flower diameter (cm)	4.45-6.85	14.411	15.369	87.931	27.839
Flowering duration (days)	33.67-92.67	26.09	26.749	95.133	52.421
Days taken to seed maturation	28.33-45.33	16.336	17.345	88.7	31.693
Seed yield/ plant (g)	21.29-437.45	70.084	70.649	98.407	143.22
Total carotenoids (mg/100 g)	96.35 -746.87	65.70	65.78	99.73	135.15
Total chlorophylls (mg/g)	1.40-22.87	63.997	64.161	99.489	131.5
Flower yield/ plant (g)	119.46-569.81	50.869	51.321	98.245	103.87

key traits, *i.e.* leaf biomass, seed yield, leaf number, total carotenoid content, total chlorophyll, and flower yield. The observed gene action for these traits suggests an additive genetic basis, implying that straightforward selection would constitute an effective breeding approach. Comparable findings have been documented by Panwar *et al.* (10), which highlight the potential of genetically diverse marigold genotypes as valuable parental lines in breeding programmes, enabling the creation of novel genotypes or hybrids with enhanced genetic diversity and better climate resilience.

The findings revealed a significant and positive association at phenotypic levels across various vegetative, floral, seed and biochemical attributes (Table 5). The expression of flower yield involves the combined influence of multiple genetic and environmental factors, making it a complex trait to study. Flower yield exhibited highly significant positive correlations at the phenotypic level with several traits, including plant height (0.37), plant spread (0.66), secondary branches (0.75), flower diameter (0.50), total chlorophyll content (0.57), and seed yield (0.62). Conversely, the time to first flowering was significantly and inversely correlated (-0.32) with flower yield. Additionally, flower diameter exhibited a significant positive correlation with the number of secondary branches per plant (0.38) and seed yield per plant (0.59), while a significant negative correlation was observed with total carotenoids content (-0.30). Earlier, Pandey *et al.* (8) noted that flower diameter showed significant negative correlation with total carotenoids. Heavier flowers, *i.e.* flower having more number of ray florets are strongly associated with the enhanced seed production and yield, making flower fresh weight a valuable selection criterion for improving plant fertility and productivity. Flowering duration was positively associated with plant stature (0.32), plant lateral growth (0.36), and number of secondary branches (0.31), and showed a highly significant positive correlation with total carotenoids content (0.69). The observed correlations between these traits and flower yield per plant exhibit favourable direction, indicating that selective breeding for these traits has potential to enhance the overall yield. Our results are consistent with the earlier findings of Pandey *et al*. (8).

A path coefficient analysis was conducted at both the genotypic and phenotypic levels, with flower yield per plant specified as the dependent variable. This analysis partitioned the genotypic and phenotypic correlations into direct and indirect influences, revealing that the number of secondary branches per plant (0.879) had a substantial positive and statistically significant direct effect on flower yield per plant. Additionally, days to first flowering (0.686), seed yield per plant (0.641), days to seed maturation (0.482), total carotenoids content (0.391), and plant spread (0.669) were also identified as key contributing factors (Table 6). The phenotypic analysis revealed that plant spread exerted the most substantial positive direct influence on flower yield per plant (0.529),

Table 5. Phenotypic correlation among vegetative attributes for thirteen characters of fifteen marigold genotypes.



r at 5 % 0.256 & 1% 0.333

followed by the number of secondary branches per plant (0.527); Conversely, seed yield per plant (0.151) and flower diameter (0.120) exhibited a relatively low direct effect. These findings align with the results published by Bhusaraddi *et al*. (3) and Poulose *et al.* (11) in their studies on marigold. Increased leaf biomass and higher greater numbers of primary branches per plant were found to have a negative direct impact on flower yield per plant, with the latter factor exhibiting this detrimental effect at both the genotypic and phenotypic levels. These findings align with the earlier findings of reported by Panwar *et al.* (10) and Namita *et al*. (7).

The experimental findings suggest that genotypes Arka Bhanu, Arka Vibha, Arka Shubha, Arka Abhi, Bidhan Marigold 1, and Pusa Bahar possess favourable floral attributes and could be highly adaptable to the environmental conditions prevalent in the state of Bihar. Genotypes, Pusa Deep, Arka Shubha, and Arka Vibha were found to be are rich in total carotenoids content could be suited for nutraceutical and poultry industries. The present study suggested traits like secondary branches, days taken to first flowering, seed yield/plant, days taken to seed maturation, total carotenoids content, and plant spread, are to be the main component of flower

Table 6. Direct and indirect effect of thirteen traits on flower yield per plant of fifteen marigold genotypes at phenotypic and genotypic level.

Trait		PH	PS	NP	NS	LB	DFI	FD	F Du	DSM	SY	TCR	TCL	r
PH	G	**0.250**	0.090	-0.589	0.472	-0.201	0.149	-0.027	-0.042	0.243	0.304	-0.068	-0.193	**0.388**
	P	**-0.090**	0.351	-0.012	0.268	-0.263	-0.028	0.010	0.019	0.012	0.066	0.013	0.029	**0.374***
PS	G	0.176	**0.129**	-0.416	0.639	-0.197	-0.002	-0.001	-0.046	0.313	0.203	0.067	-0.194	**0.671****
	P	-0.060	**0.529**	-0.009	0.371	-0.273	0.003	0.001	0.021	0.017	0.048	-0.013	0.030	**0.665****
NP	G	0.158	0.057	**-0.933**	0.362	-0.279	0.535	0.044	0.004	0.124	-0.023	-0.093	-0.062	**-0.106**
	P	-0.053	0.227	**-0.021**	0.210	-0.384	-0.097	-0.018	-0.001	0.007	-0.005	0.018	0.009	**-0.107**
NS	G	0.134	0.093	-0.384	**0.879**	-0.148	0.175	-0.115	-0.040	0.128	0.210	-0.028	-0.132	**0.772****
	P	-0.046	0.372	-0.008	**0.527**	-0.205	-0.031	0.046	0.018	0.007	0.048	0.005	0.020	**0.755****
LB	G	0.166	0.084	-0.861	0.431	**-0.303**	0.406	0.048	-0.015	0.209	-0.019	0.002	-0.115	**0.032**
	P	-0.056	0.340	-0.019	0.254	**-0.425**	-0.074	-0.021	0.007	0.011	-0.004	0.000	0.018	**0.032**
DFI	G	0.054	0.000	-0.727	0.225	-0.179	**0.686**	-0.015	0.059	-0.138	-0.156	-0.201	0.044	**-0.350**
	P	-0.019	-0.011	-0.015	0.120	-0.231	**-0.136**	0.003	-0.023	-0.006	-0.033	0.037	-0.007	**-0.319**
FD	G	0.026	0.000	0.152	0.378	0.054	0.040	**-0.268**	0.019	-0.096	0.416	-0.126	-0.057	**0.538***
	P	-0.008	0.004	0.003	0.202	0.073	-0.003	**0.120**	-0.008	-0.006	0.090	0.024	0.008	**0.500****
F Du	G	0.086	0.049	0.029	0.289	-0.038	-0.336	0.043	**-0.120**	0.123	0.034	0.277	-0.076	**0.359**
	P	-0.029	0.190	0.000	0.165	-0.050	0.053	-0.016	**0.058**	0.007	0.006	-0.054	0.012	**0.341***
DSM	G	0.126	0.084	-0.240	0.234	-0.131	-0.196	0.053	-0.031	**0.482**	0.195	0.036	-0.216	**0.395**
	P	-0.038	0.315	-0.005	0.137	-0.173	0.031	-0.025	0.015	**0.028**	0.043	-0.007	0.032	**0.354***
SY	G	0.119	0.041	0.034	0.288	0.009	-0.167	-0.174	-0.006	0.147	**0.641**	-0.134	-0.166	**0.632***
	P	-0.039	0.170	0.001	0.168	0.011	0.029	0.072	0.002	0.008	**0.151**	0.026	0.026	**0.623****
TCR	G	-0.043	0.022	0.222	-0.064	-0.002	-0.352	0.086	-0.085	0.044	-0.219	**0.391**	0.011	**0.010**
	P	0.015	0.090	0.005	-0.037	-0.002	0.064	-0.037	0.040	0.002	-0.051	**-0.078**	-0.002	**0.009**
TCL	G	0.169	0.087	-0.202	0.405	-0.121	-0.105	-0.053	-0.032	0.363	0.370	-0.014	**-0.287**	**0.579***
	P	-0.057	0.353	-0.004	0.240	-0.170	0.020	0.022	0.015	0.020	0.086	0.003	**0.045**	**0.573****

Residual effect: Genotypic (0.0422), Phenotypic (0.0435)

PH	Plant height	DFI	Days taken to first flowering	TCR	Total carotenoids content
PS	Plant spread	FD	Flower diameter	TCL	Total chlorophylls content
NP	Primary branches per plant	Fl Du	Flowering duration	FY	Flower yield/ plant
NS	Secondary branches per plant	DSM	Days taken to seed maturation		
LB	Leaf biomass	SY	Seed yield/ plant		

yield of these genotypes, efforts be made for should be focused in mass selection, genetic basis of color variation for future breeding programmes.

AUTHORS' CONTRIBUTION

Formulation of research (MK); Development of the experimental design (MK & SK); Provision of experimental materials (MK & SK); Conducting of field/lab experiments and data collection (SK & MK); Analysis and interpretation of data (SK, S, MK & VKS); Drafting of the manuscript (SK & MK), revision of manuscript (DS & RK).

DECLARATION

The authors declare that there is no conflict of interest.

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