

# **EVALUATION AND CHARACTERIZATION IN MARIGOLD**

**BY  
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CCS HARYANA AGRICULTURAL UNIVERSITY  
HISAR - 125 004 (HARYANA)**

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## **CERTIFICATE – I**

This is to certify that this thesis entitled, “**Evaluation and characterization in marigold**”, submitted for the degree of **Doctor of Philosophy** in the subject of **Horticulture-Floriculture and Landscape Architecture** to the **Chaudhary Charan Singh Haryana Agricultural University, Hisar** is a bonafide research work carried out by **Mr. Mahesh Choudhary**, Admission No. **2010A17D** under my guidance and supervision and that no part of this thesis has been submitted for any other degree.

The assistance and help received during the course of the investigation have been fully acknowledged.

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**Place: Hisar**

**Date: ...../...../.....**

**[Mahesh Choudhary]**

## LIST OF CONTENTS

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<b>Chapter No.</b>	<b>Description</b>	<b>Page (s) No.</b>
I	INTRODUCTION	1-4
II	REVIEW OF LITERATURE	5-15
III	MATERIALS AND METHODS	16-29
IV	EXPERIMENTAL RESULTS	30-81
V	DISCUSSION	82-98
VI	SUMMARY AND CONCLUSION	99-101
	BIBLIOGRAPHY	i-v
	APPENDICES	I-VI

---

## LIST OF TABLES

Table No.	Title	Page No.
3.1	Chemical properties of soil of the experimental field	16
3.2	Details of the marigold genotypes	18
4.1	Analysis of variance for different characters of marigold genotypes during 2011-12	32
4.2	Analysis of variance for different characters of marigold genotypes during 2012-13	33
4.3	Mean performance of genotypes for different characters of marigold genotypes during 2011-12	34-35
4.4	Mean performance of genotypes for different characters of marigold genotypes during 2011-12	36-37
4.5	Mean performance of genotypes for different characters of marigold genotypes during 2012-13	38-39
4.6	Mean performance of genotypes for different characters of marigold genotypes during 2012-13	40-41
4.7	Characterization of thirty genotypes of marigold based on various morphological characters	47-49
4.8	Characterization of thirty genotypes of marigold based on various flowering characters	51-52
4.9a	Mean, range, genotypic and phenotypic variances for various characters of marigold genotypes during 2011-12	54
4.9b	Coefficient of variation, heritability, expected genetic advance and genetic advance as per cent of mean for various characters of marigold genotypes during 2011-12	55
4.10a	Mean, range, genotypic and phenotypic variances for various characters of marigold genotypes during 2012-13	56
4.10b	Coefficient of variation, heritability, expected genetic advance and genetic advance as per cent of mean for various characters of marigold genotypes during 2012-13	57
4.11	Phenotypic (above diagonal) and genotypic (below diagonal) correlation coefficients among different characters in marigold during 2011-12	61-62
4.12	Phenotypic (above diagonal) and genotypic (below diagonal) correlation coefficients among different characters in marigold during 2012-13	63-64
4.13	Direct (diagonal) and indirect (off diagonal) path coefficients of different characters towards flower yield per plant in marigold during 2011-12	69-70

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4.14	Direct (diagonal) and indirect (off diagonal) path coefficients of different characters towards flower yield per plant in marigold during 2012-13	71-72
4.15	Grouping of marigold genotypes into different clusters during 2011-12	75
4.16	Grouping of marigold genotypes into different clusters during 2012-13	76
4.17	Average intra (diagonal) and inter cluster $D^2$ values of marigold genotypes in clusters during 2011-12	78
4.18	Average intra (diagonal) and inter cluster $D^2$ values of marigold genotypes in clusters during 2012-13	78
4.19	Cluster mean values for various characters in marigold genotypes during 2011-12	80
4.20	Cluster mean values for various characters in marigold genotypes during 2011-12	80
5.1	Characterization of marigold genotypes based on plant characters	96-97
5.2	Characterization of marigold genotypes based on flowering characters	98

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## LIST OF FIGURE

<b>Figure No.</b>	<b>Description</b>	<b>Page No.</b>
4.1	The dendrogram showing the clustering pattern of genotypes of marigold during 2011-12	76
4.2	The dendrogram showing the clustering pattern of genotypes of marigold during 2012-13	77
4.3	Cluster diagram showing average intra-and inter-cluster $D^2$ values of genotypes during 2011-12	79
4.4	Cluster diagram showing average intra-and inter-cluster $D^2$ values of genotypes during 2012-13	81

## LIST OF PLATES

<b>Plate No.</b>	<b>Description</b>	<b>After page</b>
1	General view of marigold field at vegetative stage	<b>18</b>
2	General view of marigold field at flowering stage	<b>18</b>
3	Branching habit	46
4	Plant growth habit	46
5	Stem colour	46
6	Leaf colour	46
7	Stem shape	46
8	Leaflet shape	46
9	Leaflet margin	50
10	Disc floret	50
11	Variability in marigold buds	54
12	Variability in marigold flowers	54

## LIST OF ABBREVIATIONS AND SYMBOLS

Sr. No.	Abbreviations	Meaning
1	%	Per cent
2	/	Per
3	@	At the rate of
4	°C	Degree celsius
5	Anon.	Anonymous
6	C.D.	Critical difference
7	C.V.	Coefficient of variance
8	cm	Centimetre
9	DAP	Days after planting
10	DUS	Distinctness, uniformity and stability
11	d.f.	Degree of freedom
12	<i>et al.</i>	<i>Et alii</i> (and others)
13	<i>etc.</i>	<i>Etcetera</i> (so on)
14	EC	Electrical conductivity
15	ECV	Environmental coefficient of variation
16	Fig.	Figure
17	FYM	Farmyard manure
18	g	Gram
19	GCV	Genotypic coefficient of variation
20	ha.	Hectare
21	<i>i.e.</i>	<i>id est</i> (that is)
22	K	Potassium
23	Kg	Kilo gram
24	PCV	Phenotypic coefficient of variation
25	P	Phosphorous
26	pH	Potential of hydrogen ion
27	q	Quintal
28	RBD	Randomized Block Design
29	R.H.	Relative humidity
30	SE(m)	Standard error of mean
31	sq. m.	Square meter
32	Temp.	Temperature
33	<i>viz.</i>	<i>Videlicet</i> (namely)

Floriculture has emerged as a viable agribusiness by improving the productivity of land, generating vast employment opportunities from grower's field to retailer's shop and ultimately improving economic status of the farmers and entrepreneurs. Commercial floriculture has increased its credibility for diversification in agriculture as well as potential foreign-exchange earner in India. The Indian subcontinent is gifted with diverse agro-climatic conditions, which provide ample opportunities for the production of all major loose flowers like marigold, jasmine, chrysanthemum, rose, crossandra, tuberose, China aster, *etc.* Abundant availability of cheap labour in India is another advantage for low production cost to compete in the international market.

In India, the growth of floriculture industry has been very slow in the first 40 years after independence due to more concentration paid to cultivation of food grains but after liberalization of economic policies in 1990s, a very significant expansion in floriculture has been recorded from mere 53 thousand hectares area and production of 233 thousand tonnes of loose flowers and 555 million cut-flowers in 1993-94 to a remarkable 1.06 lakh hectares area with production of 535 thousand tonnes of loose flowers and 2665 million cut-flowers in 2001-02 and 1.91 lakh hectares area and production of 1031 thousand tonnes of loose flowers and 69027 million cut-flowers in the year 2010-11 (Kumar *et al.*, 2011). The contribution to loose-flowers by Tamil Nadu is 24%, Karnataka 19.8%, Maharashtra 8.8%, Punjab 8% and Haryana 5.5%, whereas, in cut flower production, West Bengal contributes the major share (34.65%) followed by Maharashtra (11.47%) and Andhra Pradesh (8.98%). Haryana has 6200 hectares area under flower cultivation with production of loose flowers 60,300 tonnes and cut flowers 1084.0 lakh (numbers). Area under marigold was 4681 hectares during the year 2009-10 with production of 59619 tonnes (Anonymous, 2009).

Marigold (*Tagetes* species), a member of family Asteraceae, is the native of Central and South America, especially Mexico. It was first introduced into Spain in the early 16th century, while in India, it was introduced by Portuguese. It is found growing wild in South Africa, Australia, India, Uruguay, Kenya, Brazil, France, *etc.* The name *Tagetes* was given after 'Tages', a demigod known for his beauty. Marigold has been named after Virgin Mary. The king Curtez after conquering Mexico got fascinated by the beauty of flowers and carried it to Spain. It was then offered to the attar of Virgin "Mary" and thus named as Mary's gold, now, popularly known as marigold (Marshal, 1969).

In India, marigold ranks first among the loose flowers followed by chrysanthemum, jasmine, tuberose and crossandra (Kavitha and Anburani, 2009). There are about 33 species of the genus *Tagetes*. The important species are *Tagetes erecta*, *T. patula*, *T. tenuifolia*, *T. lucida*, *T. lacera*, *T. lemmonii*, *T. minuta*, *T. psylla* and *T. corymbosa*. The chromosome number (2n) in diploid species, i.e., *Tagetes erecta*, *T. tenuifolia*, *T. lucida*, etc. is 24, however, the chromosome number in tetraploid species, i.e., *Tagetes patula*, *T. minuta*, *T. biflora*, etc. is 48. The two commercially important species are *Tagetes erecta* L., commonly called African marigold, and *Tagetes patula* L. popular as French marigold. The African marigold is a hardy annual plant grown up to one or more than one meter, erect and branched. Its leaves are pinnate type and leaflets lanceolate and serrated. It bears single or fully doubled large-size globular heads. Flowers' colour is yellow and orange in various shades, i.e., light yellow, golden yellow, bright yellow, golden orange, cadmium orange, bright orange, or deep orange, whereas, French marigold is comparatively dwarf grown up to 20-60 cm height, hardy and bushy plant, which bears small, lemon yellow, golden yellow, or orange tinged red flowers. Botanically, the marigold inflorescence is capitulum with two types of flower, the peripheral ray floret and the central disc floret. The disc flowers in the centre are perfect having both anthers and pistil, whereas, surrounding ray flowers with strap like petals are pistillate and male sterile.

It is popular among flower growers because of wide spectrum of attractive colours, shape, size and good keeping quality has attracted the attention of flower growers. They are extensively used as loose flower, potted plant and also as a bedding plant. Loose flowers are in great demand for garland making as well as in religious and social functions. Globular shaped flowers with long stalks are used for cut flower purposes. The plant is very useful as both the leaves and the flowers are equally important from medicinal point of view. The paste and extracts from plant are used as cure for boils, ear ache, eye disease and ulcers. The oil is reported to have bronchodilatory, tranquilizing and anti-inflammatory properties (Chandhoke and Ghatak, 1969). Marigold cultivation controls the nematode population in soil and is used for making mosquito repellent products (Gupta *et al.*, 2001). Flower extract is used as a blood purifier as well as a good remedy for eye diseases and ulcer. The carotenoids extracted from petals of marigold are the major source of pigment for poultry industry as a feed additive to intensify the yellow colour of egg yolks and broiler skin (Narsude *et al.*, 2010a and Kaul *et al.*, 1997). Lutein, which is the major constituent of xanthophyll, is used for colouring foodstuffs (Singh, 2006). The essential oil present in different species of *Tagetes* can find a use in the perfume industry.

In a systemic breeding programme, collection, evaluation and characterization of the germplasm are the most important steps for gathering the basic information about variability

existing in a particular crop. Variation is helpful in the selection of suitable genotype and breeding programme. The adequacy of germplasm collection is determined by the amount of genetic variability present in it as such. For varietal identification, some morphological characters such as plant height, plant growth habit, branch habit, stem colour, leaf colour, leaf pubescence, flower colour, *etc.* are kept in mind. To get the variety registered, there is need to get it tested and documented as per the distinctiveness, uniformity and stability (DUS) tests guidelines. Therefore, it is planned to evaluate the available varieties or genotypes for their distinguished characters through morphological, growth and yield parameters.

The source of any breeding programme for developing suitable varieties depends largely on the availability of genetic variability in a given crop. The importance of genetic variability is well known in crop plants. The development of an effective plant breeding programme is dependent on the existence of genetic variability. The efficiency of selection largely depends upon the magnitude of genetic variability present in the plant population. Heritability estimates give a measure of transmission of characters from one to other generation as consistency in the performance of selection depends on heritable portion of the variability, enabling the plant breeder in isolating the elite selection in crop. Thus, the magnitude of variation and the estimates of heritability and genetic advance are the important parameters on which the prospect of selection lies.

To improve the yield through selection of better varieties, knowledge of the nature of association of flower yield and its components is very essential. Correlation coefficient is the significant selection parameter in plant breeding. It is used to find out the degree (strength) and direction of relationship between two or more variables. In plant breeding, correlation coefficient analysis measures the mutual relationship between various plant characters and determines the component character, on which, selection can be based for genetic improvement in yield, which is a very complex phenomenon. It is not only polygenic in nature but is also affected by environment. Hence, selection of the superior plants based on yield performance as such is usually not very effective. For selecting superior genotypes, the breeder has to choose from the material on the basis of its phenotypic expression. For most of the traits, the knowledge about degree of phenotypic and genotypic correlation of the traits is important. The path coefficient analysis is simply a standardized partial regression, which may be useful in choosing the characters that have direct and indirect effects on yield. Such a study may be useful and effective in selection for simultaneous improvement of the component characters that contribute towards yield.

Genetic variability, character association pattern and the direct and indirect effect of yield contributing characters on yield are very helpful for effective selection in any crop improvement programme. Looking at the importance and commercial potential, there is an

urgent need to conserve and characterize the available variability and its evaluation, and to identify potential genotypes, which would result in further improvement and to develop cultivar for specific uses. Keeping this background in view, the present study was undertaken for systemic and scientific improvement with the following objectives:

1. To study growth, flowering and yield attributing characters in various genotypes of marigold
2. To estimate genetic variability, heritability and genetic advance in different genotypes of marigold
3. To estimate the correlation and path coefficient among yield and its components

## CHAPTER-II

### REVIEW OF LITERATURE

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The present investigation was carried out to study the “Evaluation and characterization in marigold”. The pertinent literature in relation to the proposed work is reviewed under this chapter.

#### 2.1 MEAN PERFORMANCE OF MARIGOLD GENOTYPES

##### 2.1.1 Growth characters

Twenty eight genotypes of African marigold were evaluated by Ingle *et al.* (2011) who found significant variation among the genotypes for all the growth parameters. The maximum plant height (121.85 cm) was found in ‘AMC-10’ and the minimum (58.75 cm) in ‘Namdhari Cracker Jack Mix’. The maximum stem girth (18.02 mm) and plant spread (55.80 cm<sup>2</sup>) was found in ‘AMC-7’. Likewise, Khanvilkar *et al.* (2003) conducted an experiment to assess the performance of five African marigold cultivars and reported ‘Orange Boom’ the best with the maximum plant height (126.13 cm), plant spread (62.48 cm<sup>2</sup>), number of branches per plant (18.85), leaf area (3818.13 cm<sup>2</sup>) and total dry matter per plant (56.50 g).

Raghuvanshi and Sharma (2011) evaluated 14 cultivars of French marigold under mid-hill zone of Himachal Pradesh conditions and found the tallest plants (35.80 cm) in cultivar Safari Queen, which was statistically at par with cv. Harmony Boy (34.90 cm) and shortest (20.07 cm) in cv. Cupidon Varie Yellow. The genotype ‘Harmony Boy’ was also best in respect to plant spread (30.37 cm). The genotype ‘Nana Jumbo Bicolor’ showed the maximum lateral branches per plant (8.33) and ‘Bonanza Bolero’ the minimum (4.13). Similarly, Singh and Singh (2005a) evaluated 13 genotypes of *Tagetes patula* (TP<sub>1</sub> to TP<sub>13</sub>) at Pantnagar and reported that ‘TP<sub>7</sub>’ was the best with the maximum number of secondary branches (63.00) and leaf area (16.03 cm<sup>2</sup>), whereas, tallest plant (44.63 cm) and fresh weight of leaf (0.727 g) were recorded in ‘TP<sub>4</sub>’.

An experiment on evaluation of African marigold was conducted by Rao *et al.* (2005) who reported the maximum plant height (84 cm), leaf area (3762 cm<sup>2</sup>), total dry matter per plant (42.96 g) in ‘Orange Double’ and the maximum plant spread (46.0 cm) and number of branches per plant (20.00) in ‘Hyderabad Local Selection 1’. Similarly, Singh *et al.* (2003) evaluated two species of marigold (African and French marigold) under semi-arid conditions of Rajasthan. Among African marigold cultivars, they recorded the maximum plant height (71.83 cm) in ‘Excel Mixed’ followed by ‘Marigold Tall Mixed’ (71.30 cm) and the minimum in ‘Deep Orange’ (56.83 cm). The ‘Marigold Tall Mixed’ was also reported with the maximum plant spread and ‘African Double Perfection’ followed by ‘Excel Mixed’ with the highest number of branches. Among French marigold cultivars, ‘French Spanish Brocade’

attained the maximum plant height, while 'Orange Gate' followed by 'Naughty Marianta' the maximum plant spread.

Narsude *et al.* (2010a) reported that 'Pakharsangavi Local' produced the tallest plants (114.64 cm) and the maximum stem girth (5.37 cm) as compared to other genotypes. The maximum plant spread (64.48 cm) and number of branches per plant (21.46) were recorded in 'Tuljapuer Local-2' and 'Tuljapuer Local-1', respectively, whereas, 'Marigold Orange Bunch' and 'Latur Local' were reported with the minimum plant spread (59.58 cm) and number of branches per plant (14.26), respectively. Similarly, Singh and Singh (2006) evaluated performance of 29 genotypes of African marigold and reported 'TEG 8' the best with number of primary branches per plant (18.67), which was statistically at par with 'TEG 16' and significantly different from other genotypes. The genotype 'TEG 21' was recorded with the maximum plant spread (79.10 cm), whereas, the genotype 'TEG 26' exhibited the maximum stem diameter (1.77 cm) followed by 'TEG 14'.

Singh and Singh (2010) evaluated 44 genotypes of marigold *viz.*, 29 of *Tagetes erecta* (TEG1 to TEG 29), 13 of *Tagetes patula* (TPG 1 to TPG 13) and 2 of *Tagetes minuta* (TMG 1 and TMG 2) and observed the maximum number of primary branches per plant (53.67) and stem diameter (1.93 cm) in 'TMG 1', while the genotype 'TMG 2' performed better in terms of plant height. The maximum plant spread (79.10 cm) was found in 'TEG 21' followed by 'TEG 22' (70.30 cm). Singh *et al.* (2004) recorded significantly the maximum number of primary branches per plant (14.67) in 'TPG 1' among 13 genotypes of *Tagetes patula*, whereas, the maximum stem diameter (1.57 cm) and plant spread (42.90 cm) was recorded in 'TPG 10' and 'TPG 13', respectively.

### **2.1.2 Flowering characters**

The performance of marigold genotypes for flowering parameters was studied by Narsude *et al.* (2010a) who observed the maximum flowering duration (56.33 days) in 'Marigold Orange Bunch' and the maximum number of flowers per plant (71.00) in 'Tuljapuer Local-1'. Raghuvanshi and Sharma (2011) reported that the marigold cv. 'Single Petal Red' took the minimum number of days to flower (6.33 days). Longest flowering duration (39.67 days) was observed in 'Safari Tangerine' and the largest flower diameter (5.26 cm) was recorded in 'Bonanza Bolero'. Similarly, Singh and Singh (2006) found that genotype 'TEG13' had the maximum flowering duration (135.33 days), whereas 'TEG16' recorded with maximum number of flowers per plant (85.67) in marigold.

Beniwal and Dahiya (2012) evaluated 38 genotypes of marigold and observed that five genotypes of African marigold (MGH 133-1, 133-1-1, 160-8-2, 160-8 and 160-9-1) showed promising results in respect to number of flowers per plant (10-64), flower size (5.0-12.27 cm), fresh weight of flower (5.2-22.0 g), days to first flower (72-138) and flowering duration (18-42 days). Among French marigold, four genotypes (Hisar Beauty, Hisar Jaffri-2,

MGH 17-1 and 8-2) showed the best results in respect to number of flowers per plant (20-224), flower size (3.2-6.1 cm), fresh weight of flower (2.0-5.6 g), days to first flower (89-121) and flowering duration (39-55 days). Rao *et al.* (2005) reported that marigold genotype 'Orange Double' was superior in terms of the days to first flower opening (95.00 days), flowering duration (44.00 days), diameter of flower (13.40 cm) and weight of flower (16.67 g), whereas, in terms of number of flowers per plant (32.30), 'Hyderabad Local Selection-1' was found outstanding under Andhra Pradesh conditions.

Singh *et al.* (2003) evaluated African marigold cultivars under semi-arid conditions of Rajasthan and found 'Excel Mixed' the best cultivar in terms of earliest to flowering (36.33 days) and longest flowering duration (65.3 days), whereas, the maximum number of flowers per plant (44.30) and fresh weight of flowers (15.35 g) was observed in 'African Double Perfection'. The maximum (7.87 cm) flower diameter was recorded in 'Giant Mixed'. Narsude *et al.* (2010b) observed significantly the maximum flower diameter (7.83 cm) and weight of single flower (12.56 g) in 'Mulegaon Local', whereas, the minimum flower diameter (5.70 cm) and weight of flower (5.79 g) were reported in 'Marigold Orange Bunch'. Kumari *et al.* (2012) observed significant variation in flower stalk length of gerbera and maximum stalk length was recorded in cultivar 'Balance'. Similar results in gerbera cultivar also recorded by Bhayani *et al.* (2008) in gerbera.

Khanvilkar *et al.* (2003) observed that among five African marigold cultivars, 'Yellow Supreme' was recorded earliest to flower (42 days), while 'Orange Boom' required the maximum days to flower (54.13). The maximum diameter of flower (7.12 cm) and average fresh weight of flowers (8.10 g) were recorded in 'African Giant Mixed'. Singh and Misra (2009) assessed 45 genotypes of marigold and recorded that a cross of 'Pusa Narangi Gainda' x 'Late Summer' attained the maximum flower diameter and average dry weight of flowers. Likewise, Singh *et al.* (2004) found that *Tagetes patula* genotype 'TPG3' was most suitable for early bud initiation (19.33 days) and maximum dry weight of flower (0.610 g) and 'TPG12' and 'TPG7' for flowering duration (131.00 days) and number of flowers per plant (158.67), respectively.

### **2.1.3 Flower yield**

Narsude *et al.* (2010a) evaluated marigold genotypes for yield characters and reported that Tuljapur Local-1 showed significantly superior performance and produced the maximum yield per plant (630.48 g) and per hectare (24.67 tonne) followed by 'Pakharsangavi Local' and 'Tuljapur Local 2'. In the same way, Ingle *et al.* (2011) evaluated 28 genotypes of African marigold and found the maximum yield (20.83 t/ha) in 'AMC-6' followed by 'AMC-19' (20.23 t/ha). The highest flower yield per plant (295.8 g) and per hectare (21.91 tonne) was recorded by Rao *et al.* (2005) in 'Orange Double'.

Singh and Singh (2005a) evaluated 13 genotypes of French marigold and observed maximum flower yield per plant (309.40 g) in 'TP7' followed by 'TP1' (198.30 g). Similarly, Patil *et al.* (2011) assessed 20 genotypes of African marigold and found that 'AMC-6' surpassed rest of the genotypes in terms of flower yield per hectare (14.71t/ha) followed by 'AMC-19' (10.98 t/ha). Similarly, in marigold Raghuvanshi and Sharma (2011) recorded maximum weight of 100 loose flowers (620.33 g) in 'Cupidon Varie Orange' followed by 'Nana Jumbo Bicolor' (475.00 g) and maximum flower yield per m<sup>2</sup> (8.27 kg) in 'Safari Queen' followed by 'Bonanza Bolero' (7.40 kg).

Singh *et al.* (2003) evaluated two species of marigold (African and French marigold) and reported the maximum flower yield per plot (7.68 kg) and per hectare (323.19 q) in 'Excel Mixed' and 'Marigold Tall Mixed', respectively amongst African marigold cultivars and minimum yield per plot (1.83 kg) and per hectare (79.45 q) in 'GT Mixed'. Among French marigold cultivars, 'Orange Gate' and 'French Spanish Brocade' produced the maximum flower yield per plot (6.05 kg each) and per hectare (252.06 q each). Khanvilkar *et al.* (2003) reported that marigold genotype 'Orange Boom' gave significantly maximum yield (18.42 t/ha) followed by 'African Gaint Mixed' (15.58 t/ha) and check 'Local variety' the minimum flower yield (10.31 t/ha).

## **2.2 VARIABILITY PARAMETERS**

### **2.2.1 Genotypic and phenotypic coefficient of variation**

#### **2.2.1.1 Growth characters**

Sharma and Raghuvanshi (2011) reported higher PCV than GCV for all the growth characters assessed in 14 diverse genotypes of French marigold. The lowest coefficient of variation in plant height was estimated in 12 cultivars each of African and French marigold by Singh and Sen (2001), while Pattnaik and Mohanty (2002) studied 13 diverse genotypes of marigold in Bhubaneswar during *Rabi* season and observed high coefficient of variation both at genotypic and phenotypic levels for plant height. Singh and Misra (2008) observed the highest range of variation in number of leaves per plant followed by leaf biomass.

The variability studies by Singh *et al.* (2007) in African marigold exhibited the highest PCV and GCV for leaf area followed by plant height. Janakiram and Rao (1995) studied variability in 8 lines of African marigold and found that the PCV was high in closer spacing than in wider spacing for the characters like plant height and number of lateral branches per plant, while plant spread exhibited high PCV in wider spacing. Kavitha and Anburani (2010a) evaluated 30 genotypes of marigold for genetic variability of nine traits and obtained very low PCV and GCV for dry matter production followed by plant height.

Genotypic and phenotypic variability was studied by Verma *et al.* (2002) in 33 marigold genotypes. The difference among genotypes was significant for characters like number of branches per plant and plant canopy. The phenotypic coefficient of variation was

higher than genotypic coefficient of variation for all the characters. The plant canopy showed high PCV and GCV (52.25 and 51.42%, respectively).

### **2.2.1.2 Flowering characters**

Mathew *et al.* (2005a) reported a wide range of variation for 24 characters in 15 genotypes of African marigold. The GCV and PCV were obtained higher for fresh and dry weight of flowers. Singh and Misra (2008) evaluated nine parents of marigold and its 36 F<sub>1</sub> to ascertain variability parameters and found that among all the genotypes of marigold, phenotypic and genotypic coefficients were high for number of flowers per plant and fresh weight of individual flower. Namita *et al.* (2008) evaluated 11 genotypes of French marigold and observed low GCV and PCV for flower size, flowering duration, number of seeds per head and test weight. Karuppaiah and Kumar (2011a) observed high GCV for number of flower heads per plant followed by xanthophyll content, number of branches per plant, flower yield per plant, flower head size and flower head weight.

Singh and Singh (2010) reported that genotypic and phenotypic coefficients of variation were high for number of flowers per plant (GCV= 331.22 and PCV= 331.28) and fresh weight of flower (GCV= 102.79 and PCV= 102.85). It was least for days taken to bud initiation (GCV= 17.17 and PCV= 19.18) and flowering duration (GCV= 78.39 and PCV= 18.90) in marigold. Singh and Kumar (2008) observed maximum coefficients of variation for number of flowers per plant (GCV= 331.12 and PCV= 331.28) followed by average fresh weight (GCV= 102.79 and PCV= 102.85), while minimum coefficients of variation was recorded for flowering duration (GCV= 18.39 and PCV= 18.90).

Yuvraj *et al.* (2012) studied 23 genotypes of marigold and found the highest value of GCV and PCV for number of flowers per plant (116.50 and 117.95, respectively) and minimum for flower stalk length (21.05 and 23.55, respectively). Genotypic and phenotypic variations in 33 marigold genotypes were studied by Verma *et al.* (2002) who observed higher phenotypic coefficient of variation (PCV) than the genotypic coefficient of variation (GCV) in all the characters studied. The flower weight and plant canopy obtained high PCV (56.38 and 52.2) and GCV (53.84 and 51.42) and pedicel length obtained the lowest GCV (14.75).

### **2.2.1.3 Flower yield**

Kavitha and Anburani (2010a) evaluated 30 genotypes of marigold for genetic variability and found higher PCV (41.72) and GCV (40.70) for number of flowers per plant followed by flower yield per plant (PCV= 34.05 and GCV= 35.54). Pattnaik and Mohanty (2002) studied 13 diverse genotype of African marigold and observed higher phenotypic and genotypic coefficient of variation for yield of flowers per plant (PCV= 52.00 and GCV= 44.01), number of flowers per plant ((PCV= 39.76 and GCV= 29.26) and weight of individual flower (PCV= 29.77 and GCV= 27.27).

Namita *et al.* (2008) studied 11 genotypes of French marigold and found that the PCV was higher than GCV, which indicated greater genotype-environment (GxE) interaction. However, high genotypic (40.23) and phenotypic (42.70) coefficients of variation were found for number of flowers per plant followed by flower weight (GCV= 37.85 and PCV= 42.63) and flower yield (GCV= 29.30 and PCV= 32.46). Mathad *et al.* (2005a) evaluated 31 accessions of African marigold and recorded high phenotypic and genotypic coefficients of variation for flower yield per plot (PCV= 61.09 and GCV= 60.54), per plant (PCV= 61.02 and GCV= 60.47) and per hectare (PCV= 60.75 and GCV= 60.22).

## **2.2.2 Heritability and genetic advance**

### **2.2.2.1 Growth characters**

High heritability with high genetic advance was observed for number of leaves per plant and leaf biomass in the experiment conducted by Singh and Misra (2008) in marigold. Pattnaik and Mohanty (2002) conducted a trial with 13 diverse genotypes of African marigold and reported high heritability along with genetic gain for plant height. Moderate values of variation and low genetic gain have been found for plant height, plant spread and number of lateral branches in the experiment conducted by Sharma and Raghuvanshi (2011) in 14 diverse genotypes of French marigold. Janakiram and Rao (1994) found high heritability for plant height (92.20%) and plant spread (88.81%). Moderate values of genetic advance as percentage of mean were shown in plant height and plant spread, while low values were exhibited by number of main branches (18.60%).

In marigold, Niharika and Mohanty (2002) reported high heritability for plant height (80.8%), plant spread (74.6%) and leaf area (71.1%) and low heritability for number of branches (26.5%). Similarly, Janakiram and Rao (1995) also reported high heritability for characters like plant height, plant spread, number of main branches per plant and number of lateral branches per plant. High genetic advance was also observed for all the characters except number of main branches per plant. Singh and Sen (2001) recorded high heritability for plant spread (99.5%), plant height (95.9%) and number of branches (94.6%) and observed high genetic advance as per cent of mean for plant spread (77.8%) and low for number of branches (34.9%).

Karuppaiah and Kumar (2011b) studied with 34 genotypes of African marigold and observed high heritability estimates of more than 95% for plant height, stem girth, number of branches per plant, days to first flowering, flower head diameter, flower head size and number of flowers per plant. A further study on 33 marigold germplasm revealed high heritability (96.8%) and high genetic advance (104.23%) for plant canopy (Verma *et al.*, 2002).

### **2.2.2.2 Flowering characters**

In African marigold, Mathad *et al.* (2005a) reported high heritability coupled with high genetic advance over percentage of mean for days to first flower bud initiation and

flower weight. Mathew *et al.* (2005b) reported high heritability along with high genetic advance for number of buds and flowers per plant. Pattnaik and Mohanty (2002) recorded estimates of heritability in broad sense for various traits varied from 26.50% to 83.90%. Very high (>80%) heritability was recorded for individual flower weight followed by days to flower. Namita *et al.* (2008) obtained high estimates of heritability (broad sense) for all the characters studied except test weight. The high heritability was recorded for days to flowering (94.89) followed by number of flowers per plant (88.75).

Singh *et al.* (2007) reported higher broad sense heritability for all the characters in African marigold except number of flowers per plant. However, in French marigold, high heritability and genetic advance were found for the traits like number of flowers per plant, yield of flowers per plant, size of flower and average weight of flowers per plant. Singh and Singh (2010) observed high heritability with low genetic advance for days taken to bud initiation and flowering duration. Number of flowers per plant showed high heritability (99.99%) along with maximum genetic gain (682.26).

Yuvraj *et al.* (2012) observed high heritability for days to bud initiation (98.48) followed by days to first flower opening (98.36), number of flowers per plant (97.55), plant height (96.44), flower diameter (94.08), average flower weight (88.94) and flowering duration (87.79). The estimates of genetic advance were comparatively higher for number of flowers per plant (237.02). Singh and Kumar (2008) observed high heritability with high genetic advance for number of flowers per plant ( $h_2= 99.99\%$  and  $GA= 1469.18$ ) and plant height ( $h_2= 98.50\%$  and  $GA= 75.89$ ). The number of flowers per plant showed the maximum genetic gain (682.26) followed by average fresh weight (211.36).

### **2.2.2.3 Flower yield**

Thirty genotypes of marigold were evaluated by Kavitha and Anburani (2010a) who observed highest heritability for number of flowers per plant (97.65%) followed by flower yield per plant (97.61%). High heritability along with high genetic gain was observed for number of flowers per plant (81.26%), flower yield per plant (68.06%) and flower head size (53.17%).

Singh *et al.* (2007) recorded high genetic advance along with high heritability for yield of flowers per plant and plant height along with high to moderate PCV and GCV. Namita *et al.* (2008) studied 11 genotypes of French marigold and observed high heritability along with genetic advance for flower yield ( $h_2= 81.49$  and  $GA= 117.87$ ) and number of flowers per plant ( $h_2= 88.75$  and  $GA= 75.42$ ).

## **2.3 CORRELATION AND PATH ANALYSIS**

### **2.3.1 Growth characters**

Kavitha and Anburani (2010b) studied 30 germplasm of African marigold and noticed that the dry matter production had highly significant and positive association with plant height (0.999) and number of lateral branches per plant (0.933). Similarly, Singh and Saha (2009) recorded that plant height showed highly positive and significant correlation with plant spread at genotypic and phenotypic levels (0.802 and 0.794, respectively). Plant spread also had highly positive correlation with total flower yield per plant. Number of flowers per plant was negatively correlated with flower size and weight of flowers.

Naik *et al.* (2005) studied the correlation analysis for 12 characters related to growth and flowering in 10 diverse genotypes of French marigold and found that plant height had a positive and significant correlation at the genotypic and phenotypic levels with spread of plant and number of lateral branches. The spread of plant was also positively and significantly correlated with size and yield of flowers per plant.

Sharma and Raghuvanshi (2011) observed that plant height had shown a positive and significant correlation with plant spread, flower yield per m<sup>2</sup> and test weight. Plant spread also showed a positive and significant correlation with seed yield per plant, seed yield per m<sup>2</sup> and test weight. Leaf area showed a positive and significant correlation with flower yield per m<sup>2</sup>.

### **2.3.2 Flowering characters**

Character association and path analysis studies were conducted by Singh and Saha (2009) in French marigold for 14 characters who observed that flower size had significant and positive correlation with weight per flower (0.665). Singh and Singh (2005b) carried out correlation and path coefficient analysis in marigold and reported that number of flowers per plant had highly positive and significant correlation with number of primary branches per plant and significant and negative correlation with days to flowering. Among the characters studied, average fresh weight of flower recorded the maximum positive direct effect (0.370) towards number of flowers per plant, whereas, number of primary branches per plant showed maximum indirect positive effect.

Karuppaiah *et al.* (2006) studied path analysis in 34 genotypes of marigold and observed that the flower head diameter exerted positive indirect effect through number of branches and days to first flowering, whereas, its effect with flower head weight influenced the yield indirectly *via* number of branches per plant. Correlation studies in 11 varieties of African marigold conducted by Janakiram and Rao (1994) and observed that days to flower had a positive and significant correlation with plant height, plant spread, number of main branches, number of flowers per plant, flower weight and total flower yield per plant, however, number of flowers per plant had a significant and positive association with plant.

### 2.3.3 Flower yield

Correlation and path analysis study in African marigold was carried out by Kavitha and Anburani (2010b) who found that the flower yield per plant exhibited highly significant and positive correlation with number of lateral branches per plant (0.996), number of flowers per plant (0.938), flower head size (0.921) and plant height (0.821). The stem girth (0.763) and dry matter production (0.740) also exhibited significant and positive correlation with flower yield. Karuppaiah *et al.* (2006) studied 34 genotypes of African marigold and observed positive and highly significant correlation of yield with the number of branches per plant, flower head diameter, flower head weight, number of flowers per plant and xanthophylls content. Singh and Saha (2009) evaluated 30 genotypes of French marigold and found positive correlation between number of flowers per plant and total flower yield per plant and between weight per flower and total flower yield per plant.

Mathew *et al.* (2005a) studied path coefficient analysis in African marigold and observed that the number of flowers per plant exhibited highest direct effect on flower yield (4.809) followed by fresh weight of flower (1.130) and plant spread (1.00). Sharma and Raghuvanshi (2011) reported that flower yield per m<sup>2</sup> was positively and significantly correlated with plant height, plant spread, leaf area and seed yield per plant in marigold. Mathew *et al.* (2005b) evaluated 15 French marigold genotypes by using the path coefficient analysis and found the maximum direct effect of number of flowers per plant and fresh weight of flower on flower yield. The number of buds and flowers per plant, fresh and dry weight of flower had positive and highly significant correlations with flower yield.

Karuppaiah and Kumar (2010) studied interrelationship between yield and certain growth and floral attributes in 34 genotypes of African marigold and reported that the flower yield per plant was found significant and positively correlated with number of branches per plant, flower size, flower weight and number of flowers per plant. Days to first flowering showed a negative association with flower yield per plant. Path analysis revealed that number of flowers per plant and xanthophylls content exhibited high positive direct effects. Namita *et al.* (2009) studied character association and path analysis of quantitative traits in marigold and observed statistically significant and positive correlation for all the characters with flower yield except days to flowering where it was non-significant and positive. However, significant and negative correlation [genotypic (-0.467) and phenotypic (-0.459)] was observed for plant height with flower yield. Mathad *et al.* (2005b) stated that flower weight, seed yield per plant and plant height exhibited maximum positive direct effect on flower yield.

## 2.4 GENETIC DIVERGENCE

Genetic divergence in 30 African marigold genotypes studied by Kavitha and Anburani (2009), on the basis of D<sub>2</sub> values, the genotypes were grouped into eight clusters. Among the eight clusters, maximum numbers of genotypes were found in cluster IV

and cluster VIII was mono genotypic. The maximum inter cluster distance was observed between cluster IV and III ( $D^2 = 30.76$ ), closely followed by cluster IV and VIII ( $D^2 = 2.16$ ). Sharma *et al.* (2013) estimated genetic divergence in carnation genotypes using  $D^2$  statistics and grouped into eight clusters in first year and six clusters in second year. The inter-cluster distance was found maximum between cluster VI and cluster VIII in first year, while in second year, it was the maximum between cluster I and cluster 11.

Manivannan *et al.* (2003) assessed the genetic divergence in 62 genotypes of sunflower. The genotypes were grouped into seventeen clusters based on their genetic diversity. Punitha *et al.* (2010) reported genetic divergence in 17 genotypes of sunflower and they were grouped all the genotypes into four clusters. Based on the inter-cluster distance, potential lines were identified from clusters-I and III for crossing programme. Bihari *et al.* (2009) assessed 15 gladiolus genotypes to know the nature and magnitude of genetic divergence using Mahalanobis  $D^2$  statistics. The population was grouped into six clusters. Cluster-I retained maximum number of treatments which showed genetic similarities.

Sheikh and Khanday (2008) grouped 62 gladiolus genotypes into five different clusters. Cluster-I, comprising maximum genotypes, and rest of clusters had only one to four genotypes. Maximum intra-cluster distance was observed in cluster-II followed by cluster-III. Similarly maximum inter cluster distance was recorded between the cluster-IV and V (70.50) followed by cluster-I and IV (52.30) respectively. Nimbalkar *et al.* (2006) grouped 101 gladiolus genotypes into 18 clusters. Cluster-I was largest with 28 genotypes, followed by cluster-II (16), cluster-IV (12), cluster-VI (10), cluster-V (8) and cluster-III (6). The maximum intra-cluster distance was exhibited by genotypes of the cluster-VI, while the lowest by the genotypes of the cluster XI to XVIII. The inter-cluster distance was highest between the cluster-IV and cluster-XI. Raj and Misra (2000) by multivariate analysis of divergence 25 genotypes of gladiolus grouped into five clusters.

## **2.5 CHARACTERIZATION**

Characterization and identification of varieties is crucial to variety release programme and in the coming times of WTO regime for the registration of the varieties. Until a collection has been properly evaluated, it has little practical use (Chang, 1976). Characterization should eventually lead to a system of recording and storing useful data that can be readily retrieved and made available to others and help in planning breeding programmes (Dabas *et al.*, 1994). Characterization of a variety is useful to identify and avoid duplication. Qualitative traits, being more stable over generations (Raut, 2003), are reliable for the characterization of varieties. Being signatory to the General Agreement on Tariffs and Trade (GATT), the Government of India has enacted its sui generis system Protection of Plant Varieties and farmers Right Act (PPV&FRA) 2001 for providing protection to plant varieties based on distinctiveness, uniformity and stability (DUS) test apart from novelty, therefore, the characterization of a variety is prerequisite (Chakravorty and Ghosh, 2012). In literature, few

research reports are available on marigold crop, therefore, work on similar aspects of other crops has also been reviewed.

Mathew (2004) categorized 30 genotypes of marigold based on morphological parameters *viz.*, plant height, plant growth habit, branching habit, stalk shape, stem pubescence, leaf colour and shape, leaflet margin and leaf pubescence and flower characters like days to first flower, flowering duration, fresh weight of flower, size of flower, floret colour and disc floret at different stages of growth. Similarly, Gupta and Datta (2005) characterized 30 cultivars of chrysanthemum based on floral characters for the preparation of chrysanthemum check list, which will help in identification of varieties and for the selection of desirable characters for cultivar.

Singh and Singh (2006) studied 29 genotypes of African marigold and characterized them on the basis of different flower characters like days taken to bud initiation, bud diameter, bud length, flower longevity and flowering duration. Sixty five genotypes of gerbera were characterized by Aswatha and Manjunatha (2006) through floral characters like stalk length, stalk diameter, number of flowers per plant and days to flower initiation. Likewise, based on growth and flowering parameters, Adhya (2010) characterized 20 genotypes of dahlia. Ghanshyam (2012) characterized 20 gladiolus cultivars based on days to sleeping stage, days to full emergence of spike, days to opening of first floret, spike length, rachis length, size of floret and number of florets per spike.

Dilta *et al.* (2004) carried out varietal identification of 10 gladiolus cultivars by characterizing the floral characters like number of days to first flowering, spike length, floret number per spike and floret diameter. Nancee (2012) reported plant habit, foliage colour, leaf form, flower colour, pedicel colour, pod colour and seed colour the important morphological characters for the identification of cowpea genotypes. Similarly, based on the observation recorded for morphological characters in the field at various stages of the plant growth, Rana (2006) categorized 32 genotypes of cluster bean into different groups.

## CHAPTER-III

### MATERIALS AND METHODS

In this chapter the details of experiment, condition of experimental field, weather conditions prevailing during experimental period, experimental materials used, sampling and sampling procedure, observations recorded, the recording and estimation methods and statistical techniques followed are described as under:

#### 3.1 Experimental site

The present investigation entitled “Evaluation and characterization in marigold” was carried at the Experimental Orchard of the Department of Horticulture, CCS Haryana Agricultural University, Hisar during winter season of both the years, *i.e.*, 2011-12 and 2012-13. Geographically, Hisar is situated at 29° 10' North latitude and 75° 46' East longitude with an elevation of 215.2 meters above mean sea level.

#### 3.2 Climate

The tract falls in the semi-arid subtropical region having the characteristic extremes of weather conditions with hot dry winds during summers and severe cold in winters. Thus, the mean maximum and minimum temperature shows a wide degree of fluctuations during summer and winter seasons. During summer, the maximum temperature of 43-45°C is quite common. On the other hand, the temperature below freezing point accompanied by frost may also occur occasionally during December to February months. The meteorological data recorded during the crop season of both the years are presented in Appendix I and II.

#### 3.3 Soil characteristics

In order to assess the chemical properties of experimental soil, the soil samples were taken randomly from different spots in the experimental area at a depth of 10-15 cm before commencement of the experiment. A representative sample was prepared and subjected to chemical analysis. The results of analysis along with methods used for determination are presented in Table 3.1.

**Table 3.1: Chemical properties of soil of the experimental field**

Properties	Value	Reference
Organic carbon (%)	0.44	Walkley and Black rapid titration method (Piper, 1966)
Available nitrogen (kg ha <sup>-1</sup> )	140.00	Alkaline KMnO <sub>4</sub> (Subbiah and Asija, 1956)
Available phosphorus (kg ha <sup>-1</sup> )	21.00	Olsen's method (Olsen <i>et al.</i> , 1954)
Available potassium (kg ha <sup>-1</sup> )	486.00	Flame photometer method (Jackson, 1973)
EC (ds m <sup>-1</sup> )	0.42	1:2 soil water suspension (Jackson, 1967)
pH	8.18	1:2 soil water suspension (Jackson, 1967)

The soil of experimental site was low in available nitrogen, medium in available phosphorous and high in available potash and organic carbon. Based on pH and electrical conductivity, it was concluded that the soil was well suited for cultivation of marigold crop.

### **3.4 Experimental details and layout**

The study was undertaken on two species of marigold namely, *Tagetes erecta* (African marigold) and *Tagetes patula* (French marigold). The details of the experiment are as under:

Experiment design	:	Randomized Block Design (RBD)
Total number of genotypes	:	30
Replication	:	3
Spacing	:	40 cm x 40 cm
Plot size	:	3.2 m x 1.20 m
Number of plants per plot	:	24
Total number of plots	:	90

### **3.5 Experimental plant material**

The experimental material for present investigation was taken from previously maintained germplasm at Research Farm of the Department of Horticulture, CCS Haryana Agricultural University, Hisar. The experimental consisted of 30 genotypes listed in table 3.2.

### **3.6 Details of field operation**

#### **3.6.1 Method of seedlings preparation**

Nursery beds of convenient size (3 m length, 1 m width and 15 cm height) were prepared by adding well rotten farmyard manure at five-kilogram/m<sup>2</sup>. The seeds were sown on 10th August 2011-12 and 2012-13 in rows spaced at 6.0 to 8.0 cm and covered with thin layer of well rotten fine compost to ensure germination. The beds were watered every evening with water can and necessary precautions were taken against insect-pests and diseases.

#### **3.6.2 Preparation of the field**

The experimental area was ploughed well by disc plough and tilled several times to bring the soil to fine tilth by cultivator. The plots were prepared measuring 3.2 m in length and 1.2 m in width.

#### **3.6.3 Manure and fertilizers**

The experimental soil being low in nitrogen, medium in phosphorous and high in potash content, a basal dose of well rotten farmyard manure was incorporated @ 5 kg/m<sup>2</sup> into the soil at the time of field preparation to improve the fertility of the field. In addition, the

nitrogen was applied @ 10 g, phosphorous and potash each 10 g/m<sup>2</sup>. Half the quantity of nitrogen and full dose of phosphorus and potash were applied at the time of transplanting, while the remaining dose of nitrogen was applied one month after transplanting. Nitrogen was applied in the form of urea, phosphorous in the form of single super phosphate (SSP) and potassium in the form of murate of potash (MOP).

**Table 3.2: Details of the marigold genotypes**

Sr. No.	Genotypes	Type	Colour of floret
1.	Hisar Beauty	French	Dark Red, petals with yellow margin
2.	Hisar Jaffri-2	French	Orange
3.	MGH-09-271	African	Lemon with green centre
4.	MGH-09-276	African	Orange
5.	MGH-09-276-1	African	Lemon with green centre
6.	MGH-09-301	African	Golden
7.	MGH-09-302	African	Dark orange
8.	MGH-09-303	African	Orange
9.	MGH-09-304	African	Orange
10.	MGH-09-305	African	Dark orange
11.	MGH-10-101	African	Pure lemon
12.	MGH-133-1-1	African	Lemon with green center
13.	MGH-133-1-2	African	Yellow
14.	MGH-133-1-3	African	Pure green lemon
15.	MGH-133-2	African	Lemon white
16.	MGH-133-3-2	African	Light lemon
17.	MGH-133-5	African	Lemon with red centre
18.	MGH-133-5-2	African	Lemon with green centre
19.	MGH-148-3-3	African	Orange
20.	MGH-148-8	African	Golden orange
21.	MGH-160-5-1	African	Yellow
22.	MGH-160-5-2	African	Golden yellow
23.	MGH-160-5-3	African	Yellow orange
24.	MGH-160-7-1	African	Orange (flat)
25.	MGH-160-8-3-2	African	Golden
26.	MGH-160-9	African	Golden
27.	MGH-160-9-1	African	Golden yellow
28.	MGH-160-9-3	African	Orange
29.	MGH-160-9-4	African	Pale lemon
30.	MGH-07-160-8-3-3	African	Orange



**Plate 1: General view of marigold field at vegetative stage**



**Plate 2: General view of marigold field at flowering stage**

### **3.6.4 Transplanting of seedlings**

The treatments were laid out in randomized block design with three replications. One-month-old seedlings having 5-7 leaves were transplanted on 10th September 2011-12 and 2012-13. The spacing between row-to-row and plant-to-plant was kept 40 cm x 40 cm. A light irrigation was given immediately after transplanting for better establishment of seedlings in the field.

## **3.7 Cultural operations**

### **3.7.1 Gap filling**

Gap filling was done one week after transplanting and *per se*, the required plant population was maintained in plot of each treatment.

### **3.7.2 Irrigation**

The experimental plots were irrigated at an interval of one week at initial stages and 12-15 days at later stages to maintain optimum moisture throughout the experimentation.

### **3.7.3 Pinching**

The African marigold seedlings were pinched one month after transplanting in order to break their apical dominance so as to increase their lateral spread, whereas, the French marigold seedlings were kept without pinching.

### **3.7.4 Weeding**

Weeds compete with crop plants for nutrients, moisture, space and light, therefore, for better growth and development of crop plants, the experimental field was kept weed-free by hand weeding and hoeing at regular intervals.

### **3.7.5 Staking**

After 35-40 days of transplanting, each plant was supported by 75-80 cm long bamboo stick to keep the plants erect. The plant with bamboo stick was fastened loosely using a jute string to avoid lodging.

### **3.7.6 Plant protection**

The prophylactic measures were adopted timely and uniformly as and when required to protect the crop against insect-pests and diseases.

## **3.8 Plant tagging**

Five plants were selected randomly in each treatment plot and tagged for the purpose of recording data on various parameters.

## **3.9 Observations recorded**

The following observations were recorded on the tagged plants at different stages of plant growth, flowering and yield characters.

### **3.9.1 Plant characters**

Based on descriptors, the plant characters were identified as described below:

**3.9.1.1 Plant growth habit:** Plant growth habit was observed based on the nature of plant spread with narrow or wide crotch angle and divided into two categories as

- a. Compact
- b. Open

**3.9.1.2 Branching habit:** The branching habit was recorded based on origin of the primary branches on main stem and divided into five classes as

- a. No branch
- b. Basal
- c. Middle
- d. Top
- e. Full

**3.9.1.3 Stem colour:** The stem colour was determined based on visual observation of stem colour and divided into four classes as

- a. Green
- b. Dark green
- c. Purple
- d. Purple strips

**3.9.1.4 Stem shape:** The stem shape was determined based on the presence or absence of ridges on main stem and divided into two groups

- a. Smooth
- b. Ridged

**3.9.1.5 Stem pubescence:** The stem pubescence was classified based on presence or absence of hair on stem surface and divided into two categories

- a. Glabrous
- b. Non-glabrous

**3.9.1.6 Leaf colour:** The leaf colour was determined on the basis of visual observation of leaf colour and classified into four classes

- a. Pale green
- b. Light green
- c. Dark green
- d. Purple

**3.9.1.7 Leaflet shape:** The leaflet shape was determined based on visual observation of size and shape, whether the width of leaf is small, gradually tapering, or wider at centre with sharply tapering towards the tip. It was categorized into two groups

- a. Narrow pointed
- b. Oval pointed

**3.9.1.8 Leaflet margin:** The leaflet margin was determined based on type of serration. The teeth present on the leaf margin were indistinct, fine, deep, and distinct and were divided into

- a. Smooth
- b. Serrated
- c. Highly serrated

**3.9.1.9 Leaf pubescence:** The roughness and smoothness of leaf surface was examined and grouped as

- a. Glabrous
- b. Non-glabrous

**3.9.1.10 Disc floret:** Based on visibility of disc floret, the flowers were categorized into two classes

- a. Visible
- b. Non-visible

### **3.9.2 Growth characters**

**3.9.2.1 Plant height (cm):** Plant height was measured from base to the tip of the main stem at full bloom stage in each tagged plant with the help of meter scale. The average height was then worked out in cm. The plants based on height were categorized as

- a. Short - <60 cm
- b. Medium - 60-80 cm
- c. Tall - >80 cm

**3.9.2.2 Plant spread (cm):** The plant spread in North-South and East-West direction was recorded in centimetre at full bloom stage with the help of measuring scale and the average plant spread was worked out.

**3.9.2.3 Stem diameter (cm):** Diameter of the stem in each tagged plant of each plot was measured with the help of digital Vernier Calliper just above the ground level and the average was calculated.

**3.9.2.4 Stalk length (cm):** Length of stalk was measured from node to the peduncle of flower in each tagged plant of each plot and categorized into three categories

- a. Short - <10 cm
- b. Medium - 10-15 cm
- c. Long - >15 cm

**3.9.2.5 Number of primary branches per plant:** The number of branches arising from the main stem was counted at the time of full bloom on five representative plants in each plot.

**3.9.2.6 Number of secondary branches per plant:** The number of branches arising from the primary branch was counted at the time of full bloom on five representative plants in each plot.

**3.9.2.7 Fresh weight of plant (g):** Fresh weight of five randomly selected plants from each replication was recorded in gram with the help of electronic balance and average fresh weight was calculated.

**3.9.2.8 Dry weight of plant (g):** The plants taken for fresh weight were first dried at room temperature and thereafter dried in oven until the reduction in weight becomes constant then the weight was recorded as mean of five plants and expressed in grams.

### **3.9.3 Flowering characters**

**3.9.3.1 Days taken to first flower opening:** The number of days taken from transplanting to the appearance of first flower in representative plants in each plot was counted, and based on the days taken to first flower opening, the genotypes were categorized into three classes as

- a. Early - <45 days
- b. Mid - 45-55 days
- c. Late - >55 days

**3.9.3.2 Duration of flowering (days):** The total number of days was counted from the day of flower initiation to the end of flowering from representative plants in each plot. Based on duration of flowering, the genotypes were categorized into three groups

- a. Short - <45 days
- b. Medium - 45-55 days
- c. Long - >55 days

**3.9.3.3 Number of buds per plant:** The total number of buds on five randomly selected plants from each replication was counted and their average was calculated.

**3.9.3.4 Number of flowers per plant:** The total number of flowers on five randomly selected plants from each replication was counted at the end of flowering and their average was calculated. Based on average flowers per plant, the genotypes were classified as

- a. Less - <45
- b. Medium - 45-60
- c. More - >60

**3.9.3.5 Flower diameter (cm):** The flower diameter was taken at complete opening stage by using digital Vernier Calliper and mean of ten flowers from each representative plant in each plot was calculated. Based on average diameter, the flowers were classified as

- a. Small - <5.0 cm
- b. Medium - 5.0-6.5 cm
- c. Big - >6.5 cm

**3.9.3.6 Fresh weight of flower (g):** The average weight of ten flowers plucked randomly from each plant was recorded immediately after harvest. Based on average weight, the flowers were categorized into three groups

- a. Low - <5.5 g
- b. Medium - 5.5-8.5 g
- c. High - >8.5 g

**3.9.3.7 Dry weight of flower (g):** The flowers taken for fresh weight were first dried in shade and then oven dried until the reduction in weight becomes constant, and *per se*, the mean weight of ten flowers was worked out.

### **3.9.4 Flower yield**

**3.9.4.1 Flower yield per plant (g):** The average fresh weight of a flower multiplied by the number of flowers constituted the flower yield per plant and expressed in grams.

**3.9.4.2 Flower yield per plot (kg):** Flower yield of a randomly selected plant was multiplied by number of plants in a plot and recorded in kilograms.

**3.9.4.3 Flower yield per hectare (q):** The flower yield per plot was converted to hectare basis, which reflected the yield per hectare.

### **3.10 Statistical analysis**

The data obtained on various characters were subjected to statistical analysis as per randomized block design and interpretation of the data was carried out in accordance with Panse and Sukhatme (1978). The levels of significance used in F and t test were 5 and 1%.

The critical difference was calculated wherever the F test was significant. The data pertaining to above characters were subjected to the following analysis.

### 3.10.1. Analysis of variance

To test variation among the genotypes, analysis of variance was carried out as per the method suggested by Panse and Sukhatme (1967).

#### Skeleton of ANOVA

Source	d.f.	S.S.	M.S.	F
Replication	r-1	SSr	MSr	MSr/MSe
Genotype	g-1	SSg	MSg	MSg/MSe
Error	(r-1)(g-1)	Sse	MSe	
Total	(rg-1)	TSS		

### 3.10.2. Estimation of variability parameters

**Mean:** The mean value of each character was worked out by dividing the totals with corresponding number of observations.

$$X = \frac{\sum X_{ij}}{n}$$

Where,

X = Mean

X<sub>ij</sub> = Observation of j<sup>th</sup> replication and i<sup>th</sup> genotype

n = Total number of observations

**Range:** It is the difference between the lowest and highest value for each character.

**Standard error:** The standard error of mean was calculated with the help of error mean squares from the analysis of variance table as under:

$$S.E.M = \frac{\sigma^2 E}{r}$$

#### Genotypic and phenotypic coefficient of variation (GCV and PCV)

The coefficient was computed according to method suggested by Burton (1952).

$$GCV = \frac{\sigma^2 g}{X} \times 100$$

$$PCV = \frac{\sigma^2 p}{X} \times 100$$

### Genotypic and phenotypic variance

These were estimated according to the formulae given by Panse and Sukhatme (1978) for randomized block design.

$$\text{Error variance } (\sigma^2e) = \text{MSe}$$

$$\text{Genotypic variance } (\sigma^2g) = \frac{\text{MSg} - \text{MSe}}{r}$$

$$\text{Phenotypic variance } (\sigma^2p) = \sigma^2g + \sigma^2e$$

Mg = Mean sum of square for genotypes

Me = Mean sum of square for error

r = Number of replications

$\sigma^2e$  = Error variance

### Heritability (broad sense)

The total phenotypic variability depicted by a trait is composed of heritable and non-heritable components of variability. Heritability refers to the proportion of variability, which is heritable in nature to the total variability. It is due to genetic causes, whereas, non-heritable variability is contributed by error variance. Heritability in broad sense was calculated according to the following formulae suggested by Hanson *et al.* (1956).

$$H(b) = \frac{\sigma^2g}{\sigma^2p} \times 100$$

Where,

H(b) = Heritability (broad sense)

$\sigma^2g$  = Genotypic variance

$\sigma^2p$  = Phenotypic variance

### Critical difference

The critical difference for all the characters was calculated to compare the cultivars as per the following formula:

$$CD = S.Em \sqrt{2} \times t \text{ at error d.f.}$$

### Genetic advance

The expected genetic advance represents the shift in a population mean towards superior side under some selection pressure after single generation. The formula given by Johnson *et al.* (1955) was used.

$$GA = H(b) \times K \times \sigma_p$$

Where,

- GA = Expected genetic advance  
H(b) = Heritability (broad sense)  
K = Selection differential K = 2.06 at 5% selection intensity (Allard, 1960)  
 $\sigma_p$  = Phenotypic standard deviation

### Genetic advance expressed as percentage of mean

It was calculated by using the method suggested by Johnson *et al.* (1955).

$$\text{Genetic advance} = \frac{GA}{X} \times 100$$

Where,

- GA = Expected genetic advance  
X = Mean of the character under study

### 3.10.3 Correlation coefficient

Genotypic and phenotypic correlations among all the characters under study were estimated as per the method given by Searle (1961).

#### i) Genotypic correlation between x and y characters

$$r_{xy}(g) = \frac{\text{Cov}_{xy}(g)}{\sigma^2_g(x) \cdot \sigma^2_g(y)}$$

#### ii) Phenotypic correlation between x and y characters

$$r_{xy}(p) = \frac{\text{Cov}_{xy}(p)}{\sigma^2_p(x) \cdot \sigma^2_p(y)}$$

The test of significance for phenotypic correlation was tested at n-2 degree of freedom using r table.

$\text{Cov}_{xy}(g)$  and  $\text{Cov}_{xy}(p)$  denote genotypic and phenotypic covariance between character x and y, respectively.

$\sigma^2_g(x)$  and  $\sigma^2_p(x)$  denote genotypic and phenotypic variance for character x and  $\sigma^2_g(y)$  and  $\sigma^2_p(y)$  denote genotypic and phenotypic variance for character y.

### 3.10.4 Path coefficient analysis

The genotypic correlation coefficients were used to work out path coefficient analysis. The path coefficients were obtained as per the method suggested by Dewey and Lu (1959). A set of simultaneous equations in the following form were solved.

$$r_{ny} = P_{ny} + r_{n2} P_{2y} + r_{n3} P_{3y} + \dots + r_{nx} P_{xy}$$

$r_{ny}$  = correlation coefficient of one character and yield

$P_{ny}$  = path coefficients between the character and the yield

$r_{n2}, r_{n3}, \dots, r_{nx}$  = represents correlation coefficient of that character and each of the yield components in turn

The following correlation matrices were formed.

Matrix A	Matrix B	
$R_{1y}$	$r_{11}, r_{12}, r_{13} \dots r_{1n}$	$P_{1y}$
$R_{2y}$	$r_{21}, r_{22}, r_{23} \dots r_{2n}$	$P_{2y}$
$R_{3y}$	$r_{31}, r_{32}, r_{33} \dots r_{3n}$	$P_{3y}$
-	-	-
-	-	-
-	-	-
$R_{ny}$	$r_{n1}, r_{n2}, r_{n3} \dots r_{nn}$	$P_{ny}$

The technique given by Goulden (1954) was followed by inversion ( $B^{-1}$ ) of B matrix, and path coefficients  $P_{ij}$  were obtained by using the following formula:

$$P_{ij} = (B^{-1}) \times (A)$$

The indirect effects for a particular character through other characters were obtained by the multiplication of direct path and particular correlation coefficient between those two characters, respectively.

$$\text{Indirect effect} = r_{ij} \times P_{ij}$$

Where,

$$i = 1 \dots n$$

$$j = 1 \dots n \text{ and}$$

$$P_{ij} = P_{1y}, P_{2y} \dots P_{ny}$$

The individual factor, *i.e.*, the variation in yield unaccounted for those associations, was calculated from the following formula:

$$\text{Residual factor (x)} = 1 - R^2$$

Where,

$$R^2 = P_{1y} r_{1y} + P_{2y} r_{2y} + \dots + P_{ny} r_{ny}$$

$R^2$  is the squared multiple correlation coefficients and is the amount of variation in yield that can be accounted for by the effect of yield contributing components on yield.

### 3.10.5 Multivariate genetic divergence analysis (Mahalanobis, 1936)

Variance and covariance were subjected to multivariate analysis and the original interrelated variables (X's) were first transformed into a set of mutually uncorrelated variables (y's as linear function of x's) and the  $D^2$  values were worked out. Pivotal condensation method was used to compute inverse matrix of the error dispersion matrix (Rao, 1952). The generalized distance function ( $D^2$ ) between two genotypes is simply sum of square of difference in y's.

$$D^2 = \sum_{i=1}^p (Y_{1i} - Y_{2i})^2$$

The value between the variables based on p characters is:

$$D_p^2 = \sum_{i=1}^p \sum_{j=1}^p (W_{ij} d_i d_j)$$

Where,

- $D^2$  = Value between the variables on the basis of P characters
- $W_{ij}$  = Inverse matrix of pooled common dispersion obtained from error matrix
- $d$  = Difference of mean value for character of respective genotypes as indicated by i & j in brief the steps involved for the estimation of  $D^2$  values are as follows (Rao,1952)
  - a. Pivotal condensation of error variance and covariance matrix to obtain inverse matrix
  - b. Transformation of original correlated data into uncorrelated variables
  - c. Calculation of mean value of transformed characters
  - d. Calculation of  $D^2$  values

For each combination, deviation between the means was computed and  $D^2$  values were computed, arranged in the form of matrix and following grouping and mean estimates were made.

#### i. Determination of group constellations

As such, no standard rule exists for making clustering because cluster is not a well-defined term. The only criterion appears to be that any two genotypes included in same cluster should at least, on an average, show  $D^2$  value smaller than those belonging to two different clusters. The  $D^2$  values for all genotype combinations presented in the matrix form were arranged in increasing order of magnitude, and the clustering was done according to Tocher's Method suggested by Rao (1952).

At first, the two most closely associated genotypes were chosen and then third genotype was located, which had the smallest  $d^2$  value with these first two genotypes.

Similarly, the fourth genotypes were chosen to have smallest average  $d^2$  values with first three genotypes. This procedure continued, and with the addition of new genotypes, the average  $d^2$  values of the cluster increased gradually. The new genotypes were added to the cluster so long as an increase in average  $d^2$  values became abruptly higher than the highest distance values between any two genotypes at rank position number one in the increasing order of  $d^2$  matrix. Clustering was truncated by excluding that genotype to start constructing the next cluster. Now, the genotypes of first cluster were omitted, and the remaining genotypes were treated in similar fashion for constructing new cluster. A few genotypes, which had comparatively very high  $d^2$  values from the other, formed independent single genotypes cluster.

**ii. Intra- and inter-cluster distance**

The intra-cluster  $d^2$  values was calculated as the sum of  $n(n-1)$  possible pair  $d^2$  values among the genotypes within a cluster divided by  $n(n-1)$  pairs. The single genotype always has the zero intra-cluster  $d^2$  values. For calculating the intra-cluster  $d^2$  value, all the possible  $d^2$  pair values between genotypes of the two clusters were added and divided by  $n_1 n_2$  where,  $n_1$  and  $n_2$  are the number of genotypes in first and second cluster, respectively. The intra- and inter-cluster distances were calculated by taking the squared root of respective  $d^2$  values between genotypes of a particular cluster and between genotypes belonging to two different clusters, respectively.

**iii. Cluster mean value**

The cluster mean of particular character is the summation of original data values of all genotypes included in a cluster , divided by the total number of genotypes in that cluster.

The results of the experiment entitled “**Evaluation and characterization in marigold**” have been presented in this chapter. The data recorded on various morphological, growth, flowering and yield parameters of 30 marigold genotypes were subjected to statistical analysis for comparison and to work out variability, correlation and path coefficient, and the results of present investigation obtained have been interpreted under the following heads:

- 4.1 Analysis of variance
- 4.2 Mean performance of marigold genotypes
- 4.3 Characterization
- 4.4 Variability parameters
- 4.5 Correlation coefficient analysis
- 4.6 Path coefficient analysis
- 4.7 Divergence analysis

#### **4.1 ANALYSIS OF VARIANCE**

The analysis of variance of all the 18 characters observed in the present study on 30 marigold genotypes was carried out to test the significance of difference among the genotypes investigated. The mean sums of square of all the characters are presented in Table 4.1 and 4.2. Analysis of variance revealed that all the genotypes differed significantly from each other even at 1% level of probability for all the characters studied, exhibiting wide variation in the material investigated.

#### **4.2 MEAN PERFORMANCE OF MARIGOLD GENOTYPES**

##### **4.2.1 Growth characters**

The mean performance of growth characters observed on all individual genotypes in the year 2011-12 and 2012-13 are presented in Table 4.3 and 4.5.

##### **4.2.1.1 Plant height (cm)**

The genotypes showed highly significant differences with respect to plant height. The plant height ranged from 32.07 to 105.97 cm with mean value 72.50 cm in the year 2011-12. The maximum plant height was recorded in genotype MGH-09-303 (105.97 cm) followed by MGH-160-9-4 (99.48 cm) and MGH-09-276-1 (96.76 cm), whereas, the minimum plant height (32.07 cm) was observed in Hisar Beauty. In the year 2012-13, the plant height ranged from 32.72 to 106.07 cm with mean values of 75.08. The tallest plant (106.07 cm) was

observed in the genotype MGH-160-9-4 being at par with MGH-09-276-1(102.77 cm) and MGH-09-303 (101.53 cm), whereas, shortest plant (32.72 cm) was found in Hisar Beauty.

#### **4.2.1.2 Plant spread (cm)**

Plant spread ranged from 31.92 to 76.53 cm with mean value 49.08 cm in the year 2011-12, while in the year 2012-13, it was 35.06 to 78.90 cm with mean value 50.58 cm. The maximum plant spread (76.53 and 78.90 cm) was recorded in genotype Hisar Jaffri-2 in both the years, whereas, the minimum plant spread was found in genotype MGH-160-8-3-2 (31.92 cm) and Hisar Beauty (35.06 cm) in the year 2011-12 and 2012-13, respectively.

#### **4.2.1.3 Stem diameter (cm)**

The stem diameter varied from 0.58 to 2.18 cm with mean value of 1.32 cm in the year 2011-12 and 0.63 to 2.09 cm with mean value 1.33 cm in the year 2012-13. The maximum stem diameter (2.18 and 2.09 cm) was recorded in MGH-148-3-3 and minimum (0.58 and 0.63 cm) in Hisar Beauty in the year 2011-12 and 2012-13, respectively.

#### **4.2.1.4 Stalk length (cm)**

In present study, the average stalk length ranged between 4.52 and 26.36 cm with mean value 15.14 cm in the year 2011-12. The longest stalk length (26.36 cm) was recorded in genotype MGH-160-9-4, which was at par with MGH-133-5-2 (24.77 cm), while the shortest stalk length (4.52 cm) was observed in Hisar Beauty. In the year 2012-13, the stalk length values ranged from 4.24 to 27.69 cm with mean value of 14.93 cm. The maximum stalk length (27.69 cm) was found in genotype MGH-160-9-4 followed by MGH-148-8 (23.43 cm) and MGH-09-304 (22.75 cm), whereas, the minimum stalk length (4.24 cm) was observed in genotype Hisar Beauty.

#### **4.2.1.5 Number of primary branches per plant**

The number of primary branches per plant ranged from 8.13 to 23.47 with mean value of 12.69 in the year 2011-12, while in the year 2011-12, it was 8.87 to 25.53 with mean value 12.93. The highest number of primary branches per plant (23.47 and 25.53) was observed in genotype Hisar Jaffri-2, which was statistically superior to all other genotypes and the minimum (8.13 and 8.87) in genotype MGH-10-101 in the year 2011-12 and 2012-13, respectively.

**Table 4.1: Analysis of variance for different characters of marigold genotypes during 2011-12**

Sr. No.	Characters	Mean sum of square		
		Replication	Genotypes	Error
<b>A. Growth characters</b>				
1.	Plant height (cm)	1.73	883.06**	9.14
2.	Plant spread (cm)	12.22**	412.56**	11.16
3.	Stem diameter (cm)	0.004	0.305**	0.004
4.	Stalk length(cm)	0.12	104.05**	1.14
5.	No. of primary branches per plant	3.19*	50.72**	0.89
6.	No. of secondary branches per plant	2.74	1399.41**	11.08
7.	Fresh weight of plant (g)	71.23**	180731.53**	82.19
8.	Dry weight of plant (g)	25.43**	2333.77**	25.40
<b>B. Flowering characters</b>				
9.	Days taken to first flower opening	0.39	136.23**	12.14
10.	Duration of flowering	31.87**	437.98**	12.02
11.	No. of buds per plant	32.73**	2493.10**	17.60
12.	No. of flowers per plant	7.90**	2035.42**	22.83
13.	Flower diameter (cm)	0.03	3.11**	0.06
14.	Fresh weight of flower (g)	0.41	17.40**	0.13
15.	Dry weight of flower (g)	0.01	0.41**	0.01
<b>C. Flower yield</b>				
16.	Flower yield per plant (g)	4968.44**	96809.19**	1633.24
17.	Flower yield per plot (kg)	2.86	55.76**	0.94
18.	Flower yield per hectare (q)	1940.72**	37815.96**	637.98

\*, \*\* p ≤ 0.05 and 0.01, respectively

**Table 4.2: Analysis of variance for different characters of marigold genotypes during 2012-13**

Sr. No.	Characters	Mean sum of square		
		Replication	Genotypes	Error
<b>A. Growth characters</b>				
1.	Plant height (cm)	4.64*	957.38**	14.30
2.	Plant spread (cm)	36.93**	407.96**	14.28
3.	Stem diameter (cm)	0.01	0.30**	0.01
4.	Stalk length(cm)	0.38	98.09**	0.49
5.	No. of primary branches per plant	2.11	46.98**	1.62
6.	No. of secondary branches per plant	2.45	1653.91**	69.35
7.	Fresh weight of plant (g)	492.28**	160070.61**	794.56
8.	Dry weight of plant (g)	18.40**	1848.20**	17.18
<b>B. Flowering characters</b>				
9.	Days taken to first flower opening	16.74**	108.07**	13.75
10.	Duration of flowering	7.34**	472.35**	16.55
11.	No. of buds per plant	3.97*	3203.98**	22.59
12.	No. of flowers per plant	30.16**	2434.61**	29.90
13.	Flower diameter (cm)	0.39	3.09**	0.16
14.	Fresh weight of flower (g)	0.16	21.00**	0.22
15.	Dry weight of flower (g)	0.04	0.31**	0.03
<b>C. Flower yield</b>				
16.	Flower yield per plant (g)	4556.82**	98810.92**	4055.70
17.	Flower yield per plot (kg)	2.64	56.92**	2.34
18.	Flower yield per hectare (q)	1779.81**	38597.97**	1584.28

\*, \*\* p ≤ 0.05 and 0.01, respectively

**Table 4.3: Mean performance of genotypes for different characters in marigold during 2011-12**

<b>Sr. No.</b>	<b>Genotypes</b>	<b>Plant height (cm)</b>	<b>Plant spread (cm)</b>	<b>Stem diameter (cm)</b>	<b>Stalk length (cm)</b>	<b>No. of primary branches per plant</b>	<b>No. of secondary branches per plant</b>	<b>Fresh weight of plant (g)</b>	<b>Dry weight of plant (g)</b>
1.	Hisar Beauty	32.07	32.86	0.58	4.52	9.87	36.60	79.89	9.37
2.	Hisar Jaffri-2	64.03	76.53	1.58	11.50	23.47	140.27	1092.06	126.48
3.	MGH-09-271	73.61	58.88	1.34	8.80	13.00	42.47	247.07	38.62
4.	MGH-09-276	61.29	50.03	1.61	11.02	10.47	46.87	331.52	42.43
5.	MGH-09-276-1	96.76	70.53	1.05	12.73	13.40	68.87	484.79	55.91
6.	MGH-09-301	61.37	42.33	1.30	16.69	12.60	65.87	561.46	71.66
7.	MGH-09-302	51.79	59.56	0.89	7.74	8.60	36.53	224.20	30.38
8.	MGH-09-303	105.97	43.03	1.41	15.98	9.73	45.13	287.53	35.86
9.	MGH-09-304	60.32	56.95	1.61	17.88	13.07	49.53	372.24	54.41
10.	MGH-09-305	82.35	63.18	1.45	21.29	11.93	28.00	318.79	36.79
11.	MGH-10-101	77.17	55.53	1.38	23.44	8.13	28.53	204.37	26.43
12.	MGH-133-1-1	86.63	46.61	1.42	15.47	9.47	46.63	247.07	23.72
13.	MGH-133-1-2	79.20	47.23	1.37	19.67	12.27	43.73	217.25	35.60
14.	MGH-133-1-3	93.66	46.25	1.41	11.12	10.60	64.93	527.33	59.84
15.	MGH-133-2	77.39	40.80	1.38	22.62	11.53	40.13	245.85	29.07

Contd.....

Contd.....

16.	MGH-133-3-2	95.27	33.17	0.83	7.21	9.13	26.00	168.13	25.62
17.	MGH-133-5	66.90	50.93	1.06	14.07	11.00	65.07	389.23	45.18
18.	MGH-133-5-2	78.41	41.39	1.32	24.77	16.80	48.67	279.14	32.72
19.	MGH-148-3-3	65.15	68.23	2.18	16.15	10.73	59.73	1197.50	139.00
20.	MGH-148-8	80.99	35.61	1.83	21.10	8.53	56.47	535.52	63.35
21.	MGH-160-5-1	82.25	56.53	1.27	10.89	12.20	38.87	256.50	27.88
22.	MGH-160-5-2	90.53	47.33	0.92	17.87	12.67	51.00	480.79	57.17
23.	MGH-160-5-3	78.08	48.88	1.10	16.23	10.53	40.73	254.92	33.14
24.	MGH-160-7-1	85.35	40.17	1.36	18.97	19.07	30.07	209.98	28.15
25.	MGH-160-8-3-2	46.45	31.92	1.65	6.79	14.73	25.80	314.78	38.81
26.	MGH-160-9	70.64	42.81	1.11	19.09	8.87	41.40	203.44	26.78
27.	MGH-160-9-1	75.51	63.41	1.36	12.64	9.80	42.33	486.41	56.98
28.	MGH-160-9-3	72.81	38.63	1.06	16.34	22.13	55.20	234.89	30.68
29.	MGH-160-9-4	99.48	47.53	1.58	26.36	21.47	53.33	506.01	58.67
30.	MGH-07-160-8-3-3	43.65	35.60	1.16	5.21	14.93	21.40	191.61	22.73
	<b>Mean</b>	<b>72.50</b>	<b>49.08</b>	<b>1.32</b>	<b>15.14</b>	<b>12.69</b>	<b>48.01</b>	<b>371.68</b>	<b>45.45</b>
	<b>C.D. at 5%</b>	<b>4.95</b>	<b>5.48</b>	<b>0.10</b>	<b>1.75</b>	<b>1.55</b>	<b>5.46</b>	<b>14.85</b>	<b>8.26</b>
	<b>C.D. at 1%</b>	<b>6.57</b>	<b>7.27</b>	<b>0.13</b>	<b>2.32</b>	<b>2.05</b>	<b>7.24</b>	<b>19.71</b>	<b>10.96</b>

**Table 4.4: Mean performance of genotypes for different characters in marigold during 2011-12**

Sr. No.	Genotypes	Days taken to first flower opening	Duration of flowering (days)	No. of buds per plant	No. of flowers per plant	Flower diameter (cm)	Fresh weight of flower (g)	Dry weight of flower (g)	Flower yield per plant (g)	Flower yield per plot (kg)	Flower yield per hectare (q)
1.	Hisar Beauty	36.80	48.20	48.87	43.47	4.32	2.44	0.26	106.73	2.56	66.68
2.	Hisar Jaffri-2	61.20	71.93	201.80	179.53	4.06	4.85	0.59	869.18	20.86	543.24
3.	MGH-09-271	49.33	46.47	65.73	52.60	7.81	15.21	2.17	799.59	19.19	499.75
4.	MGH-09-276	52.87	51.60	70.80	54.20	8.10	13.38	2.05	724.34	17.38	452.71
5.	MGH-09-276-1	44.33	45.87	75.73	65.13	6.89	9.63	1.17	627.72	15.07	392.33
6.	MGH-09-301	49.87	66.87	67.40	55.73	6.81	9.49	1.14	528.02	12.67	330.01
7.	MGH-09-302	39.67	64.47	55.33	47.33	6.47	9.35	1.03	441.97	10.61	276.23
8.	MGH-09-303	49.93	34.67	61.40	57.53	6.64	10.01	1.42	575.19	13.81	359.50
9.	MGH-09-304	45.13	70.13	66.93	51.27	7.02	8.90	1.04	455.08	10.92	284.43
10.	MGH-09-305	50.47	51.73	54.93	40.93	6.30	8.02	0.89	328.17	7.88	205.11
11.	MGH-10-101	59.00	37.53	46.33	39.53	5.37	6.74	1.08	266.68	6.40	166.68
12.	MGH-133-1-1	47.93	41.53	56.00	47.27	5.21	6.13	0.78	288.73	6.93	180.45
13.	MGH-133-1-2	42.13	32.40	60.40	53.40	5.98	7.83	0.85	418.23	10.04	261.39
14.	MGH-133-1-3	57.13	45.60	69.47	54.33	5.44	9.91	1.15	538.66	12.93	336.66
15.	MGH-133-2	41.40	34.93	54.73	44.20	5.17	7.21	0.91	318.36	7.64	198.98

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16.	MGH-133-3-2	56.07	65.00	50.67	37.33	6.38	10.40	1.18	386.84	9.28	241.77
17.	MGH-133-5	38.07	43.47	81.93	73.87	5.25	7.64	0.93	564.31	13.54	352.69
18.	MGH-133-5-2	50.93	29.93	62.73	57.13	5.42	6.27	0.81	357.92	8.59	223.70
19.	MGH-148-3-3	50.27	65.87	85.33	72.47	7.16	8.87	1.17	642.72	15.43	401.70
20.	MGH-148-8	59.20	61.00	83.67	62.73	7.30	9.48	1.06	594.55	14.27	371.60
21.	MGH-160-5-1	56.00	39.27	43.60	36.27	7.04	9.37	1.13	337.35	8.10	210.85
22.	MGH-160-5-2	55.07	55.33	66.93	53.73	6.25	7.53	0.92	406.63	9.76	254.14
23.	MGH-160-5-3	40.60	42.33	74.13	54.87	5.06	5.84	0.70	321.40	7.71	200.88
24.	MGH-160-7-1	45.60	49.13	41.60	36.53	5.17	5.69	0.67	208.56	5.01	130.35
25.	MGH-160-8-3-2	44.67	43.72	39.53	28.07	7.11	8.65	1.08	243.88	5.85	152.42
26.	MGH-160-9	42.93	43.00	54.20	49.40	6.25	7.81	1.07	385.01	9.24	240.63
27.	MGH-160-9-1	43.13	51.27	62.13	54.87	7.44	8.48	1.02	466.16	11.19	291.35
28.	MGH-160-9-3	41.07	55.13	63.07	56.20	6.97	8.04	0.99	451.35	10.83	282.09
29.	MGH-160-9-4	48.20	30.07	74.27	60.67	6.32	7.66	0.85	465.36	11.17	290.85
30.	MGH-07-160-8-3-3	52.87	40.33	33.60	28.07	5.28	6.41	0.70	182.01	4.37	113.76
	<b>Mean</b>	<b>48.40</b>	<b>48.63</b>	<b>65.78</b>	<b>54.97</b>	<b>6.20</b>	<b>8.24</b>	<b>1.03</b>	<b>443.36</b>	<b>10.64</b>	<b>227.10</b>
	<b>C.D. at 5%</b>	<b>5.71</b>	<b>5.68</b>	<b>6.87</b>	<b>7.83</b>	<b>0.42</b>	<b>0.59</b>	<b>0.19</b>	<b>66.22</b>	<b>1.59</b>	<b>41.39</b>
	<b>C.D. at 1 %</b>	<b>7.58</b>	<b>7.44</b>	<b>9.12</b>	<b>10.39</b>	<b>0.55</b>	<b>0.79</b>	<b>0.26</b>	<b>87.88</b>	<b>2.11</b>	<b>54.13</b>

**Table 4.5: Mean performance of genotypes for different characters in marigold during 2012-13**

Sr. No.	Genotypes	Plant height (cm)	Plant spread (cm)	Stem diameter (cm)	Stalk length (cm)	No. of primary branches per plant	No. of secondary branches per plant	Fresh weight of plant (g)	Dry weight of plant (g)
1.	Hisar Beauty	32.72	35.06	0.63	4.24	10.20	36.27	77.62	10.45
2.	Hisar Jaffri-2	61.32	78.90	1.64	10.47	25.53	161.67	1139.11	124.23
3.	MGH-09-271	78.07	64.13	1.37	9.57	13.47	47.07	290.18	33.43
4.	MGH-09-276	58.81	54.41	1.67	8.59	11.80	46.13	356.04	39.61
5.	MGH-09-276-1	102.77	74.24	1.10	13.52	13.67	56.20	510.40	56.53
6.	MGH-09-301	68.66	45.65	1.20	15.33	10.40	48.40	444.29	53.37
7.	MGH-09-302	59.33	56.84	0.96	9.24	9.33	39.73	258.14	35.34
8.	MGH-09-303	101.53	40.82	1.33	16.40	10.87	42.93	271.94	36.17
9.	MGH-09-304	54.97	54.97	1.70	22.75	12.47	48.47	450.93	54.61
10.	MGH-09-305	80.24	57.57	1.47	20.85	12.00	32.20	365.52	39.92
11.	MGH-10-101	79.43	56.40	1.35	19.33	8.87	31.00	212.08	26.42
12.	MGH-133-1-1	82.84	48.01	1.46	17.11	10.07	42.87	259.77	33.37
13.	MGH-133-1-2	74.50	44.68	1.30	17.24	13.87	44.47	215.66	29.83
14.	MGH-133-1-3	97.23	46.15	1.45	9.60	11.67	48.67	592.95	65.80
15.	MGH-133-2	71.18	45.69	1.33	19.69	11.27	41.73	277.62	36.41

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16.	MGH-133-3-2	99.41	35.88	0.92	10.01	10.13	27.93	168.82	23.61
17.	MGH-133-5	70.74	45.75	1.14	13.41	10.53	56.13	420.40	50.39
18.	MGH-133-5-2	68.96	40.57	1.39	18.93	16.20	46.67	271.95	33.07
19.	MGH-148-3-3	67.63	65.21	2.09	15.15	11.40	54.33	1047.34	122.44
20.	MGH-148-8	83.61	37.53	1.90	23.43	9.67	49.87	522.03	58.82
21.	MGH-160-5-1	88.19	62.35	1.36	9.63	12.40	43.00	306.66	38.84
22.	MGH-160-5-2	92.55	53.68	0.97	19.75	11.80	48.33	505.52	57.54
23.	MGH-160-5-3	74.26	47.04	1.06	15.11	9.93	38.93	290.12	35.54
24.	MGH-160-7-1	80.53	47.06	1.21	20.39	17.33	28.67	214.50	26.93
25.	MGH-160-8-3-2	49.53	35.58	1.74	7.17	16.93	28.60	353.44	39.94
26.	MGH-160-9	78.13	47.13	1.12	17.35	9.67	44.53	198.88	32.01
27.	MGH-160-9-1	83.00	67.77	1.32	14.61	10.73	38.27	495.88	56.03
28.	MGH-160-9-3	65.14	38.23	1.08	16.24	21.43	48.60	243.13	32.49
29.	MGH-160-9-4	106.07	53.74	1.63	27.69	20.67	56.80	457.93	53.84
30.	MGH-07-160-8-3-3	41.07	36.44	1.03	4.68	13.47	22.63	177.83	21.64
	<b>Mean</b>	<b>75.08</b>	<b>50.58</b>	<b>1.33</b>	<b>14.92</b>	<b>12.93</b>	<b>46.71</b>	<b>379.89</b>	<b>45.29</b>
	<b>C.D. at 5%</b>	<b>6.20</b>	<b>6.19</b>	<b>0.09</b>	<b>1.15</b>	<b>2.09</b>	<b>13.65</b>	<b>46.19</b>	<b>6.79</b>
	<b>C.D. at 1%</b>	<b>8.22</b>	<b>8.21</b>	<b>0.12</b>	<b>1.52</b>	<b>2.77</b>	<b>18.11</b>	<b>61.20</b>	<b>9.01</b>

**Table 4.6: Mean performance of genotypes for different characters in marigold during 2012-13**

Sr. No.	Genotypes	Days taken to first flower opening	Duration of flowering (days)	No. of buds per plant	No. of flowers per plant	Flower diameter (cm)	Fresh weight of flower (g)	Dry weight of flower (g)	Flower yield per plant (g)	Flower yield/ plot (kg)	Flower yield/ hectare (q)
1.	Hisar Beauty	39.00	57.33	52.93	41.07	4.62	2.19	0.29	89.26	2.14	55.79
2.	Hisar Jaffri-2	68.07	81.13	232.40	198.47	3.96	4.42	0.53	879.56	21.11	549.72
3.	MGH-09-271	47.87	56.13	73.07	53.89	7.27	15.93	1.90	858.10	20.59	536.31
4.	MGH-09-276	57.33	62.67	76.53	55.07	8.31	15.78	1.63	869.72	20.87	543.57
5.	MGH-09-276-1	52.73	49.13	65.93	62.27	7.16	10.01	0.97	624.84	15.00	390.53
6.	MGH-09-301	48.40	70.67	87.60	54.67	6.83	8.65	1.20	473.40	11.36	295.87
7.	MGH-09-302	41.67	67.40	61.73	45.60	6.23	9.62	1.08	439.90	10.59	274.94
8.	MGH-09-303	50.40	39.13	67.67	54.20	6.35	9.80	1.21	531.34	12.75	332.09
9.	MGH-09-304	55.87	69.80	71.40	59.13	7.17	9.79	1.38	579.87	13.92	362.42
10.	MGH-09-305	45.13	65.60	52.50	40.07	6.57	8.74	0.95	350.36	8.41	218.98
11.	MGH-10-101	54.20	33.33	60.47	49.27	5.44	7.16	0.74	354.08	8.50	221.30
12.	MGH-133-1-1	54.33	47.80	64.13	56.60	5.38	7.45	0.86	422.94	10.15	264.34
13.	MGH-133-1-2	45.47	38.80	75.67	55.33	6.43	8.99	1.01	501.13	12.03	313.21
14.	MGH-133-1-3	51.93	49.87	76.87	60.87	5.22	10.04	1.41	614.41	14.75	384.01
15.	MGH-133-2	43.07	41.47	50.87	46.47	5.40	7.61	0.85	355.02	8.52	221.89
16.	MGH-133-3-2	55.33	58.07	47.73	38.97	6.17	10.30	1.34	403.07	9.67	251.92

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17.	MGH-133-5	46.07	36.60	80.20	68.67	5.60	8.17	0.94	560.98	13.46	350.62
18.	MGH-133-5-2	51.07	33.93	77.00	61.07	5.23	7.11	0.84	433.16	10.40	270.73
19.	MGH-148-3-3	48.53	64.73	81.07	62.53	7.34	9.61	1.07	602.04	14.45	376.28
20.	MGH-148-8	52.87	58.27	72.13	57.67	7.53	9.74	1.20	561.43	13.47	350.89
21.	MGH-160-5-1	53.33	39.13	57.47	43.13	7.36	9.45	1.27	408.24	9.80	255.15
22.	MGH-160-5-2	53.20	63.87	73.20	60.73	6.70	7.85	0.85	477.06	11.45	298.16
23.	MGH-160-5-3	44.73	46.00	61.07	49.20	5.26	6.17	0.72	304.96	7.31	190.29
24.	MGH-160-7-1	42.40	50.87	46.27	38.13	5.83	6.94	0.73	264.02	6.34	165.01
25.	MGH-160-8-3-2	51.07	44.87	49.87	34.33	7.26	9.84	1.15	336.33	8.07	210.21
26.	MGH-160-9	46.07	39.13	63.73	50.33	6.15	7.79	1.08	391.07	9.39	244.42
27.	MGH-160-9-1	42.67	56.27	57.47	46.87	7.68	9.63	1.23	452.46	10.86	282.79
28.	MGH-160-9-3	44.00	52.80	71.80	58.07	7.20	7.57	0.88	440.40	10.57	275.25
29.	MGH-160-9-4	43.93	36.87	75.60	64.67	6.97	8.76	1.03	566.23	13.59	353.89
30.	MGH-07-160-8-3-3	47.80	46.40	42.13	29.47	5.78	6.35	0.70	187.19	4.49	116.99
	<b>Mean</b>	<b>49.28</b>	<b>51.94</b>	<b>70.88</b>	<b>56.56</b>	<b>6.35</b>	<b>8.72</b>	<b>1.04</b>	<b>477.74</b>	<b>11.47</b>	<b>298.59</b>
	<b>C.D. at 5%</b>	<b>6.08</b>	<b>6.67</b>	<b>7.79</b>	<b>8.96</b>	<b>0.66</b>	<b>0.78</b>	<b>0.26</b>	<b>104.35</b>	<b>2.50</b>	<b>65.22</b>
	<b>C.D. at 1%</b>	<b>8.06</b>	<b>8.85</b>	<b>10.33</b>	<b>11.89</b>	<b>0.88</b>	<b>1.03</b>	<b>0.35</b>	<b>138.48</b>	<b>3.32</b>	<b>86.55</b>

#### **4.2.1.6 Number of secondary branches per plant**

Number of secondary branches per plant varied from 21.40 to 140.27 with mean value of 48.01 for the year 2011-12 and in the year 2012-13, its range from 22.63 to 161.67 with mean value of 46.71. The maximum numbers of secondary branches per plant were observed in Hisar Jaffri-2 in both the years, which was significantly higher over all genotypes. The minimum numbers of secondary branches per plant were observed in MGH-07-160-8-3-3.

#### **4.2.1.7 Fresh weight of plant (g)**

The range for fresh weight of plant was 79.89 to 1197.50 g with mean value 371.68 g. The highest fresh weight of plant (1197.50 g) was found in genotype MGH-148-3-3 followed by Hisar Jaffri-2 (1092.06 g) and MGH-148-8 (535.52 g), while it was lowest in Hisar Beauty (79.89 g) during the year 2011-12. The range of fresh weight of plant in the year 2012-13, was 77.62 to 1139.11 g with mean value 379.89 g. The maximum fresh weight of plant (1139.11 g) was recorded in genotype Hisar Jaffri-2 followed by MGH-148-3-3 (1047.34 g) and MGH-133-1-3 (592.95 g), while it was recorded minimum in Hisar Beauty (77.62 g).

#### **4.2.1.8 Dry weight of plant (g)**

Dry weight of plant varied from 9.37 to 139.00 g with mean value of 45.45 g in the year 2011-12 and in the year 2012-13, its range from 10.45 to 124.33 g with mean value 45.29. The maximum dry weight of plant (139.00 and 124.33 g) was observed in Hisar Jaffri-2 and MGH-148-3-3 in the years 2011-12 and 2012-13, respectively. The minimum dry weight of plant (9.37 and 10.45 g) was recorded in Hisar Beauty in both the years.

#### **4.2.2 Flowering characters**

The mean performance of flowering characters, observed on all individual genotypes in the year 2011-12 and 2012-13 are presented in Table 4.4 and 4.6, respectively.

##### **4.2.2.1 Days taken to first flower opening**

The perusal of data illustrated in Table 4.4 revealed that the number of days taken to first flower opening in different genotypes ranged from 36.80 to 61.20 days with mean value 48.40 days. The genotype Hisar Beauty was earliest in first flower opening (36.80 days) and at par with MGH-133-5 (38.07 days), MGH-09-302 (39.67 days), MGH-160-5-3 (40.60 days), MGH-160-9-3 (41.07 days), MGH-133-2 (41.40 days) and MGH-133-1-2 (42.13 days), whereas, the genotype Hisar Jaffri-2 took the maximum number of days to first flower opening (61.20 days). The range of days taken to first flower opening in year 2012-13 (Table 4.6) was 39.00 to 68.00 days with mean value 49.28 days. The minimum days required to first flower opening was recorded in Hisar-Beauty (39.00 days), which was at par with MGH-09-302 (41.67 days), MGH-160-7-1 (42.40 days), MGH-160-9-1 (42.67 days), MGH-133-2

(43.07 days), MGH-160-9-4 (43.93 days), MGH-160-9-3 (44.00 days) and MGH-160-5-3 (44.73 days), whereas, genotype Hisar Jaffri-2 the maximum number of days to first flower opening (68.00 days).

#### **4.2.2.2 Duration of flowering (days)**

Duration of flowering varied from 29.93 to 71.93 days with mean value of 48.63 days for the year 2011-12, whereas in the year 2012-13 its range from 33.93 to 81.13 days with mean value of 51.94 days. In the year 2011-12, the duration of flowering was maximum in Hisar Jaffri-2 (71.93 days), which was at par with genotype MGH-09-304 (70.13 days) and MGH-09-301(66.87 days), while shortest duration of flowering was recorded in MGH-133-5-2 (29.93 days). Similarly, in the year 2012-13, the significantly longest duration of flowering (81.13 days) was observed in Hisar Jaffri-2 and shortest duration of flowering (33.93 days) in MGH-133-5-2.

#### **4.2.2.3 Number of buds per plant**

The number of buds per plant varied from 33.60 to 201.80 with mean value 65.78 in the year 2011-12. The maximum number of buds per plant (201.80) was observed in Hisar Jaffri-2, which was significantly superior to all other genotypes, whereas, it was minimum (33.60) in MGH-07-160-8-3-3. In the year 2012-13, the mean value obtained was 70.88 with range from 42.13 to 232.40. The maximum number of buds was observed in Hisar Jaffri-2 and minimum in MGH-07-160-8-3-3.

#### **4.2.2.4 Number of flowers per plant**

The number of flowers per plant varied significantly from 28.07 to 179.53 among the genotypes with an average value of 54.97 during the year 2011-12, while in the year 2012-13, the range of number of flowers per plant was 29.47 to 198.47 with mean value 56.56. The maximum number of flowers (179.53 and 198.47) was observed in genotype Hisar Jaffri-2 which was significantly higher over all the genotypes, whereas, it was registered minimum (28.40 and 29.47) in the genotype MGH-07-160-8-3-3 in the years 2011-12 and 2012-13, respectively.

#### **4.2.2.5 Flower diameter (cm)**

The genotypes showed highly significant differences with respect to size of the flower. The range was 4.06 to 8.10 cm with a mean value of 6.25 cm in the year 2011-12. The largest flower (8.10 cm) was found in MGH-09-276, which was significantly higher to rest of the genotypes except MGH-09-271 (7.81 cm). Likewise, in the year 2012-13, the size of flower varied from 3.96 to 8.31 cm with average value of 6.35 cm. The maximum diameter of flower (8.31cm) was recorded in MGH-09-276, which remained at par with MGH-160-9-1

(7.68 cm). The minimum diameter of flower (4.06 and 3.96 cm) was observed in Hisar Jaffri-2 during both the years.

#### **4.2.2.6 Fresh weight of flower (g)**

The mean value for fresh weight of flower was 8.24 g and ranged from 2.44 to 15.21 g in the year 2011-12. In the year 2012-13, it ranged from 2.19 to 15.93 g with mean value of 8.71 g. In first year, the maximum fresh weight of flower (15.21 g) was recorded in MGH-09-271, which was significantly higher than all other genotypes and was followed by MGH-09-276 (13.38 g) and MGH-133-3-2 (10.40 g), whereas, it was lowest in Hisar Beauty (2.44 g). In second year, the maximum fresh weight of flower (15.93 g) was found in MGH-09-271, which was at par with MGH-09-276 (15.78 g) and minimum in Hisar Beauty (2.19 g).

#### **4.2.2.7 Dry weight of flower (g)**

The range of dry weight of flower in the year 2011-12 was 0.26 to 2.17 g with mean value of 1.03 g. The maximum dry weight of flower was found in MGH-09-271 (2.17 g) followed by MGH-09-276 (2.05 g) and MGH-09-303 (1.42 g), while it was minimum in Hisar Beauty (0.26 g). In the year 2012-13, it ranged from 0.29 to 1.90 g with mean value of 1.03 g. The highest dry weight of flower was recorded in MGH-09-271 (1.90 g) followed by MGH-09-276 (1.63 g) and MGH-133-1-3 (1.41 g) and it was minimum in Hisar Beauty (0.29 g).

### **4.2.3 Flower yield**

The results of flower yield in terms of per plant, per plot and per hectare are presented in Table 4.4 and 4.6 of the years 2011-12 and 2012-13, respectively.

#### **4.2.3.1 Flower yield per plant (g)**

Highly significant differences were observed among the genotypes for flower yield per plant. The range for flower yield per plant during the year 2011-12, was observed from 106.69 to 869.18 g with general mean of 443.36 g (Table 4.4). The highest flower yield (869.18 g) was recorded with Hisar Jaffri-2, which was significantly superior to rest of the genotypes and was followed by MGH-09-271 (799.59 g) and MGH-09-276 (724.34 g), whereas, it was lowest in Hisar Beauty (106.73 g). In the year 2012-13 (Table 4.6), the flower yield per plant ranged from 89.26 (Hisar Beauty) to 879.56 (Hisar Jaffri-2) g with an average of 477.74 g flowers among the genotypes. The genotypes MGH-09-276 (869.72 g) and MGH-09-271 (858.10 g) were at par to Hisar Jaffri-2 in flower yield per plant.

#### **4.2.3.2 Flower yield per plot (kg)**

A close sight of the data revealed that the genotypes demonstrated highly significant differences for flower yield per plot, which ranged from 2.56 to 20.86 kg with mean value of 10.64 kg in the year 2011-12. Further, the maximum flower yield per plot (20.86 kg) was recorded in Hisar Jaffri-2 followed by MGH-09-271 (19.19 kg) and MGH-09-276 (17.38 kg),

while in the year 2012-13, it was 2.14 (Hisar Beauty) to 21.11 kg (Hisar Jaffri-2) with an average value of 11.47 kg. The minimum flower yield (2.56 and 2.14 kg) per plot was observed in Hisar Beauty in both the years.

#### **4.2.3.3 Flower yield per hectare (q)**

The genotypes differed significantly for flower yield per hectare with a range of 66.68 (Hisar Beauty) to 543.23 (Hisar Jaffri-2) quintals in the year 2011-12 with overall mean value 277.10 q. The genotypes MGH-09-271, MGH-09-276, MGH-09-276-1, MGH-09-301, MGH-09-302, MGH-09-303, MGH-09-304, MGH-133-1-2, MGH-133-1-3, MGH-133-3-2, MGH-133-5, MGH-148-3-3, MGH-148-8, MGH-160-5-2, MGH-160-9, MGH-160-9-1, MGH-160-9-3 and MGH-160-9-4 showed mean value higher than the overall mean. However, in the year 2012-13, the flower yield per hectare ranged from 55.79 (Hisar Beauty) to 549.72 q per hectare (Hisar Jaffri-2) with mean value of 298.59 q per hectare.

### **4.3 CHARACTERIZATION**

Based on the observations taken for morphological characters and following the standard procedure, the thirty genotypes of marigold both African and French included in the study were categorized into different groups. The results on the basis of mean of two years (Appendix- III and IV) have been presented in Table 4.7 and 4.8.

#### **4.3.1 Plant characters**

##### **4.3.1.1 Plant growth habit**

The plant growth habit of thirty genotypes has been mentioned in Table 4.7 and depicted through the Plate 4. The categorization of individual genotypes for plant growth habit was done visually. Thirteen genotypes exhibited compact growth habit, while seventeen genotypes showed wider crotch angle with open growth habit.

##### **4.3.1.2 Branching habit**

The Branching habit of thirty different genotypes as observed has been shown in Table 4.7. These thirty genotypes exhibited common two classes of Branching habit, *viz.* basal and full (Plate 3). Out of thirty genotypes evaluated, only eight genotypes had basal branch and remaining twenty-two genotypes exhibited full Branching habit. There was no genotype in the category of middle and top Branching habit.

##### **4.3.1.3 Stem colour**

On the basis of stem colour observed (Table 4.7), four main groups of genotypes appeared, *i.e.*, green, dark green, purple and purple strips (Plate 5). Based on grouping of the thirty genotypes evaluated, eleven genotypes showed green stem colour, five genotypes dark green colour stem, seven genotypes purple stem colour and rest seven genotypes only purple strips on their stem.

#### **4.3.1.4 Stem shape**

The stem shape of thirty different genotypes as observed has been shown in Table 4.7. These genotypes exhibited common two groups of stem shape, *viz.* smooth and ridged (Plate 7) Out of thirty genotypes, fourteen genotypes had smooth shaped stem and remaining sixteen genotypes showed ridged stem.

#### **4.3.1.5 Stem pubescence**

The data pertaining to stem pubescence of thirty genotypes of marigold have been presented in Table 4.7. Based on the presence of hairiness on stem surface, the stem pubescence was divided into two categories, *i.e.*, glabrous and non-glabrous. Ten genotypes were recorded with glabrous nature, while all remaining twenty genotypes were recorded with non-glabrous nature.

#### **4.3.1.6 Leaf colour**

The leaf colour of thirty genotypes has been mentioned in Table 4.7 and depicted through the Plate 6. The categorization of individual genotypes for leaf colour was done visually. Based on leaf colour, the genotypes were classified into four categories, *viz.* pale green, light green, dark green and purple. Six genotypes had leaves with pale green colour, four with light green, thirteen with dark green and seven with purple colour.

#### **4.3.1.7 Leaflet shape**

The leaflet shape of thirty genotypes has been mentioned in Table 4.7 and depicted through the Plate 8. The categorization of individual genotypes for leaflet shape was done visually. The results showed that among these genotypes, two types of leaflet shape, *i.e.*, narrow pointed and oval pointed, were observed. The grouping pattern suggested that fourteen genotypes had leaflets with narrow pointed shape and sixteen with oval pointed shape.

#### **4.3.1.8 Leaflet margin**

Based on leaflet margin, the genotypes were classified into three categories, *i.e.*, smooth, serrated and highly serrated. The data pertaining to leaflet margin have been presented in Tables 4.7. A representative sample of leaflet margin variation observed for 30 genotypes included in the present experiment has also been presented in Plate 9. Out of these genotypes, only eight genotypes showed smooth margin, thirteen genotypes serrated margin and nine genotypes highly serrated margin.

#### **4.3.1.9 Leaf pubescence**

The leaf pubescence of 30 different genotypes as observed has been shown in Table 4.7. These genotypes were distinguished based on smoothness of leaf surface, *i.e.*, glabrous and non-glabrous. The grouping pattern suggested that nine genotypes had glabrous while remaining twenty one genotypes were positioned in non-glabrous category.



**Basal**



**Full**

**Plate 3: Branching habit**



**Compact**



**Open**

**Plate 4: Plant growth habit**



**Green**



**Dark green**



**Purple**



**Purple stripes**

**Plate 5: Stem colour**



**Pale green**



**Light green**



**Dark green**



**Purple**

**Plate 6: Leaf colour**



**Smooth**

**Ridged**

**Plate 7: Stem shape**



**Narrow pointed**

**Oval pointed**

**Plate 8: Leaflet shape**

**Table 4.7: Characterization of thirty genotypes of marigold based on various morphological characters**

<b>Diagnostic characteristics</b>	<b>No. of genotypes</b>	<b>Genotypes expressing respective characteristics</b>
<b>1. Plant growth habit</b>		
i. Compact	13	Hisar Beauty, Hisar Jaffri-2, MGH-09-276-1, MGH-09-304, MGH-09-305, MGH-133-1-1, MGH-133-2, MGH-133-3-2, MGH-133-5, MGH-148-3-3, MGH-160-9-4, MGH-160-8-3-2 and MGH-07-160-8-3-3
ii. Open	17	MGH-09-271, MGH-09-276, MGH-09-301, MGH-09-302, MGH-09-303, MGH-10-101, MGH-133-1-2, MGH-133-1-3, MGH-133-5-2, MGH-148-8, MGH-160-5-1, MGH-160-5-2, MGH-160-5-3, MGH-160-7-1, MGH-160-9, MGH-160-9-1 and MGH-160-9-3
<b>2. Branching habit</b>		
i. No branch	Nil	-
ii. Basal	8	MGH-09-301, MGH-09-305, MGH-10-101, MGH-133-1-1, MGH-133-1-3, MGH-133-2, MGH-148-3-3 and MGH-160-9-1
iii. Middle	Nil	-
iv. Top	Nil	-
v. Full	22	Hisar Beauty, Hisar Jaffri-2, MGH-09-271, MGH-09-276, MGH-09-276-1, MGH-09-302, MGH-09-303, MGH-09-304, MGH-133-1-2, MGH-133-3-2, MGH-133-5, MGH-133-5-2, MGH-148-8, MGH-160-5-1, MGH-160-5-2, MGH-160-5-3, MGH-160-7-1, MGH-160-8-3-2, MGH-160-9, MGH-160-9-3, MGH-160-9-4 and MGH-07-160-8-3-3
<b>3. Stem colour</b>		
i. Green	11	MGH-09-301, MGH-09-305, MGH-133-1-1, MGH-133-1-3, MGH-133-2, MGH-133-5, MGH-133-5-2, MGH-160-5-1, MGH-160-5-2, MGH-160-8-3-2 and MGH-160-9
ii. Dark green	5	MGH-09-276-1, MGH-148-3-3, MGH-148-8, MGH-160-7-1 and MGH-160-9-4
iii. Purple	7	Hisar Beauty, Hisar Jaffri-2, MGH-09-271, MGH-09-303, MGH-09-304, MGH-10-101 and MGH-07-160-8-3-3
iv. Purple strips	7	MGH-09-276, MGH-09-302, MGH-133-1-2, MGH-133-3-2, MGH-160-5-3, MGH-160-9-1 and MGH-160-9-3

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<b>4. Stem shape</b>		
i. Smooth	14	Hisar Jaffri-2, MGH-09-302, MGH-09-303, MGH-09-304, MGH-10-101, MGH-133-1-2, MGH-133-5, MGH-148-3-3, MGH-148-8, MGH-160-5-2, MGH-160-5-3, MGH-160-9-1, MGH-160-9-3 and MGH-07-160-8-3-3
ii. Ridged	16	Hisar Beauty, MGH-09-271, MGH-09-276, MGH-09-276-1, MGH-09-301, MGH-09-305, MGH-133-1-1, MGH-133-1-3, MGH-133-2, MGH-133-3-2, MGH-133-5-2, MGH-160-5-1, MGH-160-7-1, MGH-160-8-3-2, MGH-160-9 and MGH-160-9-4
<b>5. Stem pubescence</b>		
i. Glabrous	10	MGH-09-271, MGH-09-276-1, MGH-09-304, MGH-133-3-2, MGH-133-5-2, MGH-148-3-3, MGH-148-8, MGH-160-9-1, MGH-160-9-3 and MGH-160-9-4
ii. Non-glabrous	20	Hisar Beauty, MGH-09-276, MGH-09-301, MGH-09-305, MGH-133-1-1, MGH-133-1-3, MGH-133-2, MGH-160-5-1, MGH-160-7-1, MGH-160-8-3-3, MGH-160-9, MGH-07-160-8-3-2, Hisar Jaffri-2, MGH-09-302, MGH-09-303, MGH-10-101, MGH-133-1-2, MGH-133-5, MGH-160-5-2 and MGH-160-5-3
<b>6. Leaf colour</b>		
i. Pale green	6	MGH-09-302, MGH-133-5-2, MGH-148-3-3, MGH-148-8, MGH-160-9-1 and MGH-07-160-8-3-3
ii. Light green	4	MGH-09-303, MGH-10-101, MGH-133-1-2 and MGH-133-3-2
iii. Dark green	13	Hisar Beauty, Hisar Jaffri-2, MGH-09-271, MGH-09-276, MGH-09-305, MGH-133-1-1, MGH-133-1-3, MGH-160-5-2, MGH-160-9, MGH-160-9-4, MGH-160-9-3, MGH-160-5-3 and MGH-160-7-1
iv. Purple	7	MGH-09-276-1, MGH-09-301, MGH-09-304, MGH-133-2, MGH-133-5, MGH-160-5-1 and MGH-160-8-3-2
<b>7. Leaflet shape</b>		
i. Narrow pointed	14	MGH-09-276-1, MGH-09-302, MGH-09-304, MGH-10-101, MGH-133-1-1, MGH-133-1-2, MGH-133-2, MGH-133-3-2, MGH-133-5-2, MGH-148-8, MGH-160-5-3, MGH-160-7-1, MGH-160-8-3-2, MGH-160-9-4, MGH-160-9-3 and MGH-07-160-8-3-3
ii. Oval pointed	16	Hisar Beauty, Hisar Jaffri-2, MGH-09-271, MGH-09-276, MGH-09-301, MGH-09-303, MGH-09-305, MGH-133-1-3, MGH-133-5, MGH-148-3-3, MGH-160-5-1, MGH-160-5-2, MGH-160-9 and MGH-160-9-1

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**8. Leaflet margin**

- |                      |    |   |
|----------------------|----|---|
| i. Smooth            | 8  | MGH-09-271, MGH-09-302, MGH-09-303, MGH-133-1-1, MGH-133-3-2, MGH-133-5-2, MGH-160-9-1 and MGH-07-160-8-3-3   |
| ii. Serrated         | 13 | Hisar Beauty, Hisar Jaffri-2, MGH-09-276, MGH-09-301, MGH-10-101, MGH-133-1-2, MGH-148-3-3, MGH-133-2, MGH-160-5-1, MGH-160-7-1, MGH-160-8-3-2, MGH-160-9-3 and MGH-160-9-4 |
| iii. Highly serrated | 9  | MGH-09-276-1, MGH-09-304, MGH-09-305, MGH-133-1-3, MGH-133-5, MGH-148-8, MGH-160-5-2, MGH-160-5-3 and MGH-160-9   |

**9. Leaf pubescence**

- |                  |    |  |
|------------------|----|--|
| i. Glabrous      | 9  | MGH-09-276-1, MGH-09-302, MGH-10-101, MGH-133-3-2, MGH-148-8, MGH-160-9-1, MGH-160-9-3, MGH-160-9 and MGH-07-160-8-3-3   |
| ii. Non-glabrous | 21 | Hisar Beauty, Hisar Jaffri-2, MGH-09-271, MGH-09-276, MGH-09-301, MGH-09-303, MGH-09-304, MGH-09-305, MGH-133-1-1, MGH-133-1-2, MGH-133-1-3, MGH-133-2, MGH-133-5, MGH-133-5-2, MGH-148-3-3, MGH-160-5-1, MGH-160-5-2, MGH-160-5-3, MGH-160-7-1, MGH-160-8-3-2 and MGH-160-9-4 |

**10. Disc floret**

- |                 |    |  |
|-----------------|----|--|
| i. Visible      | 6  | Hisar Beauty, Hisar Jaffri-2, MGH-09-301, MGH-160-5-2, MGH-160-8-3-2 and MGH-160-9-3   |
| ii. Non-visible | 24 | MGH-09-271, MGH-09-276, MGH-09-303, MGH-09-304, MGH-09-305, MGH-133-1-1, MGH-133-1-2, MGH-133-1-3, MGH-133-2, MGH-133-5, MGH-133-5-2, MGH-148-3-3, MGH-160-5-1, MGH-160-5-3, MGH-160-7-1, MGH-160-9-4, MGH-07-160-8-3-3, MGH-09-276-1, MGH-09-302, MGH-10-101, MGH-133-3-2, MGH-148-8, MGH-160-9-1 and MGH-160-9 |

**11. Plant height (cm)**

- |                      |    |  |
|----------------------|----|--|
| i. Dwarf (<60 cm)    | 5  | Hisar Beauty, MGH-09-302, MGH-09-304, MGH-160-8-3-2 and MGH-07-160-8-3-3   |
| ii. Medium(60-80 cm) | 14 | Hisar Jaffri-2, MGH-09-271, MGH-09-276, MGH-09-301, MGH-10-101, MGH-133-1-2, MGH-133-2, MGH-133-5, MGH-133-5-2, MGH-148-3-3, MGH-160-5-3, MGH-160-9, MGH-160-9-1 and MGH-160-9-3 |
| iii. Tall (>80 cm)   | 11 | MGH-09-276-1, MGH-09-303, MGH-09-305, MGH-133-1-1, MGH-133-1-3, MGH-133-3-2, MGH-148-8, MGH-160-5-1, MGH-160-5-2, MGH-160-7-1 and MGH-160-9-4                                    |
-

#### **4.3.1.10 Disc floret**

The thirty genotypes of marigold were grouped into two groups *i.e.*, visible and non-visible. The data regarding disc floret have been shown in Tables 4.7 and Plate 10. Out of thirty genotypes, the six genotypes were placed in visible group and the rest twenty four in non-visible group.

#### **4.3.1.11 Plant height (cm)**

Based on plant height, the marigold genotypes investigated in the present study divided into dwarf, medium and tall types. Out of thirty genotypes, the five genotypes showed dwarf growth (<60 cm), fourteen medium growth (60-80 cm) and eleven genotypes were having tall (>80 cm) in growth. The groupings of various marigold genotypes based on plant height have been presented precisely in Table 4.7.

### **4.3.2 Flowering characters**

#### **4.3.2.1 Days taken to first flower opening**

On the basis of days taken to first flower opening, all the thirty genotypes were grouped into three categories *viz.*, early (<45 days), mid (45-55days) and late (>55 days). The grouping of various marigold genotypes based on days taken to first flower opening has been presented in Table 4.8. The grouping pattern suggested that ten genotypes took less than 45 days to first flower opening, fifteen genotypes 45-55 days (mid) and five genotypes >55 days (late).

#### **4.3.2.2 Duration of flowering (days)**

Based on this trait, the marigold genotypes investigated in the present study were categorized into the category of short (<45 days), medium (45-55 days) and long (>55 days) duration. There were thirteen genotypes, which showed short duration of flowering, seven medium duration of flowering and the remaining ten genotypes long duration of flowering. The grouping of various marigold genotypes based on duration of flowering has been presented precisely in Table 4.8.

#### **4.3.2.3 Number of flowers per plant**

The marigold genotypes based on number of flowers per plant were grouped into three categories, *i.e.*, less, medium and more flower producing. Less number of flowers per plant (<45) was recorded in eight genotypes, medium number of flowers per plant (45-60) in sixteen genotypes and more number of flowers per plant (>60) in six genotypes. The grouping of genotypes based on number of flowers per plant has been given in Table 4.8.



**Smooth**

**Serrated**

**Highly serrated**

**Plate 9: Leaflet margin**



**Visible**

**Not-visible**

**Plate 10: Disc floret**

**Table 4.8:- Characterization of thirty genotypes of marigold based on various flowering characters**

<b>Diagnostic Characteristics</b>	<b>No. of genotypes</b>	<b>Genotypes expressing respective characteristics</b>
<b>1. Days taken to first flower opening</b>		
1. Early (<45 days)	10	Hisar Beauty, MGH-09-302, MGH-133-1-2, MGH-133-2, MGH-133-5, MGH-160-5-3, MGH-160-7-1, MGH-160-9, MGH-160-9-1 and MGH-160-9-3
i. Mid (45-55 days)	15	MGH-09-271, MGH-09-276-1, MGH-09-301, MGH-09-303, MGH-09-304, MGH-09-305, MGH-133-1-1, MGH-133-1-3, MGH-133-5-2, MGH-148-3-3, MGH-160-5-1, MGH-160-5-2, MGH-160-8-3-2, MGH-160-9-4 and MGH-07-160-8-3-3,
ii. Late (>55 days)	5	Hisar Jaffri-2, MGH-09-276, MGH-10-101, MGH-133-3-2 and MGH-148-8
<b>2. Duration of flowering (days)</b>		
i. Short (<45 days)	13	MGH-09-303, MGH-10-101, MGH-133-1-1, MGH-133-1-2, MGH-133-2, MGH-133-5, MGH-133-5-2, MGH-160-5-1, MGH-160-8-3-2, MGH-160-5-3, MGH-160-9, MGH-160-9-4 and MGH-07-160-8-3-3,
ii. Medium(45-55 days)	7	Hisar Beauty, MGH-09-271, MGH-09-276-1, MGH-133-1-3, MGH-160-7-1, MGH-160-9-1 and MGH-160-9-3
iii. Long (>55 days)	10	Hisar Jaffri-2, MGH-133-3-2, MGH-148-8, MGH-148-3-3, MGH-160-5-2, MGH-09-276, MGH-09-301, MGH-09-304, MGH-09-305 and MGH-09-302
<b>3. Number of flowers per plant</b>		
i. Less (<45)	8	Hisar Beauty, MGH-09-305, MGH-10-101, MGH-133-3-2, MGH-160-5-1, MGH-160-7-1, MGH-160-8-3-2 and MGH-07-160-8-3-3,
ii. Medium (45-60)	16	MGH-09-271, MGH-09-276, MGH-09-301, MGH-09-304, MGH-09-303, MGH-133-1-1, MGH-133-1-2, MGH-133-1-3, MGH-133-5-2, MGH-160-9-1, MGH-160-5-2, MGH-160-9-3, MGH-160-5-3, MGH-09-302, MGH-133-2 and MGH-160-9
iii. High (>60)	6	Hisar Jaffri-2, MGH-09-276-1, MGH-160-9-4, MGH-133-5, MGH-148-3-3 and MGH-148-8

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**4. Stalk length (cm)**

i. Short (<10.00 cm)	7	MGH-07-160-8-3-3, Hisar Beauty, MGH-09-271, MGH-09-276, MGH-09-302, MGH-133-3-2 and MGH-160-8-3-2
ii. Mid (10.0-15.0 cm)	6	Hisar Jaffri-2, MGH-09-276-1, MGH-133-1-3, MGH-133-5, MGH-160-5-1, MGH-160-9-1
iii. Long (>15.0 cm)	17	MGH-133-1-1, MGH-133-1-2, MGH-133-5-2, MGH-148-8, MGH-148-3-3, MGH-160-5-2, MGH-160-9-4 MGH-160-5-3, MGH-160-7-1, MGH-160-9, MGH-09-301, MGH-09-303, MGH-09-304, MGH-09-305, MGH-10-101, MGH-133-2 and MGH-160-9-3

**5. Flower diameter (cm)**

i. Small (<5.0 cm)	2	Hisar Beauty and Hisar Jaffri-2
ii. Medium (5.0-6.5 cm)	16	MGH-09-302, MGH-09-303, MGH-07-160-8-3-3, MGH-133-1-1, MGH-133-1-2, MGH-133-1-3, MGH-133-2, MGH-133-5, MGH-133-5-2, MGH-133-3-2, MGH-160-5-2, MGH-160-5-3, MGH-160-7-1, MGH-160-9, MGH-09-305 and MGH-10-101
iii. Big (>6.5 cm)	12	MGH-09-271, MGH-09-276, MGH-09-276-1, MGH-09-301, MGH-09-304, MGH-148-3-3, MGH-148-8, MGH-160-5-1, MGH-160-8-3-2, MGH-160-9-1, MGH-160-9-3 and MGH-160-9-4

**6. Fresh weight of flower (g)**

i. Low (<5.5 g)	2	Hisar Beauty and Hisar Jaffri-2
ii. Medium (5.5-8.5 g)	15	MGH-09-305, MGH-160-5-2, MGH-160-9-3, MGH-133-2, MGH-133-5, MGH-160-9, MGH-160-9-1, MGH-160-9-4, MGH-10-101, MGH-133-1-1, MGH-133-1-2, MGH-133-5-2, MGH-160-5-3, MGH-160-7-1 and MGH-07-160-8-3-3
iii. High (>8.5 g)	13	MGH-09-271, MGH-09-276, MGH-09-276-1, MGH-09-301, MGH-09-302, MGH-09-303, MGH-09-304, MGH-133-1-3, MGH-133-3-2, MGH-148-3-3, MGH-148-8, MGH-160-5-1 and MGH-160-8-3-2

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#### **4.3.2.4 Stalk length (cm)**

The stalk length of thirty genotypes has been presented in Appendix III and grouping of various marigold genotypes based on stalk length has been presented precisely in Table 4.8. Based on this trait, the marigold genotypes were grouped into three categories. First group had short (<10.0 cm) stalk length and it included only six genotypes. Medium (10.0-15.0 cm) group had seventeen genotypes and seven genotypes were grouped in long (>15.0 cm) group.

#### **4.3.2.5 Flower diameter (cm)**

According to the size of flower observed and presented in Appendix IV and grouping of marigold genotypes has been given in Table 4.8. The marigold genotypes were classified into three main groups, *viz.* small, medium and big flowered. The first group had small flowers (<5.0 cm) and it included only two genotypes (Hisar Beauty and Hisar Jaffri-2). Medium (5.0-6.5 cm) group had majority of genotypes (sixteen) and remaining twelve genotypes were included in big (>6.5 cm) group of flower size.

#### **4.3.2.6 Fresh weight of flower (g)**

The fresh weight of flower of thirty different genotypes as observed has been shown in Appendix II and the data pertaining to fresh weight of flower have been presented in Table 4.10. Based on fresh weight of flower, the genotypes were classified into three groups, *i.e.*, low (< 5.5 g), medium (5.5-8.5 g) and high (> 8.5 g) in fresh weight of flower. Out of 30 genotypes, only two genotypes (Hisar Beauty and Hisar Jaffri-2) were put in low weight category, fifteen in medium weight category and remaining thirteen genotypes in the category of high flower weight.

### **4.4 VARIABILITY PARAMETERS**

The data concerning phenotypic and genotypic coefficient of variation, heritability (broad sense), genetic advance and genetic advance as per cent of mean have been presented in Table 4.9a, 4.9b, 4.10a and 4.10b, which showed considerable variation among genotypes for each character.

#### **4.4.1 Genotypic and phenotypic coefficient of variation**

The genotypic and phenotypic coefficients of variation were calculated for all the characters for the years 2011-12 and 2012-13. In the present study, the estimates of phenotypic coefficient of variation (PCV) were higher than their corresponding genotypic coefficient of variation (GCV) for all the characters (Table 4.9b and Table 4.10b) because of the fact that PCV included environmental components also.

During the year 2011-12, the maximum value of genotypic (GCV) and phenotypic coefficient of variation (PCV) were recorded for fresh weight of plant (66.02 and 66.07%)

and dry weight of plant (61.04 and 62.03%). The moderate values of GCV and PCV were recorded for number of flowers per plant (47.12 and 47.92%), number of secondary branches per plant (44.81 and 45.35%), number of buds per plant (43.68 and 44.14%) and flower yield (40.18 and 41.20%). The lower value of GCV and PCV was observed for days taken to first flower opening (13.29 and 15.12%) followed by flower diameter (16.24 and 16.74%) and plant height (22.91 and 23.27%).

**Table 4.9a: Mean, range, genotypic and phenotypic variances for various characters of marigold genotypes during 2011-12**

Characters	Mean $\pm$ SE(m)	Range		Genotypic variance	Phenotypic variance
		Min.	Max.		
Plant height (cm)	72.50 $\pm$ 1.75	32.07	105.97	291.33	300.44
Plant spread (cm)	49.08 $\pm$ 1.93	31.92	76.53	133.80	144.96
Stem diameter (cm)	1.32 $\pm$ 0.04	0.58	2.18	0.10	0.11
Stalk length (cm)	15.14 $\pm$ 0.62	4.52	26.36	34.30	35.44
No. of primary branches per plant	12.69 $\pm$ 0.54	8.13	23.47	16.61	17.50
No. of secondary branches per plant	48.01 $\pm$ 1.92	21.40	140.27	462.77	473.86
Fresh weight of plant (g)	371.68 $\pm$ 5.23	79.89	1197.50	60216.40	60298.59
Dry weight of plant (g)	45.45 $\pm$ 2.91	9.37	139.00	769.46	794.86
Days taken to first flower opening	48.40 $\pm$ 2.01	36.80	61.20	41.36	53.51
Duration of flowering	48.63 $\pm$ 2.00	29.93	71.93	141.98	154.01
No. of buds per plant	65.78 $\pm$ 2.42	33.60	201.80	825.17	842.77
No. of flowers per plant	54.97 $\pm$ 2.76	28.07	179.53	670.87	693.69
Flower diameter (cm)	6.25 $\pm$ 0.15	4.06	8.10	1.01	1.08
Fresh weight of flower (g)	8.24 $\pm$ 0.21	2.44	15.21	5.76	5.89
Dry weight of flower (g)	1.03 $\pm$ 0.07	0.26	2.17	0.13	0.15
Flower yield per plant (g)	443.36 $\pm$ 23.33	106.69	869.18	31725.35	33358.59
Flower yield per plot (kg)	10.64 $\pm$ 0.56	2.56	20.86	18.27	19.21
Flower yield per hectare (q)	277.10 $\pm$ 14.58	66.68	543.23	12392.65	13030.63



**Plate 11: Variability in marigold buds**



**Plate 12: Variability in marigold flowers**

**Table 4.9b: Coefficients of variation, heritability, expected genetic advance and genetic advance as per cent of mean for various characters of marigold genotypes during 2011-12**

Characters	Coefficients of variation (%)		Heritability (broad sense) (%)	Expected genetic advance	Genetic advance as percent of mean (5%)
	Genotypic	Phenotypic			
Plant height (cm)	22.91	23.27	96.96	34.62	46.47
Plant spread (cm)	23.57	24.53	92.30	22.89	46.64
Stem diameter (cm)	24.03	24.48	96.40	0.64	48.61
Stalk length (cm)	38.69	39.32	96.80	11.87	78.41
No. of primary branches per plant	32.12	32.96	94.92	8.18	64.46
No. of secondary branches per plant	44.81	45.35	97.66	43.79	91.23
Fresh weight of plant (g)	66.02	66.07	99.86	505.16	135.91
Dry weight of plant (g)	61.04	62.03	96.81	56.22	123.71
Days taken to first flower opening	13.29	15.12	77.30	11.65	24.07
Duration of flowering	24.51	25.52	92.19	23.57	48.47
No. of buds per plant	43.68	44.14	97.91	58.55	89.02
No. of flowers per plant	47.12	47.92	96.71	52.47	95.46
Flower diameter (cm)	16.24	16.74	94.06	2.01	32.44
Fresh weight of flower (g)	29.11	29.44	97.78	4.89	59.29
Dry weight of flower (g)	35.43	37.24	90.47	0.71	69.41
Flower yield per plant (g)	40.18	41.20	95.10	357.82	80.71
Flower yield per plot (kg)	40.18	41.20	95.10	859.00	80.71
Flower yield per hectare (q)	40.18	41.20	95.10	223.64	80.71

**Table 4.10a:- Mean range, genotypic and phenotypic variances for various characters of marigold genotypes during 2012-13**

Characters	Mean $\pm$ SE(m)	Range		Genotypic variance	Phenotypic variance
		Min.	Max.		
Plant height (cm)	75.08 $\pm$ 2.18	32.72	106.07	314.36	328.66
Plant spread (cm)	50.58 $\pm$ 2.18	35.06	78.90	131.07	145.34
Stem diameter (cm)	1.33 $\pm$ 0.03	0.63	2.09	0.09	0.10
Stalk length (cm)	14.93 $\pm$ 0.40	4.24	27.69	32.53	33.02
No. of primary branches per plant	12.93 $\pm$ 0.74	8.87	25.53	15.12	16.74
No. of secondary branches per plant	46.71 $\pm$ 4.81	22.63	161.67	528.19	597.54
Fresh weight of plant (g)	379.89 $\pm$ 16.27	77.62	1139.11	53092.02	53886.59
Dry weight of plant (g)	45.29 $\pm$ 2.39	10.45	124.33	610.34	627.52
Days taken to first flower opening	49.28 $\pm$ 2.14	39.00	68.00	31.44	45.19
Duration of flowering	51.94 $\pm$ 2.35	33.93	81.13	151.93	168.49
No. of buds per plant	70.88 $\pm$ 2.74	42.13	232.40	1060.96	1083.05
No. of flowers per plant	56.56 $\pm$ 3.16	29.47	198.47	801.57	831.47
Flower diameter (cm)	6.35 $\pm$ 0.23	3.96	8.31	0.97	1.14
Fresh weight of flower (g)	8.71 $\pm$ 0.27	2.19	15.93	6.93	7.15
Dry weight flower (g)	1.03 $\pm$ 0.09	0.29	1.90	0.10	0.12
Flower yield plant (g)	477.74 $\pm$ 36.77	89.26	879.56	31585.11	35640.80
Flower yield per plot (kg)	11.47 $\pm$ 0.88	2.14	21.11	18.20	20.53
Flower yield per hectare (q)	298.59 $\pm$ 22.98	55.79	549.72	12338.03	13922.31

**Table 4.10b:- Coefficients of variation, heritability, expected genetic advance and genetic advance as per cent of mean for various characters of marigold genotypes during 2012-13**

Characters	Coefficients of variation (%)		Heritability (broad sense) (%)	Expected genetic advance	Genetic advance as percent of mean (5%)
	Genotypic	Phenotypic			
Plant height (cm)	23.62	24.15	95.65	35.72	47.58
Plant spread (cm)	22.63	23.83	90.18	22.40	44.28
Stem diameter (cm)	23.61	23.96	97.08	0.64	47.91
Stalk length (cm)	38.24	38.53	98.51	11.66	78.19
No. of primary branches per plant	30.08	31.65	90.32	60.61	58.90
No. of secondary branches per plant	39.21	52.34	88.39	44.51	95.30
Fresh weight of plant (g)	60.65	61.11	98.53	471.15	124.02
Dry weight of plant (g)	54.55	55.31	97.26	50.19	110.83
Days taken to first flower opening	11.38	13.64	69.57	9.63	19.55
Duration of flowering	23.73	24.99	90.18	24.11	46.43
No. of buds per plant	45.94	46.43	97.91	66.38	93.65
No. of flowers per plant	50.06	50.98	96.40	57.26	101.24
Flower diameter (cm)	15.55	16.81	85.55	1.88	29.63
Fresh weight of flower (g)	30.20	30.68	96.89	5.34	61.23
Dry weight of flower (g)	30.02	33.75	79.10	0.57	55.00
Flower yield per plant (g)	37.20	39.52	88.62	344.65	72.14
Flower yield per plot (kg)	37.20	39.52	88.62	8.27	72.14
Flower yield per hectare (q)	37.20	39.52	88.62	215.41	72.14

During the year 2012-13, the highest GCV and PCV was recorded for fresh weight of plant (60.65 and 61.11%) followed by dry weight of plant (54.55 and 55.31%) and number of flowers per plant (50.06 and 50.98%), indicating sufficient amount of variability among the genotypes for all these traits and possibilities for effective improvements in these characters. The moderate value of GCV and PCV was recorded for number of buds per plant (45.94 and 46.43%), number of secondary branches per plant (39.21 and 52.34%), stalk length (38.24 and 38.53%) and flower yield (37.20 and 39.52%). The character days taken to first flower opening showed lowest GCV and PCV (11.38 and 13.64%) followed by flower diameter (15.55 and 16.81%).

#### **4.4.2 Heritability (broad sense)**

The estimates of broad sense heritability for different characters are presented in Table 4.9b and 4.10b. The heritability estimates were generally high for most of the traits except days taken to first flower opening, which was considered as moderate. During the year 2011-12, it ranged from 77.30 to 99.86 per cent. The highest heritability in broad sense was recorded for fresh weight of plant (99.86%) followed by number of buds per plant (97.91%), fresh weight of flower (97.78%) and number of secondary branches per plant (97.66%). The lowest heritability was recorded for days taken to first flower opening (77.30%).

In 2012-13, the heritability ranged from 69.57 to 98.53%. The highest heritability was recorded for fresh weight of plant (98.53%) followed by stalk length (98.51%) and number of buds per plant (97.91%), whereas, low heritability was observed for days taken to first flower opening (69.57%) and dry weight of flower (79.10%).

#### **4.4.3 Expected genetic advance and genetic advance as per cent of mean**

The expected genetic advance and genetic advance as per cent of mean for different characters have been given in Table 4.9b and 4.10b for the years 2011-12 and 2012-13, respectively. The expected genetic advance and genetic advance as per cent of mean for 2011-12 were high for fresh weight of plant (505.16 and 135.91) followed by flower yield per plot (859.00 and 80.71), flower yield per plant (357.82 and 80.71) and flower yield per hectare (223.64 and 80.71). The moderate expected genetic advance and genetic advance as per cent of mean were recorded for number of buds per plant (58.55 and 89.02), dry weight of plant (56.22 and 123.71) and number of flowers per plant (52.47 and 95.46). The lowest value of expected genetic advance and per cent of mean was found for stem diameter (0.64 and 48.61) followed by dry weight of flower (0.71 and 69.41) and flower diameter (2.01 and 32.44). For the year 2012-13, higher expected genetic advance and genetic advance as per cent of mean was estimated for fresh weight of plant (471.15 and 124.02) followed by flower yield per plant (344.65 and 72.14) and flower yield per hectare (215.41 and 72.14). The moderate values were observed for number of buds per plant (66.38 and 93.65), number of primary branches per plant (60.61 and 58.90), number of flowers per plant (57.26 and 101.24) and dry weight of plant (50.19 and 110.83), while low values were observed for dry weight of flower (0.57 and 55.00) followed by stem diameter (0.64 and 47.91) and flower diameter (1.88 and 29.63).

#### **4.5 CORRELATION COEFFICIENT ANALYSIS**

Correlation analysis was done to find out association among flower yield and different yield contributing parameters both at phenotypic and genotypic levels and the data for the year 2011-12 and 2012-13 have been presented in Tables 4.11 and 4.12, respectively.

In general, the magnitude of correlation coefficient at genotypic level was found higher than the corresponding correlation at phenotypic level, thereby indicating a strong inherent association between various characters under study.

#### **4.5.1. Correlation of yield with its components**

The correlation studies for the year 2011-12 (Table 4.11) revealed that the flower yield per plant had a positive and highly significant correlation with number of secondary branches per plant (0.686), number of buds per plant (0.685), number of flowers per plant (0.681), dry weight of plant (0.650), fresh weight of plant (0.623), fresh weight of flower (0.582), dry weight of flower (0.579), plant spread (0.538), flower diameter (0.382), stem diameter (0.379), duration of flowering (0.367) and days taken to first flower opening (0.288). However, the flower yield per plant showed positive and non-significant association with plant height (0.193) and number of primary branches per plant (0.141), and a negative and non-significant correlation with stalk length (-0.131).

In the year 2012-13 (Table 4.12), flower yield per plant showed positive and highly significant association with fresh weight of flower (0.623), number of flowers per plant (0.604), number of secondary branches per plant (0.590), number of buds per plant (0.590), fresh weight of plant (0.572), dry weight of plant (0.558), plant spread (0.527), stem diameter (0.493), days taken to first flower opening (0.480), dry weight of flower (0.425), duration of flowering (0.337) and flower diameter (0.289). Positive and significant correlation was recorded with number of primary branches per plant (0.258) and plant height (0.235). Stalk length had a positive and non-significant correlation with flower yield per plant (0.029).

#### **4.5.2. Correlation among yield components**

Plant height in the year 2011-12 expressed positive and highly significant association (Table 4.11) with stalk length (0.480) and days taken to first flower opening (0.275) and positive and significant correlation with fresh weight of flower (0.227). It also exhibited a negative and highly significant correlation with duration of flowering (-0.278). Similarly, in the year 2012-13, plant height showed positive and highly significant association with stalk length (0.454), dry weight of flower (0.441) and fresh weight of flower (0.281) while positive and significant association with plant spread (0.222). Plant height had negative and significant correlation with duration of flowering (-0.259).

Plant spread expressed positive and highly significant association with fresh weight of plant (0.560), dry weight of plant (0.554), number of buds per plant (0.527), number of flowers per plant (0.527), number of secondary branches per plant (0.494), stem diameter (0.272) and duration of flowering (0.272) in the year 2011-12, while in 2012-13, plant spread exhibited positive and highly significant association with fresh weight of plant (0.592), dry

weight of plant (0.581), number of flowers per plant (0.493), number of secondary branches per plant (0.487), number of buds per plant (0.464), duration of flowering (0.358) and days taken to first flower opening (0.292). Positive and significant association of plant spread was also observed with stem diameter (0.262) and dry weight of flower (0.262).

A positive and highly significant correlation of stem diameter was observed with dry weight of plant (0.605), fresh weight of plant (0.598), days taken to first flower opening (0.396), stalk length (0.354), flower diameter (0.327) and number of buds per plant (0.276) in the year 2011-12. It also showed a positive and significant correlation with dry weight of flower (0.268), fresh weight of flower (0.249), number of flowers per plant (0.231) and number of secondary branches per plant (0.224). In the year 2012-13, stem diameter showed positive and highly significant correlation with fresh weight of plant (0.595), dry weight of plant (0.594), fresh weight of flower (0.372), stalk length (0.369), days taken to first flower opening (0.357), flower diameter (0.349) and number of buds per plant (0.286). Stalk length had highly significant and negative association with duration of flowering (-0.290) in the year 2011-12, whereas, in the year 2012-13, stalk length did not show significant association with any of the characters.

Number of primary branches per plant expressed positive and highly significant association with number of secondary branches per plant (0.429), number of flowers per plant (0.428) and number of buds per plant (0.406). It also exhibited positive and significant association with fresh weight of plant (0.255) and dry weight of plant (0.254). Negative and significant correlation of number of primary branches per plant was observed with fresh weight of flower (-0.230), dry weight of flower (-0.227) in the year 2011-12, while in 2012-13, a positive and highly significant association of number of primary branches per plant was seen with number of secondary branches (0.558), number of flowers per plant (0.556), number of buds per plant (0.554), fresh weight of plant (0.343) and dry weight of plant (0.315) and a negative and significant correlation with dry weight of flower (-0.161).

**Table 4.11: Phenotypic (above diagonal) and genotypic (below diagonal) correlation coefficients among different characters in marigold during 2011-12**

Characters	Plant height	Plant spread	Stem diameter	Stalk length	No. of primary branches per plant	No. of secondary branches per plant	Fresh weight of plant	Dry weight of plant
Plant height	<b>1.000</b>	0.107	0.102	0.480**	0.016	0.060	0.036	0.021
Plant spread	0.107	<b>1.000</b>	0.272**	0.027	0.077	0.494**	0.560**	0.554**
Stem diameter	0.098	0.283	<b>1.000</b>	0.354**	0.118	0.224*	0.598**	0.605**
Stalk length	0.496	0.038	0.361	<b>1.000</b>	0.148	0.044	0.087	0.087
No. of primary branches per plant	0.019	0.075	0.123	0.158	<b>1.000</b>	0.429**	0.255*	0.254*
No. of secondary branches per plant	0.064	0.511	0.235	0.042	0.444	<b>1.000</b>	0.737**	0.725**
Fresh weight of plant	0.038	0.584	0.609	0.088	0.263	0.745	<b>1.000</b>	0.981**
Dry weight of plant	0.018	0.591	0.616	0.088	0.266	0.742	0.997	<b>1.000</b>
Days taken to first flower opening	0.329	0.156	0.396	0.068	0.060	0.279	0.391	0.380
Duration of flowering	-0.297	0.299	0.098	-0.305	0.018	0.393	0.496	0.540
No. of buds per plant	0.025	0.559	0.285	0.038	0.417	0.950	0.747	0.750
No. of flowers per plant	0.013	0.562	0.238	0.034	0.442	0.959	0.725	0.726
Flower diameter	0.105	0.124	0.340	-0.061	-0.190	-0.212	0.071	0.117
Fresh weight of flower	0.234	0.167	0.257	-0.171	-0.243	-0.090	0.031	0.087
Dry weight of flower	0.193	0.184	0.281	-0.141	-0.253	-0.082	0.013	0.061
Flower yield per plant	0.199	0.579	0.396	-0.036	0.139	0.712	0.638	0.678

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Characters	Days taken to first flower opening	Duration of flowering	No. of buds per plant	No. of flowers per plant	Flower diameter	Fresh weight of flower	Dry weight of flower	Flower yield per plant
Plant height	0.275**	-0.278**	0.024	0.015	0.091	0.227*	0.171	0.193
Plant spread	0.104	0.272**	0.527**	0.527**	0.122	0.156	0.162	0.538**
Stem diameter	0.346**	0.096	0.276**	0.231**	0.327**	0.249*	0.268*	0.379**
Stalk length	0.074	-0.290**	0.031	0.034	-0.062	-0.163	-0.123	-0.031
No. of primary branches per plant	0.056	0.060	0.406**	0.428**	-0.172	-0.230*	-0.227*	0.141
No. of secondary branches per plant	0.243*	0.366**	0.928**	0.929**	-0.194	-0.090	-0.077	0.686**
Fresh weight of plant	0.346**	0.476**	0.738**	0.713**	0.069	0.031	0.012	0.623**
Dry weight of plant	0.325**	0.517**	0.735**	0.704**	0.117	0.083	0.063	0.650**
Days taken to first flower opening	<b>1.000</b>	0.180	0.289**	0.253*	0.055	0.204	0.217*	0.288**
Duration of flowering	0.203	<b>1.000</b>	0.410**	0.365**	0.200	0.140	0.060	0.367**
No. of buds per plant	0.326	0.435	<b>1.000</b>	0.971**	-0.217*	-0.104	-0.078	0.685**
No. of flowers per plant	0.273	0.382	0.998	<b>1.000</b>	-0.264*	-0.158	-0.108	0.681**
Flower diameter	0.074	0.218	-0.231	-0.276	<b>1.000</b>	0.799**	0.721**	0.382**
Fresh weight of flower	0.234	0.148	-0.102	-0.155	0.836	<b>1.000</b>	0.925**	0.582**
Dry weight of flower	0.241	0.052	-0.080	-0.124	0.785	0.969	<b>1.000</b>	0.579**
Flower yield per plant	0.315	0.389	0.712	0.675	0.405	0.600	0.607	<b>1.000</b>

\*, \*\* P < 0.05 and 0.01, respectively

**Table 4.12: Phenotypic (above diagonal) and genotypic (below diagonal) correlation coefficients among different characters in marigold during 2012-13**

Characters	Plant height	Plant spread	Stem diameter	Stalk length	No. of primary branches per plant	No. of secondary branches per plant	Fresh weight of plant	Dry weight of plant
Plant height	<b>1.000</b>	0.222*	0.074	0.454**	-0.063	-0.011	0.086	0.095
Plant spread	0.227	<b>1.000</b>	0.262*	0.040	0.174	0.487**	0.592**	0.581**
Stem diameter	0.072	0.290	<b>1.000</b>	0.329**	0.207	0.269*	0.595**	0.594**
Stalk length	0.467	0.039	0.335	<b>1.000</b>	0.073	-0.006	0.073	0.099
No. of primary branches per plant	-0.074	0.210	0.219	0.077	<b>1.000</b>	0.558**	0.343**	0.315**
No. of secondary branches per plant	-0.013	0.576	0.293	-0.004	0.609	<b>1.000</b>	0.708**	0.688**
Fresh weight of plant	0.088	0.630	0.611	0.077	0.359	0.764	<b>1.000</b>	0.990**
Dry weight of plant	0.094	0.618	0.611	0.099	0.341	0.760	0.998	<b>1.000</b>
Days taken to first flower opening	0.146	0.361	0.459	-0.082	0.260	0.634	0.530	0.505
Duration of flowering	-0.277	0.367	0.141	-0.161	0.117	0.429	0.524	0.508
No. of buds per plant	-0.069	0.503	0.299	-0.038	0.582	0.996	0.729	0.720
No. of flowers per plant	-0.090	0.527	0.278	0.011	0.603	0.945	0.733	0.722
Flower diameter	0.177	0.157	0.375	0.141	-0.098	-0.326	0.036	0.038
Fresh weight of flower	0.294	0.224	0.386	-0.054	-0.182	-0.192	0.028	0.023
Dry weight of flower	0.505	0.262	0.249	0.003	-0.190	-0.148	0.090	0.093
Flower yield per plant	0.262*	0.592	0.536	0.033	0.291	0.632	0.620	0.610

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Characters	Days taken to first flower opening	Duration of flowering	No. of buds per plant	No. of flowers per plant	Flower diameter	Fresh weight of flower	Dry weight of flower	Flower yield per plant
Plant height	0.093	-0.259*	-0.070	-0.012	0.172	0.281**	0.441**	0.235*
Plant spread	0.292**	0.358**	0.464**	0.493**	0.140	0.203	0.262*	0.527**
Stem diameter	0.357**	0.126	0.286**	0.267*	0.349**	0.372**	0.224*	0.493**
Stalk length	-0.074	-0.154	-0.040	0.011	0.122	-0.054	0.022	0.029
No. of primary branches per plant	0.196	0.096	0.554**	0.556**	-0.112	-0.159	-0.161*	0.258*
No. of secondary branches per plant	0.497**	0.393**	0.930**	0.954**	-0.277**	-0.173	-0.130	0.590**
Fresh weight of plant	0.441**	0.494**	0.723**	0.709**	0.026	0.025	0.058	0.572**
Dry weight of plant	0.421**	0.470**	0.707**	0.694**	0.340	0.017	0.066	0.558**
Days taken to first flower opening	<b>1.000</b>	0.254*	0.545**	0.542**	-0.039	0.144	0.069	0.480**
Duration of flowering	0.328	<b>1.000</b>	0.432**	0.390**	0.133	0.090	0.041	0.337**
No. of buds per plant	0.660	0.456	<b>1.000</b>	0.968**	-0.305**	-0.167	-0.175	0.590**
No. of flowers per plant	0.664	0.403	0.995	<b>1.000</b>	-0.345**	-0.204	-0.176	0.604**
Flower diameter	-0.052	0.122	-0.340	-0.386	<b>1.000</b>	0.694**	0.528**	0.289**
Fresh weight of flower	0.184	0.082	-0.174	-0.224	0.755	<b>1.000</b>	0.718**	0.623**
Dry weight of flower	0.162	0.023	-0.171	-0.199	0.643	0.823	<b>1.000</b>	0.425**
Flower yield per plant	0.633	0.344	0.630	0.590	0.316	0.630	0.521	<b>1.000</b>

\*, \*\* P< 0.05 and 0.01, respectively

In the year 2011-12, the number of secondary branches per plant was having positive and highly significant correlation with number of flowers per plant (0.929), number of buds per plant (0.928), fresh weight of plant (0.737), dry weight of plant (0.725) and duration of flowering (0.366), whereas, it showed positive and significant correlation with days taken to first flowering opening (0.243). In the year 2012-13, the number of secondary branches per plant exhibited positive and highly significant correlation with number of flowers per plant (0.954), number of buds per plant (0.930), fresh weight of plant (0.708), dry weight of plant (0.688), days taken to first flower opening (0.497) and duration of flowering (0.393) and a negative and highly significant association with flower diameter (-0.277).

Fresh weight of plant expressed a positive and highly significant correlation with dry weight of plant (0.981), number of buds per plant (0.738), number of flowers per plant (0.713), duration of flowering (0.476), days taken to first flower opening (0.396) and with remaining traits, its association was non-significant in the year 2011-12. In the year 2012-13, fresh weight of plant had positive and highly significant association with dry weight of plant (0.990), number of buds per plant (0.723), number of flowers per plant (0.709), duration of flowering (0.494) and days taken to first flower opening (0.441).

In the year 2011-12, dry weight of plant had positive and highly significant correlation with number of buds per plant (0.735), number of flowers per plant (0.704), duration of flowering (0.517) and days taken to first flower opening (0.325). Similarly, in the year 2012-13, dry weight of plant showed positive and highly significant correlation with number of buds per plant (0.707), number of flowers per plant (0.694), duration of flowering (0.470) and dry weight of plant (0.421).

Days taken to first flower opening showed positive and highly significant correlation with number of buds per plant (0.289), while it expressed positive and significant association with number of flowers per plant (0.253) and dry weight of flower (0.217) in the year 2011-12. In the year 2012-13, days taken to first flower opening expressed positive and highly significant correlation with number of buds per plant (0.545) and number of flowers per plant (0.542) while, it showed positive and significant correlation with duration of flowering (0.254).

Duration of flowering had positive and highly significant association with number of buds per plant (0.410) and number of flowers per plant (0.365) in the year 2011-12. Likewise, in next year, the number of buds per plant (0.432) and number of flowers per plant (0.390) expressed positive and highly significant association with duration of flowering.

In the year 2011-12, the number of buds per plant exhibited positive and highly significant correlation with number of flowers per plant (0.971), number of secondary branches (0.928), fresh weight of plant (0.738), dry weight of plant (0.735), plant spread (0.527), duration of flowering (0.410), number of primary branches per plant (0.406), days

taken to first flower opening (0.289) and stem diameter (0.276), whereas, it was negative and significant with flower diameter (-0.217). In the year 2012-13, the number of buds per plant had positive and highly significant association with number of flowers per plant (0.968), number of secondary branches (0.930), fresh weight of plant (0.723), dry weight of plant (0.707), number of primary branches (0.554), days taken to first flower opening (0.545), plant spread (0.464), duration of flowering (0.432) and stem diameter (0.286).

Number of flowers per plant expressed positive and highly significant correlation with number of buds per plant (0.971), number of secondary branches (0.929), fresh weight of plant (0.713), dry weight of plant (0.704), plant spread (0.527), number of primary branches (0.428) and duration of flowering (0.365), whereas, it showed negative and significant association with flower diameter (-0.217) in the year 2011-12. In the year 2012-13, the number of flowers per plant expressed positive and highly significant correlation with number of buds per plant (0.968), number of secondary branches (0.954), fresh weight of plant (0.709), dry weight of plant (0.694), number of primary branches per plant (0.556), days taken to first flower opening (0.542), plant spread (0.493) and duration of flowering (0.390). Number of flowers showed negative and significant correlation with flower diameter (-0.345).

Flower diameter showed positive and highly significant correlation with fresh weight of flower (0.799), dry weight of flower (0.721) and stalk diameter (0.327). Negative and significant association was observed with number of flowers per plant (-0.264) and number of buds per plant (-0.217) in the year 2011-12. In the year 2012-13, flower diameter expressed positive and significant association with fresh (0.694) and dry weight of flower (0.528) and stem diameter (0.349), whereas, flower diameter exhibited negative and significant association with number of flowers per plant (-0.345), number of buds per plant (-0.305) and number of secondary branches per plant (0.277).

In the year 2011-12, fresh weight of flower had positive and highly significant correlation with dry weight of flower (0.925) and flower diameter (0.799). It showed negative and significant correlation with number of primary branches per plant (-0.230). Similarly, in the year 2012-13, fresh weight of flower exhibited positive and highly significant correlation with dry weight of flower (0.718), flower diameter (0.694), stem diameter (0.372) and plant height (0.281).

#### **4.6 PATH COEFFICIENT ANALYSIS**

Simple correlation coefficient indicates association between any two characters but does not give a complete picture of complex relationship. Therefore, it is essential to have path coefficient analysis in order to get clear picture of association among characters, as it splits the correlation coefficient into the measure of direct and indirect effects of a set of independent variables (characters) on the dependant variable through other component traits. The direct and indirect effects of various characters along with their genotypic correlation

coefficients with flower yield per plant at genotypic level have been presented in Table 4.13 and 4.14. In the present study, path coefficients were worked out using flower yield per plant as dependant and remaining fifteen characters *viz.*, plant height, plant spread, stem diameter, stalk length, number of primary branches per plant, number of secondary branches per plant, fresh and dry weight of plant, days taken to first flower opening, duration of flowering, number of buds per plant, number of flowers per plant, flower diameter, fresh weight of flower and dry weight of flower as independent variables.

#### 4.6.1 Direct effects

The critical evaluation of path coefficient analysis (Table 4.13), in which diagonal values represented direct effects, indicates that the number of flowers per plant had the highest direct and positive effect (2.092) on flower yield per plant, closely followed by dry weight of plant (0.729), fresh weight of flower (0.603) and dry weight of flower (0.138). Number of secondary branches per plant (0.096), plant height (0.066), duration of flowering (0.046), stalk length (0.043) and stem diameter (0.031) also had direct positive effect on flower yield per plant. Similarly, in the other hand, the number of buds per plant (-1.449) followed by fresh weight of plant (-0.571) had the negative direct effect, while the characters like number of primary branches per plant (-0.094), plant spread (-0.072), days taken to first flower opening (-0.067) and flower diameter (-0.018) also had direct negative effect but of lower magnitude in the year 2011-12.

In the year 2012-13, the number of flowers per plant exhibited strong direct and positive effect (1.922) on flower yield per plant (Table 4.14) followed by fresh weight of flower (0.861), fresh weight of plant (0.825) and flower diameter (0.114). Stalk length (0.091) and dry weight of flower (0.074) also had direct and positive effect on flower yield per plant. The high negative direct effect was recorded for number of buds per plant (-0.748) followed by dry weight of plant (-0.692), number of primary branches per plant (-0.160), days taken to first flower opening (-0.145), plant spread (-0.129), plant height (-0.119) and number of secondary branches per plant (-0.117).

#### 4.5.2 Indirect effects

Regarding indirect effects, it was observed that the number of secondary branches per plant had the highest positive indirect effect *via* number of buds per plant (2.087), closely followed by high positive indirect effects of number of flowers per plant (2.005), dry weight of plant (1.519), fresh weight of plant (1.517), plant spread (1.176) and number of primary branches per plant (0.925) *via* number of flowers per plant in the year 2011-12, while the number of flowers per plant had high negative indirect effect (-1.445) *via* number of buds per plant. The other characters *viz.*, number of secondary branches per plant (-1.375), dry weight of plant (-1.087) and fresh weight of plant (-1.082) also exhibited high negative indirect effect on flower yield per plant through number of buds per plant. In the year 2012-13, number of

secondary branches per plant had the highest positive indirect effect (Table 4.14) *via* number of flowers per plant (1.941), closely followed by high positive indirect effects that of number of buds per plant (1.913), number of primary branches per plant (1.159), fresh weight of plant (1.408), dry weight of plant (1.387), days taken to first flower opening (1.227) and plant spread (1.013), whereas, the number of secondary branches per plant showed high negative indirect effect (-0.753) through number of buds per plant, closely followed by number of flowers per plant (-0.745), fresh weight of plant (-0.546) and dry weight of plant (-0.539).

In the year 2011-12, plant spread had the high positive indirect effect *via* number of flowers per plant (1.176) and medium positive indirect effect *via* dry weight of plant (0.431) and fresh weight of flower (0.100), whereas, low positive indirect effect was observed through number of secondary branches per plant (0.049), dry weight of flower (0.025), duration of flowering (0.014), stem diameter (0.009), plant height (0.007) and stalk length (0.002).

Medium negative and indirect effect was recorded *via* number of buds per plant (-0.810) and fresh weight of plant (-0.333). In next year, the plant spread recorded high positive and indirect effect *via* number of flowers per plant (1.013), medium and positive indirect effect *via* fresh weight of plant (0.520) and fresh weight of flower (0.193), low positive and indirect effect *via* dry weight of flower (0.019), flower diameter (0.018) and stalk length (0.004), while other remaining characters showed negative but low indirect effect on flower yield per plant.

Fresh weight of plant had high and indirect effect through number of flowers per plant (1.517), medium and positive indirect effect *via* dry weight of plant (0.727) and low positive indirect effect through stem diameter (0.019), number of secondary branches per plant (0.071), stalk length (0.004), plant height (0.003), duration of flowering (0.023), dry weight of flower (0.002) and fresh weight of flower, while high negative indirect effect was observed through number of buds per plant (-1.082) and medium and negative indirect effect *via* fresh weight of plant (-0.571) in 2011-12. In next year, fresh weight of plant had high positive and indirect effect through number of flowers per plant (1.408), low positive and indirect effect through stalk length (0.007), fresh weight of flower (0.007) and flower diameter (0.004), whereas, the remaining characters showed low negative and indirect effects on flower yield per plant.

In the year 2011-12, the number of secondary branches per plant contributed high indirectly positive effect towards flower yield per plant *via* number of flowers per plant (2.005) and medium indirect effect *via* dry weight of plant (0.541), whereas, it had the low and positive indirect effect through stem diameter (0.007), plant height (0.004), flower diameter (0.004), stalk length (0.002) and duration of flowering (0.018). It had high indirect negative effect through number of buds per plant (-1.376).

**Table 4.13: Direct (diagonal) and indirect (off diagonal) path coefficients of different characters towards flower yield per plant in marigold during 2011-12**

Characters	Plant height	Plant spread	Stem diameter	Stalk length	No. of primary branches per plant	No. of secondary branches per plant	Fresh weight of plant	Dry weight of plant
Plant height	<b>0.066</b>	-0.008	0.003	0.021	-0.002	0.006	-0.022	0.013
Plant spread	0.007	<b>-0.072</b>	0.009	0.002	-0.007	0.049	-0.333	0.431
Stem diameter	0.006	-0.020	<b>0.031</b>	0.015	-0.012	0.022	-0.347	0.449
Stalk length	0.033	-0.003	0.011	<b>0.043</b>	-0.015	0.004	-0.050	0.064
No. of primary branches per plant	0.001	-0.005	0.004	0.007	<b>-0.094</b>	0.042	-0.150	0.194
No. of secondary branches per plant	0.004	-0.037	0.007	0.002	-0.042	<b>0.096</b>	-0.426	0.541
Fresh weight of plant	0.003	-0.042	0.019	0.004	-0.025	0.071	<b>-0.571</b>	0.727
Dry weight of plant	0.001	-0.042	0.019	0.004	-0.025	0.071	-0.569	<b>0.729</b>
Days taken to first flower opening	0.022	-0.011	0.012	0.003	-0.006	0.027	-0.223	0.277
Duration of flowering	-0.020	-0.021	0.003	-0.013	-0.002	0.038	-0.283	0.394
No. of buds/plant	0.002	-0.040	0.009	0.002	-0.039	0.091	-0.426	0.547
No. of flowers per plant	0.001	-0.040	0.007	0.001	-0.042	0.092	-0.414	0.530
Flower diameter	0.007	-0.009	0.011	-0.003	0.018	-0.020	-0.040	0.085
Fresh weight of flower	0.015	-0.012	0.008	-0.007	0.023	-0.009	-0.018	0.063
Dry weight of flower	0.013	-0.013	0.009	-0.006	0.024	-0.008	-0.007	0.044

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Characters	Days taken to first flower opening	Duration of flowering	No. of buds per plant	No. of flowers per plant	Flower diameter	Fresh weight of flower	Dry weight of flower	Genotypic correlation with flower yield per plant
Plant height	-0.022	-0.014	-0.036	0.028	-0.002	0.141	0.027	0.199
Plant spread	-0.011	0.014	-0.810	1.176	-0.002	0.100	0.025	0.579**
Stem diameter	-0.027	0.005	-0.413	0.499	-0.006	0.155	0.039	0.396**
Stalk length	-0.005	-0.014	-0.055	0.071	0.001	-0.103	-0.020	-0.036
No. of primary branches per plant	-0.004	0.001	-0.604	0.925	0.003	-0.147	-0.035	0.139
No. of secondary branches per plant	-0.019	0.018	-1.376	2.005	0.004	-0.055	-0.011	0.712**
Fresh weight of plant	-0.026	0.023	-1.082	1.517	-0.001	0.019	0.002	0.638**
Dry weight of plant	-0.026	0.025	-1.087	1.519	-0.002	0.053	0.008	0.678**
Days taken to first flower opening	<b>-0.067</b>	0.009	-0.472	0.571	-0.001	0.141	0.033	0.315**
Duration of flowering	-0.014	<b>0.046</b>	-0.630	0.799	-0.004	0.089	0.007	0.389**
No. of buds per plant	-0.022	0.020	<b>-1.449</b>	2.087	0.004	-0.061	-0.011	0.712**
No. of flowers per plant	-0.018	0.018	-1.445	<b>2.092</b>	0.005	-0.094	-0.017	0.675**
Flower diameter	-0.005	0.010	0.334	-0.578	<b>-0.018</b>	0.504	0.109	0.405**
Fresh weight of flower	-0.016	0.007	0.148	-0.325	-0.015	<b>0.603</b>	0.134	0.600**
Dry weight of flower	-0.016	0.002	0.116	-0.259	-0.014	0.584	<b>0.138</b>	0.607**

\*, \*\* P< 0.05 and 0.01, respectively  
Residual effect= 0.135

**Table 4.14: Direct (diagonal) and indirect (off diagonal) path coefficients of different characters towards flower yield per plant in marigold during 2012-13**

Characters	Plant height	Plant spread	Stem diameter	Stalk length	No. of primary branches per plant	No. of secondary branches per plant	Fresh weight of plant	Dry weight of plant
Plant height	<b>-0.119</b>	-0.029	-0.006	0.043	0.012	0.002	0.073	-0.065
Plant spread	-0.027	<b>-0.129</b>	-0.025	0.004	-0.034	-0.067	0.520	-0.427
Stem diameter	-0.009	-0.037	<b>-0.085</b>	0.031	-0.035	-0.034	0.504	-0.422
Stalk length	-0.055	-0.005	-0.028	<b>0.091</b>	-0.012	0.000	0.064	-0.069
No. of primary branches per plant	0.009	-0.027	-0.019	0.007	<b>-0.160</b>	-0.071	0.297	-0.236
No. of secondary branches per plant	0.002	-0.074	-0.025	0.000	-0.097	<b>-0.117</b>	0.631	-0.526
Fresh weight of plant	-0.010	-0.081	-0.052	0.007	-0.058	-0.089	<b>0.825</b>	-0.690
Dry weight of plant	-0.011	-0.080	-0.052	0.009	-0.055	-0.089	0.824	<b>-0.692</b>
Days taken to first flower opening	-0.017	-0.047	-0.039	-0.008	-0.042	-0.074	0.438	-0.349
Duration of flowering	0.033	-0.047	-0.012	-0.015	-0.019	-0.050	0.433	-0.351
No. of buds per plant	0.008	-0.065	-0.025	-0.003	-0.093	-0.118	0.602	-0.498
No. of flowers per plant	0.001	-0.068	-0.024	0.001	-0.097	-0.118	0.605	-0.499
Flower diameter	-0.021	-0.020	-0.032	0.013	0.016	0.038	0.030	-0.027
Fresh weight of flower	-0.035	-0.029	-0.033	-0.005	0.029	0.023	0.023	-0.016
Dry weight of flower	-0.060	-0.034	-0.021	0.000	0.030	0.017	0.074	-0.064

Contd.....

Contd.....

Characters	Days taken to first flower opening	Duration of flowering	No. of buds per plant	No. of flower per plant	Flower diameter	Fresh weight of flower	Dry weight of flower	Genotypic correlation with flower yield per plant
Plant height	-0.021	0.028	0.052	-0.016	0.020	0.253	0.037	0.262*
Plant spread	-0.052	-0.036	-0.377	1.013	0.018	0.193	0.019	0.592**
Stem diameter	-0.067	-0.014	-0.224	0.535	0.043	0.332	0.018	0.536**
Stalk length	0.012	0.016	0.028	0.022	0.016	-0.046	0.000	0.033
No. of primary branches per plant	-0.038	-0.012	-0.436	1.159	-0.011	-0.157	-0.014	0.291**
No. of secondary branches per plant	-0.092	-0.043	-0.753	1.941	-0.037	-0.166	-0.011	0.632**
Fresh weight of plant	-0.077	-0.052	-0.546	1.408	0.004	0.024	0.007	0.620**
Dry weight of plant	-0.073	-0.051	-0.539	1.387	0.004	0.020	0.007	0.610**
Days taken to first flower opening	<b>-0.145</b>	-0.033	-0.494	1.277	-0.006	0.159	0.012	0.633**
Duration of flowering	-0.048	<b>-0.099</b>	-0.342	0.775	0.014	0.071	0.002	0.344**
No. of buds per plant	-0.096	-0.045	<b>-0.748</b>	<b>1.913</b>	-0.039	-0.150	-0.013	0.630**
No. of flowers per plant	-0.097	-0.040	-0.745	<b>1.922</b>	-0.044	-0.193	-0.015	0.590**
Flower diameter	0.008	-0.012	0.254	-0.743	<b>0.114</b>	0.650	0.048	0.316**
Fresh weight of flower	-0.027	-0.008	0.130	-0.431	0.086	<b>0.861</b>	0.061	0.630**
Dry weight of flower	-0.024	-0.002	0.129	-0.382	0.074	0.709	<b>0.074</b>	0.521**

\*, \*\* P < 0.05 and 0.01, respectively  
Residual effect = 0.163

In the year 2012-13, the number of secondary branches per plant contributed high positive and indirect effects towards flower yield per plant through number of flowers per plant (1.941), moderate positive and indirect effect through fresh weight of plant (0.631) and low positive and indirect effect through plant height (0.002). Its moderate negative and indirect effect on flower yield per plant was through number of buds per plant (-0.753), dry weight of plant (-0.526) and fresh weight of flower (-0.166), while the other characters *viz.*, days taken to first flower opening (-0.092), plant spread (-0.074), stem diameter (-0.025), duration of flowering (-0.011) and number of primary branches per plant showed low negative and indirect effect on flower yield per plant.

In the year 2011-12, duration of flowering showed medium and indirect positive effects on flower yield per plant *via* number of flowers per plant (0.799) and dry weight of plant (0.399), while it showed moderate and negative indirect effect *via* number of buds per plant (-0.630). In the year 2012-13, duration of flowering had high indirect positive effect *via* number of flowers per plant (0.775) and fresh weight of plant (0.433), low positive indirect effect *via* fresh weight of flower (0.071), plant height (0.033), flower diameter (0.014), dry weight of flower (0.002), while it had moderate and negative indirect effect *via* dry weight of plant (-0.351) and number of buds per plant (-0.342). The other characters showed low negative indirect effect. Number of flowers per plant had the moderate positive indirect effect *via* dry weight of plant (0.530) and low positive indirect effect through stem diameter (0.007), plant height (0.001), stalk length (0.001), number of secondary branches per plant (0.092), duration of flowering (0.018) and flower diameter (0.005), whereas, it had high and negative indirect effect *via* number of buds per plant (-1.445) in 2011-12. In the year 2012-13, the number of flowers per plant had the medium positive indirect effect *via* fresh weight of plant (0.605), whereas, it showed low and positive indirect effect *via* plant height (0.001) and stalk length (0.001). It had moderate negative indirect effect *via* number of buds per plant (-0.745), dry weight of plant (-0.499), fresh weight of flower (-0.193) and number of secondary branches per plant (-0.118), whereas, low and indirect effect *via* number of primary branches per plant (-0.097), plant spread (-0.068), flower diameter (-0.044), duration of flowering (-0.040), stem diameter (-0.024) and dry weight of flower (-0.015).

In the year 2011-12, flower diameter registered moderate and indirect positive effects on flower yield per plant *via* fresh weight of flower (0.504), number of buds per plant (0.334) and dry weight of flower (0.109). Low and indirect positive effects were observed *via* plant height (0.007), stem diameter (0.011), number of primary branches per plant (0.018), dry weight of plant (0.085) and duration of flowering (0.010). The flower diameter posted its medium to low and indirect negative effects on flower yield per plant *via* number of flowers per plant (-0.578), fresh weight of plant (-0.040), number of secondary branches per plant (-

0.020), plant spread (-0.009), days taken to first flower opening (-0.005) and stalk length (-0.003). In the year 2012-13, flower diameter had medium and positive indirect effects *via* fresh weight of flower (0.650) and number of buds per plant (0.254) and low and positive indirect effects *via* dry weight of flower (0.061), number of secondary branches per plant (0.038), fresh weight of plant (0.030), number of primary branches per plant (0.016), stalk length (0.013) and days taken to first flower opening (0.008). Its moderate and indirect negative effect on flower yield per plant was *via* number of flowers per plant (-0.743) and low and indirect negative effect *via* stem diameter (-0.032), dry weight of plant (-0.027), plant height (-0.021), plant spread (-0.020) and duration of flowering (-0.012).

The fresh weight of flower posted its medium to low and indirect positive effects on flower yield per plant *via* number of buds (0.148), dry weight of flower (0.134), dry weight of plant (0.063), number of primary branches per plant (0.023), plant height (0.015), stem diameter (0.008) and duration of flowering (0.007). Contrarily, its negative and medium indirect effects was observed *via* number of flowers per plant (-0.325) and other characters *viz.*, fresh weight of plant (-0.018), days taken to first flower opening (-0.016), flower diameter (-0.015), plant spread (-0.012), number of secondary branches per plant (-0.009) and stalk length (-0.007), showed low and negative indirect effect on flower yield per plant in the year 2011-12. In the year 2012-13, fresh weight of flower had its medium high positive and indirect effect *via* number of buds per plant (0.130), whereas, its low positive and indirect effect was *via* number of primary branches per plant (0.029), number of secondary branches per plant (0.023), fresh weight of plant (0.023), flower diameter (0.086) and dry weight of flower (0.061). The number of flowers per plant (-0.431) showed medium and negative indirect effect on flower yield per plant and low and negative indirect effect *via* days taken to first flower opening (-0.027), duration of flowering (-0.008), plant height (-0.035), plant spread (-0.029), stalk diameter (-0.033), stalk length (-0.005) and dry weight of plant (-0.016).

#### **4.6 DIVERGENCE ANALYSIS**

Estimation of degree of divergence between biological populations and computation of relevant contribution of different components to total divergence is done completely by Mahalanobis's generalized distance estimated through  $D^2$  statistic. During any hybridization programme, the selection of parents using  $D^2$  statistic provides the required potential parents, which are under study with respect to an array of characters. With the selection of genotypes, based on their genetic distance and yield potential, a breeder can formulate an appropriate crossing programme for the desired crop improvement.

The significant values of mean sum of squares due to genotypes from the analysis of variance (Table 4.1 and 4.2) revealed the presence of significant variation among the genotypes for all the characters investigated but such analysis is unable to tell anything about

extent of genetic diversity present among the genotypes taken for the investigation. To overcome this problem and simultaneously to quantify genetic divergence between any two genotypes or group of genotypes, Mahalanobis'  $D^2$  statistics (1936) as described by Rao (1952) was used and the grouping of genotypes into different clusters was done by following Tocher's method (Rao, 1952).

#### 4.6.1 Grouping of marigold genotypes into various clusters

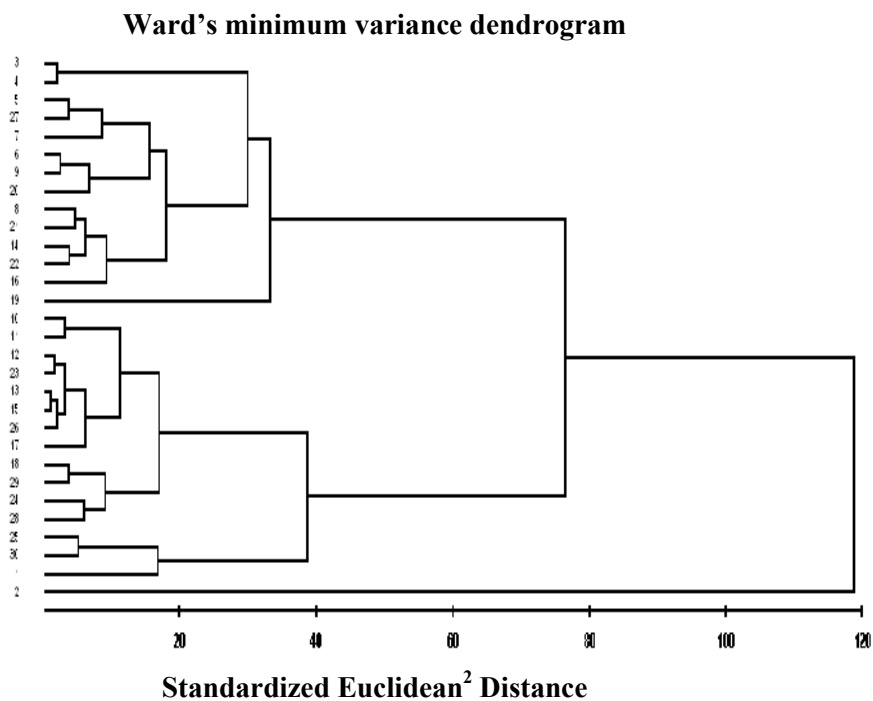
The thirty genotypes of marigold assessed in the present study were classified into various clusters based on the degree of divergence and similarity among them. These genotypes differed widely and classified into six distinct clusters (Table 4.15, 4.16 and Fig. 4.1 and 4.2). In the year 2011-12, the cluster-IV possessed the maximum (12) number of genotypes followed by cluster-II having the 11 genotypes. The clusters-V and I included three and two genotypes, respectively, while the clusters-III and VI each accommodated one genotype.

In the year 2012-13 (Table 4.16), cluster-II was the largest one with 13 genotypes followed by cluster-V with nine genotypes and cluster-IV with three genotypes, whereas, clusters-I and III each accommodated two genotypes and cluster-VI had only single genotype.

**Table 4.15: Grouping of marigold genotypes into different clusters during 2011-12**

Clusters	Number of genotypes	Name of genotype (s)
I	2	MGH-09-271 MGH-09-276
II	11	MGH-09-276-1, MGH-160-9-1, MGH-09-302, MGH-09-301, MGH-09-304, MGH-148-8, MGH-09-303, MGH-160-5-1, MGH-133-1-3, MGH-160-5-2, MGH-133-3-2
III	1	MGH-148-3-3
IV	12	MGH-09-305, MGH-10-101, MGH-133-1-1, MGH-160-5-3, MGH-133-1-2, MGH-133-2, MGH-160-9, MGH-133-5, MGH-133-5-2, MGH-160-9-4, MGH-160-7-1, MGH-160-9-3
V	3	MGH-160-8-3-2, MGH-07-160-8-3-3, Hisar Beauty
VI	1	Hisar Jaffri-2

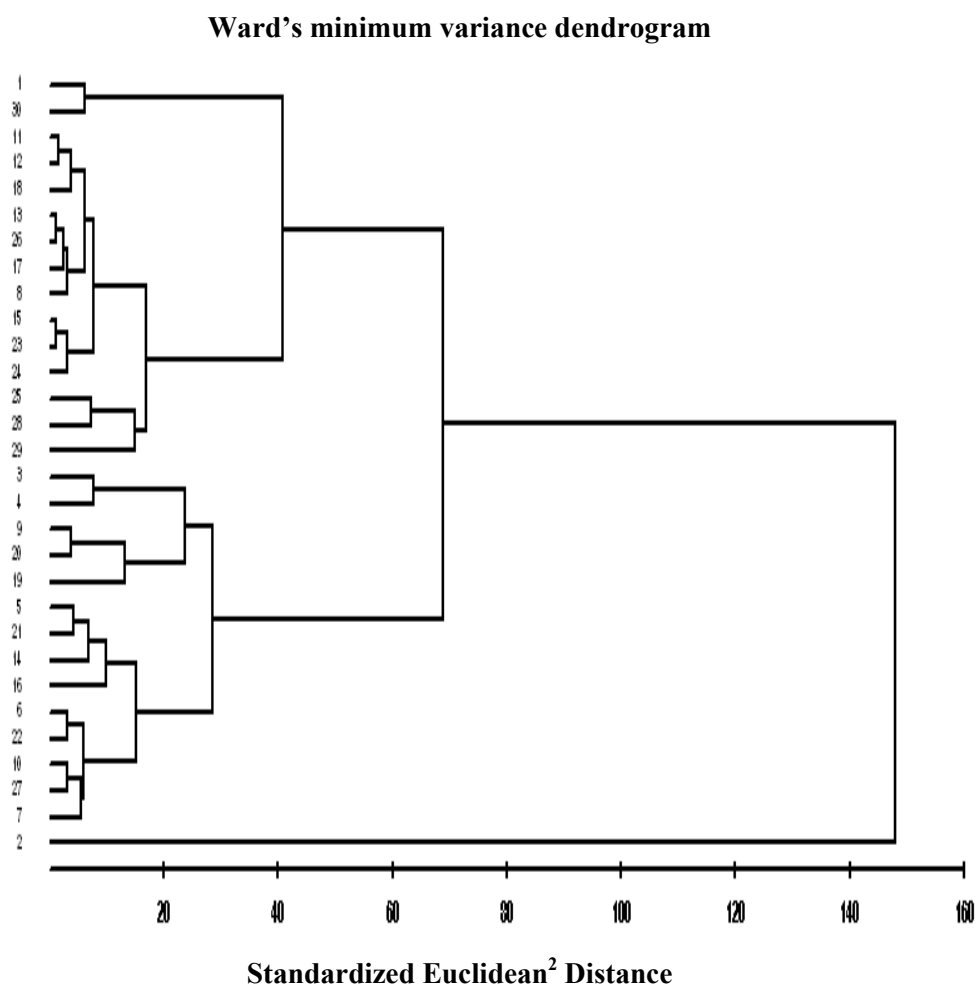
**Fig. 4.1:** The dendrogram showing the clustering pattern of genotypes of marigold during 2011-12



**Table 4.16:** Grouping of marigold genotypes into different clusters during 2012-13

<b>Clusters</b>	<b>Number of genotypes</b>	<b>Name of genotype (s)</b>
<b>I</b>	2	Hisar Beauty, MGH-07-160-8-3-3
<b>II</b>	13	MGH-10-101, MGH-133-1-1, MGH-133-5-2, MGH-133-1-2, MGH-160-9, MGH-133-5, MGH-09-303, MGH-133-2, MGH-160-5-3, MGH-160-7-1, MGH-160-8-3-2, MGH-160-9-3, MGH-160-9-4
<b>III</b>	2	MGH-09-271, MGH-09-276
<b>IV</b>	3	MGH-09-304, MGH-148-8, MGH-148-3-3
<b>V</b>	9	MGH-09-276-1, MGH-160-5-1, MGH-133-1-3, MGH-133-3-2, MGH-09-301, MGH-160-5-2, MGH-09-305, MGH-160-9-1, MGH-09-302
<b>VI</b>	1	Hisar Jaffri-2

**Fig. 4.2:** The dendrogram showing the clustering pattern of genotypes of marigold during 2012-13



#### 4.6.2 Intra- and inter-cluster average $D^2$ values

Average intra- and inter-cluster  $D^2$  values among 30 genotypes for the year 2011-12 (Table 4.17) revealed that the cluster-I had the minimum intra-cluster value (1.98), indicating that the genotypes within this cluster were genetically less variable, while cluster-V showed the maximum intra-cluster  $D^2$  value (4.68) followed by cluster-II (3.97) and cluster-IV (3.42), revealing thereby the existence of diverse genotypes that fall in these clusters. With respect to inter-cluster,  $D^2$  value ranged from 4.38 to 13.31. The minimum inter-cluster  $D^2$  value was observed between cluster-II and IV, indicating close relationship among the genotypes included in these clusters. The maximum inter-cluster value was observed between cluster-V and VI (13.31) followed by cluster-I and VI (12.27), cluster-IV and VI (11.64), cluster-II and VI (11.17) and cluster-III and V (9.47), indicating that the genotypes included in these clusters were genetically diverse and might give rise to high heterotic response.

**Table 4.17: Average intra (diagonal) and inter cluster D<sup>2</sup> values of marigold genotypes in clusters during 2011-12**

Clusters	I	II	III	IV	V	VI
I	<b>1.98</b>	5.08	7.12	6.46	7.93	12.27
II		<b>3.97</b>	6.57	4.38	6.12	11.17
III			<b>0.00</b>	7.65	9.47	8.99
IV				<b>3.42</b>	5.36	11.64
V					<b>4.68</b>	13.31
VI						<b>0.00</b>

For the year 2012-13, the average intra- and inter-cluster D<sup>2</sup> values for six clusters have been presented in Table 4.18. The maximum intra-cluster distance was observed for cluster-IV (4.12) followed by cluster-III (3.92), cluster-V (3.67) and so on.

**Table 4.18: Average intra (diagonal) and inter cluster D<sup>2</sup> values of marigold genotypes in clusters during 2012-13**

Clusters	I	II	III	IV	V	VI
I	<b>3.50</b>	5.65	8.69	8.39	6.53	14.61
II		<b>3.41</b>	6.06	5.42	4.13	12.88
III			<b>3.92</b>	5.40	5.08	12.87
IV				<b>4.12</b>	4.86	11.63
V					<b>3.67</b>	12.61
VI						<b>0.00</b>

The nearest inter-cluster distance was found between cluster-II and V (4.13) followed by cluster-IV and V (4.86), cluster III and V (5.08). The widest inter-cluster distance (14.61) was found between cluster-I and VI followed by cluster-II and VI (12.88), cluster-III and VI (12.87), cluster-V and VI (12.61).

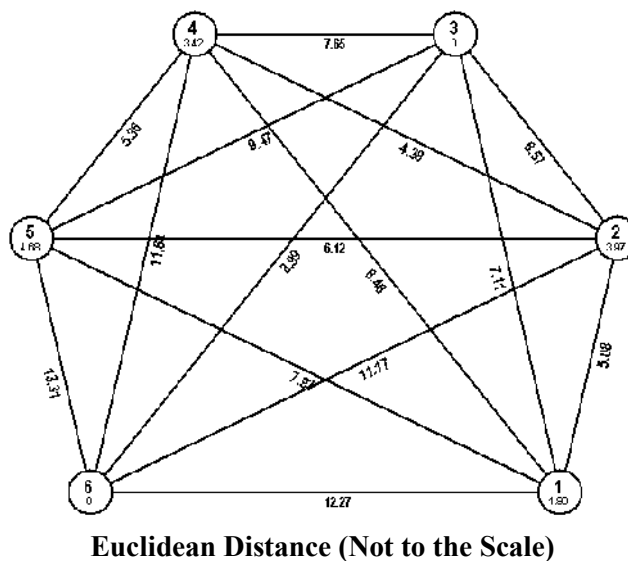
#### **4.6.3 Cluster-wise mean values of characters**

The cluster means and contribution of each trait toward genetic divergence for the year 2011-12, are presented in Table 4.19. The perusal of data revealed considerable differences among the clusters for most of the characters studied. The maximum mean plant height (81.31) was observed in cluster-II, followed by cluster-IV (79.53), while the minimum mean plant height was observed in cluster-V (40.72). The genotypes included in cluster-VI showed maximum plant spread (76.53) followed by cluster-III (68.23), whereas, the genotypes included in the cluster-V recorded the minimum plant spread (33.96). Cluster-III

had the maximum (2.18), while cluster-V had the lowest (1.13) value for stem diameter. The highest cluster mean value for the stalk length was observed in cluster-IV (19.86) followed by cluster-III (16.15), whereas, the minimum value was recorded in cluster-V (5.51). The maximum number of primary (23.47) and secondary (140.27) braches per plant was recorded in cluster-V, while cluster-III and V had the minimum (10.73 and 27.93, respectively) cluster mean value.

The maximum fresh and dry weight of plant was recorded in cluster-III (1197.50 and 139.00, respectively) and minimum (195.42 and 23.63, respectively) in cluster-V. The days taken to first flower opening showed earliest flowering mean performance in cluster-V (44.78) followed by cluster-IV (45.69) and the delayed flowering occurred in cluster-VI (61.20). Duration of flowering illustrated the highest cluster mean value (71.93) in cluster-VI followed by cluster-III (65.87). Number of buds and flowers per plant exhibited the highest cluster mean values (201.80 and 179.53, respectively) in cluster-VI, whereas, cluster-V showed the lowest cluster mean value (40.67 and 33.31, respectively) for both these characters.

**Fig. 4.3 Cluster diagram showing average intra-and inter-cluster  $D^2$  values of genotypes during 2011-12**



The highest flower diameter (7.96) was observed in cluster-I followed by cluster III (7.16), whereas, the lowest flower diameter (4.06) was recorded in cluster-VI. Fresh and dry weight of flower revealed the highest cluster mean values (14.30 and 2.11, respectively) in cluster-I, whereas, cluster-VI showed the lowest cluster mean value (4.85 and 0.59, respectively) for both these characters. Flower yield per plant exhibited the highest mean performance (869.18) for cluster-VI followed by cluster-I (761.97), whereas, the lowest mean value (177.52) was in cluster-V.

**Table 4.19: Cluster mean values for various characters in marigold genotypes during 2011-12**

Clusters	X <sub>1</sub>	X <sub>2</sub>	X <sub>3</sub>	X <sub>4</sub>	X <sub>5</sub>	X <sub>6</sub>	X <sub>7</sub>	X <sub>8</sub>	X <sub>9</sub>	X <sub>10</sub>	X <sub>11</sub>	X <sub>12</sub>	X <sub>13</sub>	X <sub>14</sub>	X <sub>15</sub>	X <sub>16</sub>
I	67.45	54.46	1.48	9.91	11.73	44.67	289.29	40.53	51.10	49.03	68.27	53.40	7.96	14.30	2.11	761.97
II	81.31	50.43	1.26	13.80	10.94	49.59	398.63	49.01	50.50	54.50	63.93	52.39	6.70	9.33	1.11	487.11
III	65.15	68.23	2.18	16.15	10.73	59.73	1197.50	139.00	50.27	65.87	85.33	72.47	7.16	8.87	1.17	642.72
IV	79.53	46.97	1.30	19.86	13.60	43.46	275.91	33.91	45.69	40.93	60.36	51.17	5.71	7.07	0.88	364.51
V	40.72	33.46	1.13	5.51	13.18	27.93	195.42	23.63	44.78	44.08	40.67	33.31	5.57	5.83	0.68	177.52
VI	64.03	76.53	1.58	11.50	23.47	140.27	1092.06	126.48	61.20	71.93	201.80	179.53	4.06	4.85	0.59	869.18

Where,

X<sub>1</sub>= plant height (cm)      X<sub>5</sub>= No. of primary branches per plant      X<sub>9</sub>= Days taken to first flower opening      X<sub>13</sub>= Flower diameter (cm)  
X<sub>2</sub>= Plant spread (cm)      X<sub>6</sub>= No. of secondary branches per plant      X<sub>10</sub>= Duration of flowering (days)      X<sub>14</sub>=Fresh weight of flower (g)  
X<sub>3</sub>= Stem diameter (cm)      X<sub>7</sub>= Fresh weight of plant (g)      X<sub>11</sub>= No. of buds per plant      X<sub>15</sub>= Dry weight of flower (g)  
X<sub>4</sub>= Stalk length (cm)      X<sub>8</sub>= Dry weight of plant (g)      X<sub>12</sub>= No. of flowers per plant      X<sub>16</sub>= Flower yield per plant (g)

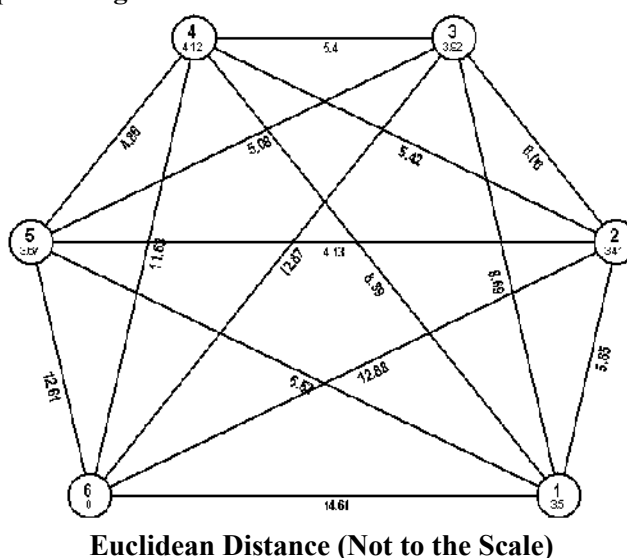
**Table 4.20: Cluster mean values for various characters in marigold genotypes during 2012-13**

Clusters	X <sub>1</sub>	X <sub>2</sub>	X <sub>3</sub>	X <sub>4</sub>	X <sub>5</sub>	X <sub>6</sub>	X <sub>7</sub>	X <sub>8</sub>	X <sub>9</sub>	X <sub>10</sub>	X <sub>11</sub>	X <sub>12</sub>	X <sub>13</sub>	X <sub>14</sub>	X <sub>15</sub>	X <sub>16</sub>
I	36.90	35.75	0.83	4.46	11.83	29.45	127.73	16.05	43.40	51.87	47.53	35.27	5.20	4.27	0.50	138.22
II	77.14	45.44	1.32	17.39	13.66	42.46	283.65	35.88	47.45	41.66	64.95	52.80	6.04	7.95	0.93	420.09
III	68.44	59.27	1.52	9.08	12.63	46.60	323.11	36.52	52.60	59.40	74.80	54.48	7.79	15.86	1.43	863.91
IV	68.74	52.57	1.90	20.44	11.18	50.89	673.43	78.63	52.42	64.27	74.87	59.78	7.35	9.71	1.22	581.11
V	85.71	55.57	1.20	13.61	11.35	42.53	405.35	47.44	49.38	57.78	64.50	50.36	6.66	9.37	1.22	471.53
VI	61.32	78.90	1.64	10.47	25.53	161.67	1139.11	124.23	68.00	81.13	232.40	198.47	3.96	4.42	0.53	879.56

Where,

X<sub>1</sub>= plant height (cm)      X<sub>5</sub>= No. of primary branches per plant      X<sub>9</sub>= Days taken to first flower opening      X<sub>13</sub>= Flower diameter (cm)  
X<sub>2</sub>= Plant spread (cm)      X<sub>6</sub>= No. of secondary branches per plant      X<sub>10</sub>= Duration of flowering (days)      X<sub>14</sub>=Fresh weight of flower (g)  
X<sub>3</sub>= Stem diameter (cm)      X<sub>7</sub>= Fresh weight of plant (g)      X<sub>11</sub>= No. of buds per plant      X<sub>15</sub>= Dry weight of flower (g)  
X<sub>4</sub>= Stalk length (cm)      X<sub>8</sub>= Dry weight of plant (g)      X<sub>12</sub>= No. of flowers per plant      X<sub>16</sub>= Flower yield per plant (g)

**Fig. 4.4: Cluster diagram showing average intra-and inter-cluster  $D^2$  values of genotypes during 2012-13**



In the year 2012-13, the mean values of 16 characters recorded for the genotypes grouped in 6 different clusters are presented in Table 4.20. The highest cluster mean value for plant height was observed in cluster-V (85.71) followed by cluster-II (77.14). Cluster-VI had the maximum (78.90), while cluster-I had the lowest (35.75) value for plant spread. The maximum stem diameter and stalk length (1.90 and 20.44, respectively) was found in cluster-IV, whereas, cluster-I was recorded the lowest cluster mean value (0.84 and 4.46, respectively) for both of these characters. The highest number of primary (25.53) and secondary braches per plant (161.67) was reported in cluster-VI. However, the cluster-IV and I showed the lowest cluster mean value (11.18 and 29.45, respectively). Fresh and dry weight of plant was found highest in cluster-VI (1139.11 and 124.23, respectively) and lowest in cluster-I (127.73 and 16.05, respectively). The days taken to first flower opening showed earliest flowering mean performance in cluster-I (43.40) followed by cluster-II (47.45), whereas, the delayed flowering occurred in the cluster-VI (68.00).

The longest flowering duration (81.13) was obtained in cluster-VI and it was lowest (41.66) for the genotypes under cluster-II. Cluster-VI genotypes showed the maximum number of buds (232.40) and flowers (198.47), while the minimum number of buds (47.53) and flowers per plant (35.27) was recorded in cluster-I. With respect to flower diameter, the maximum mean (7.79) was recorded by the genotypes in cluster-III, while cluster-I depicted the minimum mean flower diameter (3.96). The genotypes forming cluster-III registered the highest fresh (15.86) and dry weight (1.43) of flower, whereas, the genotypes of cluster-I had the lowest fresh (4.27) and dry weight (0.50) of flower. The maximum flower yield per plant (879.56) was found in cluster-VI followed by cluster-III (863.91) and the lowest (138.22) in cluster-I.

Marigold (*Tagetes* species) gained popularity among the growers due to its easy cultivation, wide adaptability, different colour, shape, size and good keeping quality. It is used for making garlands, wreaths and religious offerings and is also ideal for garden display both in beds and pots. It has also medicinal value. The main objectives of marigold breeding are early flowering, good shape, attractive colour, flower size, high flower yield and xanthophylls content. To meet the continuously expanding needs of varietal improvement, the collection, evaluation, conservation and characterization of entire existing germplasm are essential for more rewarding breeding efforts. Characterization of a variety is useful to identify and avoid duplication. Practically a variety must be distinct, uniform and stable in the characters that are adopted for use in varietal characterization and identification.

The present investigation was undertaken with the objective to understand the nature and magnitude of variability, association and path coefficient among yield and its component in thirty genotypes of marigold. The observed results have been discussed in this chapter in light of findings of earlier research works under the following heads:

- 5.1 Analysis of variance
- 5.2 Mean performance of marigold genotypes
- 5.3 Variability parameters
- 5.4 Correlation coefficients analysis
- 5.5 Path coefficients analysis
- 5.6 Divergence analysis
- 5.7 Characterization

#### **5.1 ANALYSIS OF VARIANCE**

The results of analysis of variance revealed that mean sums of square due to genotypes were significant for all the traits (Table 4.1 and 4.2) even at 1% level of probability, indicating considerable variability present in experimental material. Similar findings were reported by Singh and Misra (2008), Sharma and Raghuvanshi (2011), Singh and Kumar (2008) and Namita *et al.* (2008) in marigold.

#### **5.2 MEAN PERFORMANCE OF MARIGOLD GENOTYPES**

##### **5.2.1 Growth characters**

The mean performance of growth characters *viz.*, plant height, plant spread, stem diameter, stalk length, number of primary branches per plant, number of secondary branches

per plant and fresh and dry weight of plant, observed on all individual genotypes in the year 2011-12 and 2012-13 are presented in Table 4.3 and 4.5, respectively.

The results showed that there were significant differences among the genotypes for plant height. The maximum plant height (105.97 cm) was recorded in genotype MGH-09-303, whereas, it was minimum (32.07 cm) in Hisar Beauty in the year 2011-12. Similarly, in the year 2012-13, the maximum plant height (106.07 cm) was observed in MGH-160-9-4 and the minimum (32.72 cm) in Hisar Beauty. Plant height is attributed to be an important varietal character that depends upon the genetic constitution. The variation in plant height among the various genotypes might be due to genotypic differences in phenotypic expression of plant height and variations in different genotype-environmental interaction effects on plant height. Similar variation in plant height due to genotypes was also reported by Rao *et al.* (2005), Singh and Singh (2006) and Khanvilkar *et al.* (2003) in marigold.

Considering the values for plant spread in all the genotypes during 2011-12 and 2012-13, the maximum plant spread (76.53 and 78.90 cm, respectively) was observed in genotype Hisar Jaffri-2, whereas, the minimum plant spread (31.92 and 35.06 cm) was observed in MGH-160-8-3-2 and Hisar Beauty, respectively. Singh *et al.* (2003), Narsude *et al.* (2010a) and Raghuvanshi and Sharma (2011) also reported variation in plant spread due to the inherent character of marigold genotypes.

The maximum stem diameter (2.18 and 2.09 cm) was observed in MGH-148-3-3 and the minimum (0.58 and 0.63 cm) in Hisar Beauty in the year 2011-12 and 2012-13, respectively. Production of strong and sturdy stem or thin and weak stem might be dependent upon the genotype that could have been further persuaded by the environmental conditions. Hence, variation in stem diameter of the studied genotypes could have resulted due to their genetic makeup and environmental conditions prevailed during experimentation. The findings of the present investigation confirm well with results reported by Ingle *et al.* (2011), Singh *et al.* (2004) and Singh and Singh (2006) in marigold.

The results of stalk length clearly indicated that the genotype MGH-160-9-4 was significantly superior than other genotypes with mean value 26.36 and 27.69 cm in both the years of investigation. Moreover, the genotype Hisar Beauty was found to have minimum stalk length 4.52 and 4.24 cm in the year 2011-12 and 2012-13, respectively. The variation in stalk length among the various genotypes might be due to genotypic differences in phenotypic expression of stalk length and variations in different genotype-environmental interaction effects on stalk length. It could have also been influenced by other plant characters *viz.*, plant height, stem diameter etc. Variation in stalk length has also been reported by Kumari *et al.* (2012) and Bhayani *et al.* (2008) in gerbera.

In the year 2011-12 and 2012-13, the genotypes studied showed highly significant differences for number of primary branches per plant. The maximum value 23.47 and 25.53 was recorded in Hisar Jaffri-2 and the minimum 8.13 and 8.87 in MGH-10-101 in both years, respectively. The variation in number of primary branches per plant might be primarily due to their genetic makeup that could have also been influenced by the environmental conditions. Similar findings have also been reported by Raghuvanshi and Sharma (2011), Rao *et al.* (2005), Singh and Singh (2010) and Narsude *et al.* (2010a) in marigold.

The maximum number of secondary branches per plant was found in Hisar Jaffri-2 with the mean value of 140.27 and 161.67 in 2011-12 and 2012-13, respectively, while the minimum number of secondary branches per plant (21.40 and 22.63) was observed in MGH-07-160-8-3-3 in 2011-12 and 2012-13, respectively. The number of secondary branches per plant is an important genotypic character in marigold that might be primarily governed by the genetic makeup of the genotypes. Similar results have also been reported by Singh and Singh (2005a) and Khanvilkar *et al.* (2003) in marigold.

The results showed highly significant difference among the genotypes for fresh weight of plant. The maximum fresh weight of plant, *i.e.*, 1197.50 and 1139.11 g, was observed in MGH-148-3-3 and Hisar Jaffri-2 and minimum fresh weight of plant (79.89 and 77.62 g) in Hisar Beauty in 2011-12 and 2012-13, respectively. The variation in fresh weight of plant might be due to the congenial environment to express the dominant genes in the genotypes. The increase in this character could be due to higher uptake of nitrogen. Nitrogen is a very important constituent of protoplasm and its favourable effect on chlorophyll content of leaves might have increase the synthesis of carbohydrates, amino acids etc. from which phytohormones have been synthesized resulting in increase in vegetative characters. Variation in vegetative growth parameters has also been reported by Singh and Singh (2005a) and Singh and Singh (2010) who observed significant variation in vegetative growth parameters among marigold germplasm.

The maximum dry weight of plant (139.00 and 124.33 g) was observed in genotype MGH-148-3-3 and minimum dry weight of plant (9.37 and 10.45 g) in Hisar-Beauty in 2011-12 and 2012-13, respectively. The high accumulation of dry matter in MGH-148-3-3 was owing to vigorous growth of their plants. The dry weight of plant exhibited highly positive correlation with fresh weight of plant. Similar results were obtained by Khanvilkar *et al.* (2003) and Rao *et al.* (2005) in marigold.

### **5.2.2 Flowering characters**

The results regarding to flowering characters *i.e.* days taken to first flower opening, duration of flowering, number of buds per plant, number of flowers per plant and fresh and

dry weight of flower, observed on all individual genotypes in the year 2011-12 and 2012-13 are presented in Table 4.4 and 4.6, respectively.

The results revealed highly significant difference in days taken to first flower opening among the genotypes that ranged from a minimum of 36.80 and 39.00 in Hisar Beauty to the maximum 61.20 and 68.00 days in Hisar Jaffri-2 in the years 2011-12 and 2012-13, respectively. The time required for days taken to first flower opening is an important genotypic character in marigold that might be primarily governed by the genetic makeup of the genotypes. The results observed were in line with earlier findings of Beniwal and Dahiya (2012), Rao *et al.* (2005), Khanvilkar *et al.* (2003) and Singh *et al.* (2003) in marigold.

The duration of flowering varied from 29.93 to 71.93 and 33.93 to 81.13 during the year 2011-12 and 2012-13, respectively. The longest flowering duration (71.93 and 81.13 days) was observed in Hisar Jaffri-2, whereas, the shortest flowering duration (29.93 and 33.93 days) was observed in MGH-133-5-2. This could be due to more dry matter accumulation because of absorption of more nitrogen and other nutrients and nutrients uptake in addition to prevailing favourable environment, *i.e.*, low night temperature and short day lengths. The genetic control of all these characters and modification in their expression due to environmental conditions might be the possible causes of observed variation. Similar findings have been also reported by Rao *et al.* (2005), Raghuvanshi and Sharma (2011) and Khanvilkar *et al.* (2003) in marigold.

The results showed that there was highly significant difference in number of buds per plant among the genotypes. The maximum number of buds per plant (201.80 and 232.40) was recorded in Hisar Jaffri-2, while the minimum number of buds per plant (33.60 and 42.13) was found in MGH-07-160-8-3-3 in both the years of investigation. The variation in number of buds per plant might be due to hereditary traits of the genotypes. Thus, it could be concluded that the variation in number of buds per plant might be primarily due to their genetic makeup that could have also been influenced by the environmental conditions. The results observed were in line with earlier findings of Beniwal and Dahiya (2012), Khanvilkar *et al.* (2003) and Singh *et al.* (2003) in marigold.

The results indicated that there was highly significant difference in number of flowers per plant among the genotypes. The maximum number of flowers per plant (179.53 and 198.47) was recorded in Hisar Jaffri-2, while the minimum number of flowers per plant (28.07 and 29.47) was observed in MGH-07-160-8-3-3 during 2011-12 and 2012-13. It could be stated that variation among the genotypes for number of flowers per plant might be due to genotypic and environmental differences. Similar results were reported by Narsude *et al.*

(2010b), Beniwal and Dahiya (2012), Singh *et al.* (2004) and Singh and Misra (2009) in marigold.

The results pointed out that there was highly significant difference for fresh weight of flower among the genotypes. The maximum fresh weight of flower (15.93 and 15.21 g) was recorded in MGH-09-271, whereas, the minimum (2.44 and 2.19 g) was observed in Hisar Beauty in 2011-12 and 2012-13. The weight of flower appeared to be associated with diameter of flower as evident from the results. Therefore, it could be concluded that the variation in fresh weight of flower among the genotypes might be due to their genetic makeup. The results are in accordance with the finding of Singh and Misra (2009), Rao *et al.* (2005), Narsude *et al.* (2010b) and Beniwal and Dahiya (2012) in marigold.

The results of dry weight of flower clearly indicated that the genotypes MGH-09-271 was significantly superior over other genotypes with the mean value of 2.17 and 1.90 g whereas the minimum was found in Hisar Beauty with the mean value of 0.26 and 0.29 g during the year 2011-12 and 2012-13. The difference in dry weight of flower might be due to inherent characters of the individual genotypes. The findings of the present investigation confirm well with results reported by Singh and Singh (2006) and Singh *et al.* (2003) in marigold.

### **5.2.3 Flower yield**

The results of flower yield in terms of per plant, per plot and per hectare are presented in Table 4.4 and 4.6, revealed highly significant difference in flower yield among the genotypes. The maximum flower yield per plant (869.18 and 879.56 g) was recorded in Hisar Jaffri-2, while the minimum flower yield per plant (106.69 and 89.26 g) was observed in Hisar Beauty in the year 2011-12 and 2012-13, respectively. The flower yield per plot and per hectare might have direct correlation with yield per plant, as has been indicated by the results. The maximum flower yield per plot (20.86 and 21.11 kg) and flower yield per hectare (543.24 and 549.72 q) were obtained in Hisar Jaffri-2. The minimum flower yield per plot (2.56 and 2.14 kg) and per hectare (66.68 and 55.79 q) was recorded in Hisar Beauty in the year 2011-12 and 2012-13, respectively. Flower yield exhibited highly positive correlation with number of flowers per plant, flower diameter and weight of flower. Similar results have also been reported by Rao *et al.* (2005), Singh and Singh (2006), Narsude *et al.* (2010a) and Beniwal and Dahiya (2012) in marigold.

## **5.3 VARIABILITY PARAMETERS**

Variability refers to the presence of differences among the individuals of plant population, which might be due to the differences either in genetic constitution of an individual of a population or in environment, in which they are grown. The existence of

variability is essential for resistance to biotic and abiotic factors as well as wider adaptability. Selection is effective only when there is genetic variability among the individuals in a population. Hence, insight into the magnitude of variability present in a population is of paramount importance to a plant breeder for starting a judicious breeding programme.

In the present investigation, comparison of coefficients of variation indicated that the phenotypic coefficient of variation (PCV) was higher than genotypic coefficients of variation (GCV) for all the characters (Table 4.9a and 4.10a), which indicated the effect of environment on the character expression. The results were in accordance with those of Singh and Misra (2008), Sharma and Raghuvanshi (2011), Verma *et al.* (2002) and Janakiram and Rao (1995) in marigold.

Among all the characters, high GCV and PCV were observed for fresh weight of plant followed by dry weight of plant, number of flowers per plant, number of buds per plant and number of secondary branches per plant in comparison to other characters (Table 4.9b and 4.10b), indicating the presence of high amount of genetic variability for these traits and effective for selection because the response to selection is directly proportional to the variability present in the experimental material. These results are in conformity with the previous results as reported by Namita *et al.* (2008), Pattnaik and Mohanty (2002), Singh and Sen (2001), Verma *et al.* (2002) and Mathew *et al.* (2005a) in marigold. However, the low estimates of PCV and GCV observed for days taken to first flower opening and flower diameter indicated that the genotypes used had less genetic variability for these characters. These results are in confirmation with the findings of Pattnaik and Mohanty (2002), Sharma and Raghuvanshi (2011) and Namita *et al.* (2008). Narrow difference between PCV and GCV revealed that variability existing among different genotypes of marigold was mainly due to genetic makeup and there was less environmental influence on the expression of this trait. Same results had also been recorded by Singh and Misra (2008) in marigold.

The heritability estimate of a quantitative character is very important since phenotypic expression of a genotype may be altered by environment at various stages of its development. Heritability indicates the effectiveness with which selection for genotypes can be done on the basis of its phenotypic variation. It expresses the extent to which individual phenotypes are determined by their genotypes. The heritability estimates serve as a useful guide to the breeder because selection would be fairly easy for the characters with high heritability. Thus, a close correspondence between the genotype and phenotype will be attributed to a relatively smaller contribution of the environment to phenotype, but for a character with low heritability, selection may not be effective due to the masking effect of environment on genotypic effect. The response to selection depends upon the relative magnitude of heritable variation present in relation to the phenotypic variation. Therefore, it is

desirable to partition observed variability into its heritable and non-heritable components. Burton (1952) suggested that genotypic coefficient of variation along with heritability would give a better idea about the efficiency of selection. Thus, a character with high genotypic coefficient of variation and high heritability will be more valuable in selection programme.

In present investigation, high heritability along with high genotypic coefficient of variance was recorded for fresh weight of plant, number of secondary branches per plant, fresh weight of flower, number of buds and flowers per plant and stalk length (Table 4.9b and 4.10b). This indicates good correspondence between genotypic and phenotypic values and thereby low environmental effect on the expression of these characters. These results are in agreement with the findings of Mathew *et al.* (2005a), Kavitha and Anburani (2010a), Yuvraj *et al.* (2012) and Karuppaiah and Kumar (2011a) in marigold. Low value of heritability was recorded for days taken to first flower opening. Singh and Singh (2010) reported low heritability for days taken to bud initiation in marigold.

Heritability estimates alone do not provide reliable information about the gene action governing the expression of a particular character and also it does not provide the information of the amount of genetic progress that would result from the selection of best individuals. Johanson *et al.* (1955) pointed out that the heritability estimates along with genetic advance were more useful than heritability estimates alone in predicting the response to selection. In the present investigation, genetic advance as per cent of mean was also estimated in order to determine the relative merits of different characters that could be further utilized in the selection programme. Relative comparison of heritability along with genetic advance as a percentage of mean over the characters indicated that characters *viz.*, fresh weight of plant, flower yield per plant and per hectare had high heritability estimates along with high genetic advance as a percentage of mean (Table 4.9b and 4.10b). Panse (1957) suggested that the genotypic variations for such characters are probably due to high additive gene effects and least influenced by the environment. The phenotypic selection based on such a character is likely to be more effective for the improvement of the genotype and hence these characters offer good promise for further breeding programme using simple breeding methods. Similar results were also reported by Singh *et al.* (2007), Singh and Singh (2010), Singh and Kumar (2008), Namita *et al.* (2008) and Mathew *et al.* (2005a) in marigold. Thus, high heritability along with high genetic advance as a percentage of mean was observed for other characters also like dry weight of plant, number of buds per plant, number of flowers per plant and number of secondary branches per plant. In this condition, selection will be more effective for these characters. However, low genetic advance was reported for dry weight of flower, stem diameter, flower diameter, fresh weight of flower and number of primary branches per plant, therefore, selection for these characters would not be much effective.

#### 5.4 CORRELATION COEFFICIENT ANALYSIS

Correlation between traits could be due to linkage or pleiotropy. Correlation due to linkage can be manipulated or changed through recombination but it could be impossible to overcome the correlation due to pleiotropy. In later case, genetic improvement in one trait is not eventually possible without bringing a change in the associated component traits.

Yield is a complex character and it depends on a number of characters, therefore, yield can be improved by direct as well as indirect selection. To identify component characters, correlation is an important tool. Further estimates of correlation at genotypic as well as phenotypic level are more informative. The strong inherent association between various traits under study is indicated by the fact that the magnitudes of genetic correlation were in general higher than their corresponding phenotypic coefficient for all the characters (Table 4.11 and 4.12).

From Table 4.11, it is found that flower yield per plant in the year 2011-12 had positive and highly significant correlation with number of secondary branches per plant, number of buds per plant, number of flowers per plant, dry weight of plant, fresh weight of plant, fresh weight of flower, dry weight of flower, plant spread, flower diameter, stem diameter, duration of flowering and days taken to first flower opening, while in 2012-13 (Table 4.12), flower yield per plant had the positive and highly significant association with fresh weight of flower, number of flowers per plant, number of secondary branches per plant, number of buds per plant, fresh weight of plant, dry weight of plant, plant spread, stem diameter, days taken to first flower opening, dry weight of flower, duration of flowering and flower diameter. Similar observations were also made by Karuppaiah *et al.* (2006), Singh and Saha (2009), Mathew *et al.* (2005b) and Kavitha and Anburani (2010b) in marigold.

Number of flowers per plant in both the years showed a highly significant and positive correlation with number of buds per plant, number of secondary branches per plant, plant spread, number of primary branches per plant, fresh weight of plant, dry weight of plant and duration of flowering, which is in accordance the findings of Janakiram and Rao (1994), Singh and Saha (2009), Karuppaiah *et al.* (2006) and Singh and Singh (2005b) in marigold. Fresh weight of flower had positive and highly significant correlation with dry weight of flower, flower diameter and negative and significant correlation with number of primary branches per plant in the year 2011-12. Similarly, in the year 2012-2013, fresh weight of flower exhibited positive and highly significant correlation with dry weight of flower, flower diameter, stem diameter and plant height. The results were also supported by findings of Naik *et al.* (2005) and Mathew *et al.* (2005b) in marigold.

The above mentioned discussion reveals that the study of any character in isolation is not only undesirable but meaningless. The knowledge about associations between characters helps us to identify characters that have importance in selection programme. The associations are either negative or positive in nature. If the association is positive, improvement in one character will simultaneously bring about an improvement in other character, but if they are negatively correlated, improvement in one character may be adversely affected. In such cases, a proper balance is necessary in order to obtain maximum gains. Thus, the result indicated that the characters namely, number of flowers per plant, number of buds per plant, fresh weight of flower, plant spread and number of secondary branches per plant are important yield determiners.

## **5.5 PATH COEFFICIENTS ANALYSIS**

Correlation gives the extent of relationship between the variables, it further revealed whether the characters under study are associated or not but it is difficult to perceive that which one of them is affecting the other. A better picture of the contribution of each component building up the total genetic architecture of a complex character may be obtained through the analysis of causal schemes. Hence, in such a situation, path coefficient analysis devised by Wright (1921) had been useful in partitioning direct and indirect causes of association, which allows a detailed examination of specific forces acting to produce a given correlation and measures the relative importance of each causal character. Such a study provides a realistic basis for the allocation of weightage to each attribute in deciding a suitable criterion for genetic improvement. The aim of this analysis in the present investigation was to compare the results obtained from simple correlation and path coefficient analysis and to demonstrate the significance of path coefficient analysis in determining the true nature of character association.

In present study, path coefficient analysis was computed both at genotypic and phenotypic levels for all the characters. Path coefficient analysis was carried out by taking flower yield per plant as dependent variable to partition correlation coefficients into direct and indirect effects in order to determine the contribution of different characters towards the flower yield per plant. Direct and indirect effects of various characters on flower yield per plant indicated that there is an agreement between direction and magnitude of direct effect of various character and correlation with flower yield per plant. Thus, a significant improvement in flower yield per plant can be expected through selection in the component traits with high positive direct effects. It is clear from the Table 4.13 and 4.14 that high positive direct effect towards flower yield per plant was exerted by number of flowers per plant followed by fresh weight of flower and flower diameter. These results are in confirmation with earlier findings

of Namita *et al.* (2009), Mathew *et al.* (2005b), Karuppaiah *et al.* (2006) and Karuppaiah and Kumar (2011b) in marigold.

The positive and significant correlation of flower yield per plant in the year 2011-12 and 2012-13 was obtained with plant spread, number of secondary branches per plant, fresh weight of plant, number of buds per plant, number of flowers per plant and fresh weight of flower, indicating that more the plant spread and number of secondary branches per plant the more will be the number of buds and number of flowers through better vegetative growth, thus, ultimately increasing the flower yield. These findings are in agreement with the findings of Mathad *et al.* (2005b), Karuppaiah and Kumar (2011b) and Mathew *et al.* (2005b) in marigold.

The magnitude of residual effect was low, which indicated that major portion of contribution towards flower yield per plant might be explained on the basis of characters included in the present study. However, some more characters not included in the present study may contribute to account for the residual effect. Thus, on the basis of present study, it may be concluded that the characters like number of flowers per plant and fresh weight of flower are important characters effecting flower yield since they had high positive direct effect.

## **5.6 DIVERGENCE ANALYSIS**

Creation of variability and selection within, leading to diverse genotypes is the common protocol that a conventional plant breeder follows. Genetic relationship among genotypes thus generated can be measured by similarity or dissimilarity of any number of quantitative characters, assuming that the differences between characters of genotypes ultimately reflect in the divergence of the genotypes. In heterosis breeding programme, the diversity of parents is always emphasized upon. More diverse the parents within a reasonable range, better is the chances of improving economic traits under consideration in the resulting offspring. However, it is a difficult task for the breeder to select the most suitable and genetically divergent parents, unless one is provided with necessary information about genetic variability and genetic diversity present in the available germplasm.

Generally, geographical diversity is considered and taken as a measure of genetic diversity when no scientific tool is available. However, inferential criterion may not be used for discrimination among the populations occupying ecologically marginal habits. The multivariate analysis, using Mahalanobis's  $D^2$  statistic, provides a useful statistical tool for measuring the genetic diversity in a given population with respect to the characters considered together. Further, the problem of selecting diverse parents for hybridisation programme can

be narrowed, if one can identify the characters, responsible for the discrimination between populations.

In present study, based on  $D^2$  values, all the thirty genotypes were grouped into six clusters in both the years, *i.e.*, 2011-12 and 2012-13 (Table 4.15 and 4.16), indicating the presence of appreciable amount of genetic diversity among the genotypes under study. In the year 2011-2012, the maximum number of genotypes (12) was grouped into cluster-IV, followed by cluster-II with 11 genotypes and cluster-V and I possessed 3 and 2 genotypes, respectively, whereas, cluster-III and VI accommodated 1 genotype each. However, in the year 2012-2013, the cluster-II possessed the highest number of genotypes, *i.e.*, 13, followed by cluster-V with 9 genotypes, cluster-IV with 3, clusters-I and III with two genotypes each and cluster-VI with one genotype. Grouping of genotypes into six clusters suggested the presence of considerable diversity in the material under investigation. Kavitha and Anburani (2009) formed eight clusters in 30 genotypes of marigold on the basis of 9 characters.

The study revealed that genetic diversity has nothing to do with geographical diversity as the genotypes from different parts of the country were accommodated in the same clusters. There are forces other than geographical separation, such as natural and artificial selection, exchange of breeding material, genetic drift and environmental variation, which are responsible for diversity. The magnitudes of diversity among parents determine the inherent potential of a cross. Therefore, the selection of a parent based on the genetic divergence would be desirable for creating the maximum variability. Similar results were reported by Kavitha and Anburani (2009) in marigold, Sharma *et al.* (2013) in carnation, Punitha *et al.* (2010) and Manivannan *et al.* (2003) in sunflower and Bihari *et al.* (2009), Sheikh and Khanday (2008), Nimbalkar *et al.* (2006) and Raj and Misra (2000) in gladiolus.

The intra- and inter-distances (Table 4.17 and 4.18) revealed that inter-cluster distance values were greater than intra-cluster distance values in both the years. In the year 2011-12, the maximum intra-cluster distance was observed for cluster-V (4.68), while it was lowest for the genotypes of cluster-I (1.98), indicating that genotypes of cluster-V varied in genetic architecture and might have originated from different genetic pool. In cluster-I, the trend was exactly reverse of the cluster-V. The inter-cluster distance between the genotypes of cluster-V and cluster-VI (13.31) was noticed maximum, suggesting about possibility of genetic makeup of these genotypes. The genotypes of cluster-II and cluster-IV (4.38) exhibited lowest inter-cluster distance, indicating the resemblance among the genotypes of this group for all characters studied. Low magnitude of inter-cluster distance values suggested that very little domestication had occurred, whereas, in the year 2012-13, the maximum intra-cluster distance (4.12) was recorded in cluster-IV and it was recorded minimum in cluster-II (3.42). With respect to inter-cluster distance, it was found maximum between clusters-I and

VI (14.61) followed by cluster-II and VI (12.88) and cluster-III and VI (12.87), whereas, the lowest inter-cluster distance (4.13) was observed between cluster-II and V. Similar results had also been suggested by Bihari *et al.* (2009), Sheikh and Khanday (2008), Nimbalkar *et al.* (2006) and Raj and Misra (2000) in gladiolus and Punitha *et al.* (2010) and Manivannan *et al.* (2003) in sunflower and Kavitha and Anburani (2009) in marigold.

In fact, the genotypes forming single genotype clusters were extraordinary for one or more characters, which made them so divergent from others. This fact also reflected in cluster means. Analysis of clusters means indicated substantial variations among clusters grouped according to  $D^2$  analysis. Based on the range of means, it was possible to know the characters influencing divergence. The cluster having single or less genotypes revealed highest or lowest mean values for different characters as evident from mean data (Table 4.19 and 4.20). Although, the distance between various clusters was reflected in cluster means but it was not proportional for few characters. It seems that there were some other factors responsible for divergence. Therefore, a hybridization programme may be initiated involving the genotypes belonging to diverse clusters with high mean for almost all component characters.

## **5.7 CHARACTERIZATION**

Characterization of any variety is an important requirement for its release in order to fulfill the conditions of distinctness, uniformity and stability (DUS) test as laid down under the seed act of Government of India. In India, it has led to an enactment of Plant Variety Protection and Farmer's Right Act 2001. This act protects the registration of novel varieties and genotypes. The morphological characters used to distinguish a cultivar must be capable of its precise description and recognition and that such characters are considered important only when having the least environmental influence. The genuineness of a cultivar can be tested by means of heritable morphological, physiological and biochemical characters of seed, seedling and plants.

The identification and certification of cultivars based only on morphological traits may not prove adequate because of some variation caused due to environmental changes. Also, with the increased number of genotypes being evolved, the discrimination methods assisted with the use of molecular markers such as proteins, isoenzymes and biochemical traits would widen the scope of identification further over that of morphological characteristics and furnish more reliable indices for varietal identification. However, in present study, more emphasis was placed on a combination of various qualitative and quantitative characters, since no single criterion could precisely identify a large number of genotypes, even of the same region. Based upon the exigencies and necessity, the present investigation was also conducted on the characterization of marigold genotypes using

morphological descriptors. Thus, distinguishing characters were studied on the basis of plant and floral characters (Table 5.1 and 5.2).

### **5.6.1 Characterization of marigold genotypes based on morphological characters**

In the present investigation, the plant morphological characteristics such as plant height, plant growth habit, branching habit, stem colour, stalk shape, stem pubescence, leaf colour, leaflet shape and margin and leaf pubescence were utilized for the characterization of individual genotypes of marigold (Table 4.7).

On the basis of plant growth habit, the thirty marigold genotypes were classified into two groups, *i.e.*, compact and open. Out of these, 13 genotypes showed compact, whereas, remaining 17 genotypes showed open growth habit. Similarly, the examination of branching habit made it possible to club 30 marigold genotypes into four groups, *i.e.*, basal, middle, top and full. Majority of the genotypes (22) exhibited full branching habit, while remaining 8 genotypes showed basal branching habit. There was no genotype with middle and top branching habit.

Based on stem colour, the genotypes assessed were classified into green, dark green, purple and purple strips, which represented on 11, 5, 7 and 7 genotypes, respectively. The marigold genotypes assessed exhibited two different shape of stem *viz.*, smooth and ridged, where 14 genotypes had smooth and remaining 16 genotypes exhibited ridge shape of stem. Likewise, on the basis of stem pubescence, the two main groups of marigold genotypes were distinguished as glabrous and non-glabrous. Most of the genotypes (20) were found non-glabrous, while only 10 genotypes showed glabrous nature.

Among the thirty genotypes, on the basis of leaf colour, the four main groups of marigold genotypes were distinguished as pale green, light green, dark green and purple. Six genotypes showed pale green, another four genotypes had light green and 13 genotypes had dark green, while 7 genotypes had purple colour of leaves. Thus, there appeared not much larger difference in leaf colour of most of the genotypes. For leaflet shape the genotypes exhibited two discrete leaf shape *viz.*, narrow pointed and oval pointed. Out of 30 genotypes, 14 genotypes possessed narrow pointed and remaining 16 genotypes showed oval pointed leaflet shape. On the basis of leaflet margin, three main groups were made, *i.e.*, smooth, serrated and highly serrated. For the characterization of marigold genotypes, most of the genotypes (13) showed serrated margin, 8 genotypes expressed smooth and remaining 9 genotypes showed highly serrated margin of leaflet.

The thirty genotypes of marigold were classified into glabrous and non-glabrous groups on the basis of leaf pubescence. The 9 genotypes come under glabrous category, whereas, 21 genotypes come under non-glabrous category. Based on the presence or absence

of disc, six genotypes were placed in visible group, while remaining twenty four genotypes in invisible group. On the basis of plant height, the marigold genotypes were categorized as dwarf, medium and tall types. There were 5, 14 and 11 number of genotypes, which showed dwarf, medium and tall growth, respectively. Similar studies based on plant characters have been reported by Mathew (2004) and Singh and Singh (2006) in marigold, Adhya (2010) in dahlia, Nancee (2012) in cowpea and Rana (2006) in cluster bean.

### **5.6.2 Characterization of marigold genotypes based on flowering parameters**

The flowering characters are presented in Table 4.8. On the basis of days taken to first flower opening, all the 30 genotypes were grouped into three categories *viz.*, early, mid and late. The grouping pattern suggested that ten genotypes took less than 45 days to first flower opening, fifteen genotypes in mid and remaining five genotypes in late category. The study of duration of flowering made it possible to club the marigold genotypes in three groups *viz.*, short, medium and long. There were 13 genotypes, which showed short duration of flowering, seven medium duration of flowering and the remaining ten genotypes long duration of flowering.

The marigold genotypes were grouped into three categories, *i.e.*, less, medium and more on the basis of number of flowers per plant. Less number of flowers was recorded in 8 genotypes, whereas, medium number of flowers was observed in 16 genotypes. Six genotypes produced more number of flowers. Based on stalk length, the marigold genotypes were grouped into three categories. First group had short stalk length and it included only 7 genotypes. Medium group had 6 genotypes and 17 genotypes were grouped in long group.

According to the size of flower observed, marigold genotypes were classified into three main groups *viz.*, small (2 genotypes), medium (16 genotypes) and big flowered (12 genotypes). Based on fresh weight of flower, the genotypes were classified into three groups, *i.e.*, low, medium, and high. Wide variation was observed in present investigation. The results of the present study are in agreement with several other such reports on characterizations of dahlia genotypes (Adhya, 2010), gladiolus (Dilta *et al.* 2004; Ghanshyam, 2012), marigold (Mathew, 2004), gerbera (Aswath and Manjunath, 2006) and chrysanthemum (Gupta and Datta, 2005) using the flower characters.

**Table 5.1: Characterization of marigold genotypes based on plant characters**

<b>Sr. No.</b>	<b>Genotypes</b>	<b>Plant growth habit</b>	<b>Branching habit</b>	<b>Stem colour</b>	<b>Stem shape</b>	<b>Stem pubescence</b>	<b>Leaf colour</b>
1	Hisar Beauty	Compact	Full	Purple	Ridged	Non-glabrous	Dark green
2	Hisar Jaffri-2	Compact	Full	Purple	Smooth	Non-glabrous	Dark green
3	MGH-09-271	Open	Full	Purple	Ridged	Glabrous	Dark green
4	MGH-09-276	Open	Full	Purple strips	Ridged	Non-glabrous	Dark green
5	MGH-09-276-1	Compact	Full	Dark green	Ridged	Glabrous	Purple
6	MGH-09-301	Open	Basal	Green	Ridged	Non-glabrous	Purple
7	MGH-09-302	Open	Full	Purple strips	Smooth	Non-glabrous	Pale green
8	MGH-09-303	Open	Full	Purple	Smooth	Non-glabrous	Light green
9	MGH-09-304	Compact	Full	Purple	Smooth	Glabrous	Purple
10	MGH-09-305	Compact	Basal	Green	Ridged	Non-glabrous	Dark green
11	MGH-10-101	Open	Basal	Purple	Smooth	Non-glabrous	Light green
12	MGH-133-1-1	Compact	Basal	Green	Ridged	Non-glabrous	Dark green
13	MGH-133-1-2	Open	Full	Purple strips	Smooth	Non-glabrous	Light green
14	MGH-133-1-3	Open	Basal	Green	Ridged	Non-glabrous	Dark green
15	MGH-133-2	Compact	Basal	Green	Ridged	Non-glabrous	Purple
16	MGH-133-3-2	Compact	Full	Purple strips	Ridged	Glabrous	Light green
17	MGH-133-5	Compact	Full	Green	Smooth	Non-glabrous	Purple
18	MGH-133-5-2	Open	Full	Green	Ridged	Glabrous	Pale green
19	MGH-148-3-3	Compact	Basal	Dark green	Smooth	Glabrous	Pale green
20	MGH-148-8	Open	Full	Dark green	Smooth	Glabrous	Pale green
21	MGH-160-5-1	Open	Full	Green	Ridged	Non-glabrous	Purple
22	MGH-160-5-2	Open	Full	Green	Smooth	Non-glabrous	Dark green
23	MGH-160-5-3	Open	Full	Purple strips	Smooth	Non-glabrous	Dark green
24	MGH-160-7-1	Open	Full	Dark green	Ridged	Non-glabrous	Dark green
25	MGH-160-8-3-2	Compact	Full	Green	Ridged	Non-glabrous	Purple
26	MGH-160-9	Open	Full	Green	Ridged	Non-glabrous	Dark green
27	MGH-160-9-1	Open	Basal	Purple strips	Smooth	Glabrous	Pale green
28	MGH-160-9-3	Open	Full	Purple strips	Smooth	Glabrous	Dark green
29	MGH-160-9-4	Compact	Full	Dark green	Ridged	Glabrous	Dark green
30	MGH-07-160-8-3-3	Compact	Full	Purple	Smooth	Non-glabrous	Pale green

Contd.....

Contd.....

<b>Sr. No.</b>	<b>Genotypes</b>	<b>Leaflet Shape</b>	<b>Leaflet margin</b>	<b>Leaf pubescence</b>	<b>Disc floret</b>	<b>Plant height</b>
1	Hisar Beauty	Oval pointed	Serrated	Non-glabrous	Visible	Dwarf
2	Hisar Jaffri-2	Oval pointed	Serrated	Non-glabrous	Visible	Medium
3	MGH-09-271	Oval pointed	Smooth	Non-glabrous	Non-visible	Medium
4	MGH-09-276	Oval pointed	Serrated	Non-glabrous	Non-visible	Medium
5	MGH-09-276-1	Narrow pointed	Highly serrated	Glabrous	Non-visible	Tall
6	MGH-09-301	Oval pointed	Serrated	Non-glabrous	Visible	Medium
7	MGH-09-302	Narrow pointed	Smooth	Glabrous	Non-visible	Dwarf
8	MGH-09-303	Oval pointed	Smooth	Non-glabrous	Non-visible	Tall
9	MGH-09-304	Narrow pointed	Highly serrated	Non-glabrous	Non-visible	Dwarf
10	MGH-09-305	Oval pointed	Highly serrated	Non-glabrous	Non-visible	Tall
11	MGH-10-101	Narrow pointed	Serrated	Glabrous	Non-visible	Medium
12	MGH-133-1-1	Narrow pointed	Smooth	Non-glabrous	Non-visible	Tall
13	MGH-133-1-2	Narrow pointed	Serrated	Non-glabrous	Non-visible	Medium
14	MGH-133-1-3	Oval pointed	Highly serrated	Non-glabrous	Non-visible	Tall
15	MGH-133-2	Narrow pointed	Serrated	Non-glabrous	Non-visible	Medium
16	MGH-133-3-2	Narrow pointed	Smooth	Glabrous	Non-visible	Tall
17	MGH-133-5	Oval pointed	Highly serrated	Non-glabrous	Non-visible	Medium
18	MGH-133-5-2	Narrow pointed	Smooth	Non-glabrous	Non-visible	Medium
19	MGH-148-3-3	Oval pointed	Serrated	Non-glabrous	Non-visible	Medium
20	MGH-148-8	Narrow pointed	Highly serrated	Glabrous	Non-visible	Tall
21	MGH-160-5-1	Oval pointed	Serrated	Non-glabrous	Non-visible	Tall
22	MGH-160-5-2	Oval pointed	Highly serrated	Non-glabrous	Visible	Tall
23	MGH-160-5-3	Narrow pointed	Highly serrated	Non-glabrous	Non-visible	Medium
24	MGH-160-7-1	Narrow pointed	Serrated	Non-glabrous	Non-visible	Tall
25	MGH-160-8-3-2	Narrow pointed	Serrated	Non-glabrous	Visible	Dwarf
26	MGH-160-9	Oval pointed	Highly serrated	Glabrous	Non-visible	Medium
27	MGH-160-9-1	Oval pointed	Smooth	Glabrous	Non-visible	Medium
28	MGH-160-9-3	Narrow pointed	Serrated	Glabrous	Visible	Medium
29	MGH-160-9-4	Narrow pointed	Serrated	Non-glabrous	Non-visible	Tall
30	MGH-07-160-8-3-3	Narrow pointed	Smooth	Glabrous	Non-visible	Dwarf

**Table 5.2: Characterization of marigold genotypes based on flowering characters**

<b>Sr. No.</b>	<b>Genotypes</b>	<b>Days taken to first flower opening</b>	<b>Duration of flowering</b>	<b>No. of flowers per plant</b>	<b>Stalk length</b>	<b>Flower diameter</b>	<b>Fresh weight of flower</b>
1	Hisar Beauty	Early	Medium	Less	Small	Small	Low
2	Hisar Jaffri-2	Late	Long	High	Mid	Small	Low
3	MGH-09-271	Mid	Medium	Medium	Small	Big	High
4	MGH-09-276	Late	Long	Medium	Small	Big	High
5	MGH-09-276-1	Mid	Medium	High	Mid	Big	High
6	MGH-09-301	Mid	Long	Medium	Long	Big	High
7	MGH-09-302	Early	Long	Medium	Small	Medium	High
8	MGH-09-303	Mid	Short	Medium	Long	Medium	High
9	MGH-09-304	Mid	Long	Medium	Long	Big	High
10	MGH-09-305	Mid	Long	Less	Long	Medium	Medium
11	MGH-10-101	Late	Short	Less	Long	Medium	Medium
12	MGH-133-1-1	Mid	Short	Medium	Long	Medium	Medium
13	MGH-133-1-2	Early	Short	Medium	Long	Medium	Medium
14	MGH-133-1-3	Mid	Medium	Medium	Mid	Medium	High
15	MGH-133-2	Early	Short	Medium	Long	Medium	Medium
16	MGH-133-3-2	Late	Long	Less	Small	Medium	High
17	MGH-133-5	Early	Short	High	Mid	Medium	Medium
18	MGH-133-5-2	Mid	Short	Medium	Long	Medium	Medium
19	MGH-148-3-3	Mid	Long	High	Long	Big	High
20	MGH-148-8	Late	Long	High	Long	Big	High
21	MGH-160-5-1	Mid	Short	Less	Mid	Big	High
22	MGH-160-5-2	Mid	Long	Medium	Long	Medium	Medium
23	MGH-160-5-3	Early	Short	Medium	Long	Medium	Medium
24	MGH-160-7-1	Early	Medium	Less	Long	Medium	Medium
25	MGH-160-8-3-2	Mid	Short	Less	Small	Big	High
26	MGH-160-9	Early	Short	Medium	Long	Medium	Medium
27	MGH-160-9-1	Early	Medium	Medium	Mid	Big	Medium
28	MGH-160-9-3	Early	Medium	Medium	Long	Big	Medium
29	MGH-160-9-4	Mid	Short	High	Long	Big	Medium
30	MGH-07-160-8-3-3	Mid	Short	Less	Small	Medium	Medium

Marigold (*Tagetes* species Linn), a member of Asteraceae family is one of the important loose flower crops grown commercially in India. It has attracted the attention of flower growers due to its wide spectrum of attractive colours, shape, size and good keeping quality. The leaves and flowers of marigold have medicinal properties and also used as food additives. Looking at the importance, the present investigation **“Evaluation and characterization in marigold”** was carried out at Experimental Orchard of the Department of Horticulture, Chaudhary Charan Singh Haryana Agricultural University, Hisar during winter season in the year 2011-12 and 2012-13 to estimate genetic variability, heritability and genetic advance to find out the yield contributing attributes and to characterize the genotype based upon field parameters.

The experimental material consisted of thirty genotypes of both African and French marigold. These were evaluated in the field in a randomized block design with three replications. The observations were recorded for growth, flowering and yield characters. The results of the investigation presented in chapter four are summarized here as under:

The analysis of variance revealed that the mean sum of squares due to genotypes were highly significant for all the characters studied indicating a wide range of variability in the material investigated. The mean performance of both the years (Appendix-III and IV) showed that the genotype MGH-09-303 recorded the maximum plant and Hisar Beauty the minimum. The maximum plant spread, number of primary and secondary branches per plant and fresh as well as dry weight of plant were obtained in Hisar Jaffri-2. The longest stalk was observed in genotype MGH-160-9-4, while it was the minimum in Hisar Beauty. The genotype Hisar Beauty required the minimum number of days to first flower opening, while Hisar Jaffri-2 needed the maximum days to first flower opening. The longest duration of flowering was observed in Hisar Jaffri-2 and it was the minimum in MGH-160-9-4. The maximum number of buds and flowers per plant were recorded in Hisar Jaffri-2 and minimum in MGH-07-160-8-3-3. The maximum flower diameter and fresh weight of flower was recorded in MGH-09-276 and MGH-09-271, respectively, while it was the minimum in Hisar Beauty. The genotype Hisar Jaffri-2 produced the highest flower yield followed by MGH-09-271 and MGH-09-276, while the lowest flower yield was obtained in Hisar Beauty.

The influence of environment was very meager on expression of all the characters under studied, which was evident from the narrow gap between genotypic and phenotypic variances as well as coefficient of variation. Phenotypic coefficient of variation was higher in

magnitude than the genotypic coefficient of variation for all the characters. The high GCV and PCV values were recorded in fresh and dry weight of plant, number of secondary branches per plant and number of buds and flowers per plant, whereas, low GCV and PCV values were observed for flower diameter and days taken to first flower opening. Heritability in broad sense and genetic advance as per cent mean were higher for fresh and dry weight of plant, number of secondary branches per plant and number of buds and flowers per plant. Hence, these traits may be utilized for marigold improvement through selection.

Correlation analysis revealed high significant positive correlation of flower yield per plant with number of secondary branches per plant, number of buds and flowers per plant, fresh and dry weight of plant, fresh and dry weight of flower, plant spread, flower diameter, stem diameter, duration of flowering and days taken to first flower opening. Number of flowers per plant showed a highly significant and positive correlation with number of buds per plant, number of secondary branches per plant, plant spread, number of primary branches per plant, fresh and dry weight of plant and duration of flowering. Path analysis depicted that number of flowers per plant had the highest direct and positive effect on flower yield per plant, closely followed by fresh weight of flower, flower diameter, dry weight of flower and dry weight of plant. Number of secondary branches per plant, plant height, duration of flowering, stalk length and stem diameter also had direct positive effect on flower yield per plant.

Based on  $D^2$  values, thirty genotypes of marigold were grouped into six clusters in both the years of investigation. In the year 2011-12, cluster-IV was the biggest with 12 genotypes followed by cluster-II and V. The maximum intra-cluster  $D^2$  values were observed for cluster-V, II and IV, while it was lowest for the cluster-I. The maximum inter-cluster distance was noticed between the genotypes of cluster-V and cluster-VI. The genotypes of cluster-II and cluster-IV exhibited lowest inter-cluster distance, whereas, in the year 2012-13, the maximum intra-cluster distance was recorded in cluster-IV and it was recorded minimum in cluster-II (3.42). With respect to inter-cluster distance, it was found maximum between clusters-I and VI followed by cluster-II and VI and cluster-III and VI, whereas, the lowest inter-cluster distance was observed between cluster-II and V. The genotype included in cluster-VI in both the years had the highest number of flowers per plant and flower yield.

The investigation revealed that the plant and flower characters *viz.*, plant height, plant growth habit, branching habit, stem colour, stalk shape, stem pubescence, leaf colour, leaflet shape and margin, leaf pubescence, days taken to first flower opening, stalk length, duration of flowering, number of flowers per plant, flower diameter and fresh weight of flower were found quite useful in characterization and categorization of marigold genotypes.

## **CONCLUSION**

The results of the present investigation suggested that the marigold genotypes could be effectively categorized and characterized based on morphological characters and as such, these traits could be utilized as good descriptors in the identification and maintenance of marigold genotypes. This existed ample variation and diversity in marigold could be utilized for crop improvement programme through direct selection and hybridization to create and release variability for selection. The genotypes for hybridization could be selected from the most diverse clusters to expectedly yield a wide spectrum of variation.

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\*Original not seen

**Appendix: 1. Weekly metrological data recorded during crop growing season of 2011-12**

Standard weeks	Duration	Mean temperature (°C)		Relative humidity (%)		Average wind speed (km/hr)	Bright sunshine (hr)	Rainfall (mm)
		Maximum	Minimum	Morning	Evening			
36	4-10 September	32.8	24.7	96	79	5.6	4.6	79.2
37	11-17 September	33.5	24.8	94	73	4.0	6.5	26.6
38	18-24 September	32.6	22.2	94	59	2.9	8.8	33.8
39	25 Sep.-1 October	33.5	19.8	89	45	4.7	10.0	0.0
40	2-8 October	34.1	18.3	83	40	3.6	9.9	0.0
41	9-15 October	34.0	17.7	89	38	2.1	8.9	0.0
42	16-22 October	33.7	13.9	86	31	1.8	9.3	0.0
43	23-29 October	31.5	13.5	88	32	1.7	8.1	0.0
44	30 Oct.-5 November	31.5	11.8	88	28	1.7	6.8	0.0
45	6-12 November	30.9	12.8	89	32	1.9	6.8	0.0
46	13-19 November	29.9	10.5	90	33	2.1	8.4	0.0
47	20-26 November	28.7	10.9	96	42	1.5	6.3	0.0
48	27 Nov.-3 December	25.5	8.7	96	37	1.8	6.0	0.0
49	4-10 December	27.4	12.2	91	46	4.3	6.1	0.0
50	11-17 December	22.8	3.7	93	32	2.1	6.6	0.0
51	18-24 December	21.2	3.3	98	43	2.8	5.9	0.0
52	25-31 December	19.6	1.2	99	50	1.2	5.6	0.0
1	1-7 January	19.1	7.6	98	53	4.2	1.8	0.0
2	8-14 January	17.0	2.5	98	51	2.4	6.1	0.0
3	15-21 January	17.7	6.7	95	64	3.6	3.0	14.4
4	22-28 January	19.1	3.5	94	44	2.6	6.9	0.0
5	29 Jan.-4 February	20.6	5.1	90	40	2.5	7.4	0.0
6	5-11 February	19.1	2.3	84	43	3.5	7.4	0.0
7	12-18 February	19.9	5.0	87	39	4.9	5.7	0.0
8	19-25 February	23.3	7.4	88	44	4.1	6.8	0.0
9	26 Feb.-3 March	25.2	7.4	84	32	4.2	8.9	0.0
10	4-10 March	26.9	8.9	89	30	4.7	8.1	0.0
11	11-17 March	27.4	9.6	87	35	4.3	8.7	0.0
12	18-24 March	30.2	11.5	75	28	5.0	7.6	0.0
13	25-31 March	32.2	14.7	80	35	5.1	7.8	0.0
14	1-7 April	35.6	19.0	67	35	6.5	9.0	0.0
15	8-14 April	34.3	18.1	74	41	7.3	9.0	7.3
16	15-21 April	33.0	17.7	83	42	4.4	7.7	25.5
17	22-28 April	33.3	17.4	74	35	4.9	7.8	0.5

Source: Department of Agricultural Metrology, CCS Haryana Agricultural University, Hisar

**Appendix: II. Weekly metrological data recorded during crop growing season of 2012-13**

Standard weeks	Duration	Mean temperature (°C)		Relative humidity (%)		Average wind speed (km/hr)	Bright sunshine (hr)	Rainfall (mm)
		Maximum	Minimum	Morning	Evening			
37	9-15 September	34.9	25.9	88	65	4.8	7.5	17.0
38	16-22 September	32.6	22.4	89	55	3.9	7.3	7.3
39	23-29 September	33.9	19.8	82	41	3.7	9.7	0.0
40	30 Sept.-6 October	35.4	16.8	78	29	2.7	10.1	0.0
41	7- 13 October	34.3	16.2	81	29	2.8	9.3	0.0
42	14-20 October	32.3	16.4	86	46	4.0	7.7	1.6
43	21-27 October	29.2	12.5	92	40	2.5	8.0	3.8
44	28 Oct.- 3 November	29.2	12.0	94	39	1.3	6.0	0.0
45	4-10 November	29.2	11.0	91	33	1.8	4.3	0.0
46	11-17 November	27.6	8.9	95	44	1.4	5.8	0.0
47	18-24 November	26.3	7.4	88	32	2.1	7.5	0.0
48	25 Nov.-1 December	24.2	6.5	92	46	2.1	7.5	0.0
49	2-8 December	24.5	5.4	92	47	1.7	7.9	0.0
50	9-15 December	22.1	10.4	92	62	4.9	3.6	5.5
51	16-22 December	22.1	4.4	93	50	2.8	8.0	0.0
52	23-29 December	15.0	4.3	95	75	3.8	3.7	0.0
1	30 Dec.-5 January	11.6	1.6	99	81	2.9	2.0	0.0
2	6-12 January	18.8	4.0	96	48	3.6	6.1	0.0
3	13-19 January	18.4	7.2	95	63	5.0	4.1	43.0
4	20-26 January	19.7	3.5	92	42	1.9	8.3	0.0
5	27 Jan.- 2 February	22.6	8.1	95	59	2.2	5.2	4.0
6	3-9 February	20.3	6.6	98	53	5.5	7.3	10.8
7	10-16 February	21.4	8.9	96	63	3.7	4.8	6.0
8	17-23 February	21.1	9.7	97	67	5.0	5.4	11.9
9	24 Feb.- 2 March	24.3	8.5	92	43	5.0	9.5	0.0
10	3-9 March	29.6	10.9	90	41	3.2	9.4	0.0
11	10-16 March	28.2	12.5	96	58	3.1	7.8	30.5
12	17-23 March	30.3	14.6	88	45	4.8	8.5	0.0
13	24-30 March	27.7	13.0	92	45	4.0	7.1	0.6
14	31 March-6 April	32.3	14.4	76	34	4.5	8.9	0.0
15	7-13 April	35.2	16.7	74	27	4.5	8.9	1.5
16	14-20 April	37.0	17.0	58	21	5.9	8.7	0.8
17	21-27 April	35.7	20.5	63	27	5.7	8.5	0.0

Source: Department of Agricultural Metrology, CCS Haryana Agricultural University, Hisar

**Appendix: III. Mean value of marigold genotypes for different characters for the years 2011-12 and 2012-13**

<b>Sr. No.</b>	<b>Genotypes</b>	<b>Plant height (cm)</b>	<b>Plant spread (cm)</b>	<b>Stem diameter (cm)</b>	<b>Stalk length (cm)</b>	<b>Number of primary branches per plant</b>	<b>Number of secondary branches per plant</b>	<b>Fresh weight of plant (g)</b>	<b>Dry weight of plant (g)</b>
1	Hisar Beauty	32.40	33.96	0.61	4.38	10.04	36.44	78.76	9.91
2	Hisar Jaffri-2	62.68	77.72	1.61	10.99	24.50	150.97	1115.59	125.36
3	MGH-09-271	75.84	61.51	1.36	9.19	13.24	44.77	268.63	36.03
4	MGH-09-276	60.05	52.22	1.64	9.81	11.14	46.50	343.78	41.02
5	MGH-09-276-1	99.77	72.39	1.08	13.13	13.54	62.54	497.60	56.22
6	MGH-09-301	65.02	43.99	1.25	16.01	11.50	57.14	502.88	62.52
7	MGH-09-302	55.56	58.20	0.93	8.49	8.97	38.13	241.17	32.86
8	MGH-09-303	103.75	41.93	1.37	16.19	10.30	44.03	279.74	36.02
9	MGH-09-304	57.65	55.96	1.66	20.32	12.77	49.00	411.59	54.51
10	MGH-09-305	81.30	60.38	1.46	21.07	11.97	30.10	342.16	38.36
11	MGH-10-101	78.30	55.97	1.37	21.39	8.50	29.77	208.23	26.43
12	MGH-133-1-1	84.74	47.31	1.44	16.29	9.77	44.75	253.42	28.55
13	MGH-133-1-2	76.85	45.96	1.34	18.46	13.07	44.10	216.46	32.72
14	MGH-133-1-3	95.45	46.20	1.43	10.36	11.14	56.80	560.14	62.82
15	MGH-133-2	74.29	43.25	1.36	21.16	11.40	40.93	261.74	32.74

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16	MGH-133-3-2	97.34	34.53	0.88	8.61	9.63	26.97	168.48	24.62
17	MGH-133-5	68.82	48.34	1.10	13.74	10.77	60.60	404.82	47.79
18	MGH-133-5-2	73.69	40.98	1.36	21.85	16.50	47.67	275.55	32.90
19	MGH-148-3-3	66.39	66.72	2.14	15.65	11.07	57.03	1122.42	130.72
20	MGH-148-8	82.30	36.57	1.87	22.27	9.10	53.17	528.78	61.09
21	MGH-160-5-1	85.22	59.44	1.32	10.26	12.30	40.94	281.58	33.36
22	MGH-160-5-2	91.54	50.51	0.95	18.81	12.24	49.67	493.16	57.36
23	MGH-160-5-3	76.17	47.96	1.08	15.67	10.23	39.83	272.52	34.34
24	MGH-160-7-1	82.94	43.62	1.29	19.68	18.20	29.37	212.24	27.54
25	MGH-160-8-3-3	47.99	33.75	1.70	6.98	15.83	27.20	334.11	39.38
26	MGH-160-9	74.39	44.97	1.12	18.22	9.27	42.97	201.16	29.40
27	MGH-160-9-1	79.26	65.59	1.34	13.63	10.27	40.30	491.15	56.51
28	MGH-160-9-3	68.98	38.43	1.07	16.29	21.78	51.90	239.01	31.59
29	MGH-160-9-4	102.78	50.64	1.61	27.03	21.07	55.07	481.97	56.26
30	MGH-07-160-8-3-3	42.36	36.02	1.10	4.95	14.20	22.02	184.72	22.19

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**Appendix: IV. Mean value of marigold genotypes for different characters for the years 2011-12 and 2012-13**

<b>Sr. No.</b>	<b>Genotypes</b>	<b>Days taken to first flower opening</b>	<b>Duration of flowering (days)</b>	<b>Number of buds plant</b>	<b>Number of flowers per plant</b>	<b>Flower diameter (cm)</b>	<b>Fresh weight of flower (g)</b>	<b>Dry weight of flower (g)</b>	<b>Flower yield per plant (g)</b>	<b>Flower yield per plot (kg)</b>	<b>Flower yield per hectare (q)</b>
1	Hisar Beauty	37.90	52.77	50.90	42.27	4.47	2.32	0.28	98.00	2.35	61.24
2	Hisar Jaffri-2	64.60	76.53	217.10	189.00	4.01	4.64	0.56	874.37	20.99	546.48
3	MGH-09-271	48.60	51.30	69.40	53.25	7.54	15.57	2.04	828.85	19.89	518.03
4	MGH-09-276	55.10	57.14	73.67	54.64	8.21	14.58	1.51	797.03	19.13	498.14
5	MGH-09-276-1	48.53	47.50	70.83	63.70	7.03	9.82	1.40	626.28	15.04	391.43
6	MGH-09-301	49.14	68.77	77.50	55.20	6.82	9.07	1.17	500.71	12.02	312.94
7	MGH-09-302	40.67	65.94	58.53	46.47	6.35	9.49	1.06	440.94	10.60	275.59
8	MGH-09-303	50.17	36.90	64.54	55.87	6.50	9.91	1.32	553.27	13.28	345.80
9	MGH-09-304	50.50	69.97	69.17	55.20	7.10	9.35	1.21	517.48	12.42	323.43
10	MGH-09-305	47.80	58.67	53.72	40.50	6.44	8.38	0.92	339.27	8.15	212.05
11	MGH-10-101	56.60	35.43	53.40	44.40	5.41	6.95	0.91	310.38	7.45	193.99
12	MGH-133-1-1	51.13	44.67	60.07	51.94	5.30	6.79	0.82	355.84	8.54	222.40
13	MGH-133-1-2	43.80	35.60	68.04	54.37	6.21	8.41	0.93	459.68	11.04	287.30
14	MGH-133-1-3	54.53	47.74	73.17	57.60	5.33	9.98	1.28	576.54	13.84	360.34
15	MGH-133-2	42.24	38.20	52.80	45.34	5.29	7.41	0.88	336.69	8.08	210.44

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16	MGH-133-3-2	55.70	61.54	49.20	38.15	6.28	10.35	1.26	394.96	9.48	246.85
17	MGH-133-5	42.07	40.04	81.07	71.27	5.43	7.91	0.94	562.65	13.50	351.66
18	MGH-133-5-2	51.00	31.93	69.87	59.10	5.33	6.69	0.83	395.54	9.50	247.22
19	MGH-148-3-3	49.40	65.30	83.20	67.50	7.25	9.24	1.12	622.38	14.94	388.99
20	MGH-148-8	56.04	59.64	77.90	60.20	7.42	9.61	1.13	577.99	13.87	361.25
21	MGH-160-5-1	54.67	39.20	50.54	39.70	7.20	9.41	1.20	372.80	8.95	233.00
22	MGH-160-5-2	54.14	59.60	70.07	57.23	6.48	7.69	0.89	441.85	10.61	276.15
23	MGH-160-5-3	42.67	44.17	67.60	52.04	5.16	6.01	0.71	313.18	7.51	195.59
24	MGH-160-7-1	44.00	50.00	43.94	37.33	5.50	6.32	0.70	236.29	5.68	147.68
25	MGH-160-8-3-3	47.87	44.30	44.70	31.20	7.19	9.25	1.12	290.11	6.96	181.32
26	MGH-160-9	44.50	41.07	58.97	49.87	6.20	7.80	1.08	388.04	9.32	242.53
27	MGH-160-9-1	42.90	53.77	59.80	50.87	7.56	9.06	1.13	459.31	11.03	287.07
28	MGH-160-9-3	42.54	53.97	67.44	57.14	7.09	7.81	0.94	445.88	10.70	278.67
29	MGH-160-9-4	46.07	33.47	74.94	62.67	6.65	8.21	0.94	515.80	12.38	322.37
30	MGH-07-160-8-3-3	50.34	43.37	37.87	28.94	5.53	6.38	0.70	184.60	4.43	115.38

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## ABSTRACT

<b>Title of Thesis</b>	:	Evaluation and characterization in marigold
<b>Name of Degree Holder</b>	:	Mahesh Choudhary
<b>Admission Number</b>	:	2011A17D
<b>Title of Degree</b>	:	Doctor of Philosophy in Horticulture (Floriculture and Landscape Architecture)
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<b>Year of award of degree</b>	:	2013
<b>Major subject</b>	:	Horticulture
<b>Number of pages in Thesis</b>	:	101 + v + VI
<b>Number of words in Abstract</b>	:	Approx. 374

**Key words:** Characterization, correlation and path analysis, genetic advance, heritability, marigold

The present experiment was conducted at Experimental Orchard of the Department of Horticulture, CCS Haryana Agricultural University, Hisar during winter seasons of 2011-12 and 2012-13 on thirty genotypes of both African and French marigold to estimate the genetic variability, heritability, genetic advance and varietal characterization. The observations were recorded on growth, flowering and yield parameters. The analysis of variance revealed that the mean sum of squares due to genotypes were highly significant for all the characters studied, indicating a wide range of variability in the material investigated. The highest flower yield was observed in genotype Hisar Jaffri-2 followed by MGH-09-271 and MGH-09-276, while it was lowest in Hisar Beauty. The high GCV and PCV values were observed for fresh and dry weight of plant, number of secondary branches per plant, number of buds per plant and number of flowers per plant.

Heritability in broad sense and genetic advance as per cent mean were higher for fresh weight of plant, dry weight of plant, number of flowers per plant, number of buds per plant and number of secondary branches per plant. Association analysis revealed high significant positive correlation of flower yield per plant with number of secondary branches per plant, number of buds per plant, number of flowers per plant, dry weight of plant, fresh weight of plant, fresh weight of flower, dry weight of flower, plant spread, flower diameter, stem diameter, duration of flowering and days taken to first flower opening, indicating selection of these characters for crop improvement and breeding strategies. Path analysis depicted that number of flowers per plant had the highest direct and positive effect on flower yield per plant, closely followed by fresh weight of flower, flower diameter, dry weight of flower and dry weight of plant.

Based on  $D^2$  values, all the thirty genotypes were grouped into six clusters in both the years, *i.e.*, 2011-12 and 2012-13, indicating the presence of considerable amount of genetic diversity among the genotypes under study. On the basis of morphological characters, the marigold genotypes were characterized and categorized effectively. The plant growth habit, branching habit, leaflet shape, leaf colour, stalk shape, disc floret, floret colour, *etc.*, were the key characters, therefore, can be used as morphological descriptors for the varietal identification in marigold.

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2. Genetic variability in quantitative characters of gladiolus (*Gladiolus x hybridus* Hort.). *Internat. J. agric. Sci.*, **8**(1): 138-141.
3. Performance of gerbera (*Gerbera jamesonii* Bolus ex Hooker F.) cultivars under fan and pad cooled greenhouse conditions. *Res. on Crops*, **13**(1): 299-301.
4. Evaluation of gladiolus (*Gladiolus x hybridus* Hort.) varieties for cut flower production under sub-humid conditions of Rajasthan. *Crop Res.* **41**(1, 2 & 3): 123-126.
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8. Path coefficient analysis studies in gladiolus. *Asian J. Hort.*, **6**(2): 455-458.
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12. Response of vase solution on keeping quality of cut spikes of gladiolus cv. Priscilla. *Asian J. Hort.*, **6**(2): 319-321.

I hereby, declare that all the information given in the resume is true to the best of my knowledge.

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## **UNDERTAKING OF COPY RIGHT**

I, **Mahesh Choudhary**, Admission No. **2010A17D** undertake that I give copy right to the Chaudhary Charan Singh Haryana Agricultural University, Hisar of my thesis entitled, **“Evaluation and characterization in marigold”**.

I also undertake that, patent, if any, arising out of the research work conducted during the program shall be filed by me only with due permission of the competent authority of CCS HAU, Hisar.

**Signature of Student**