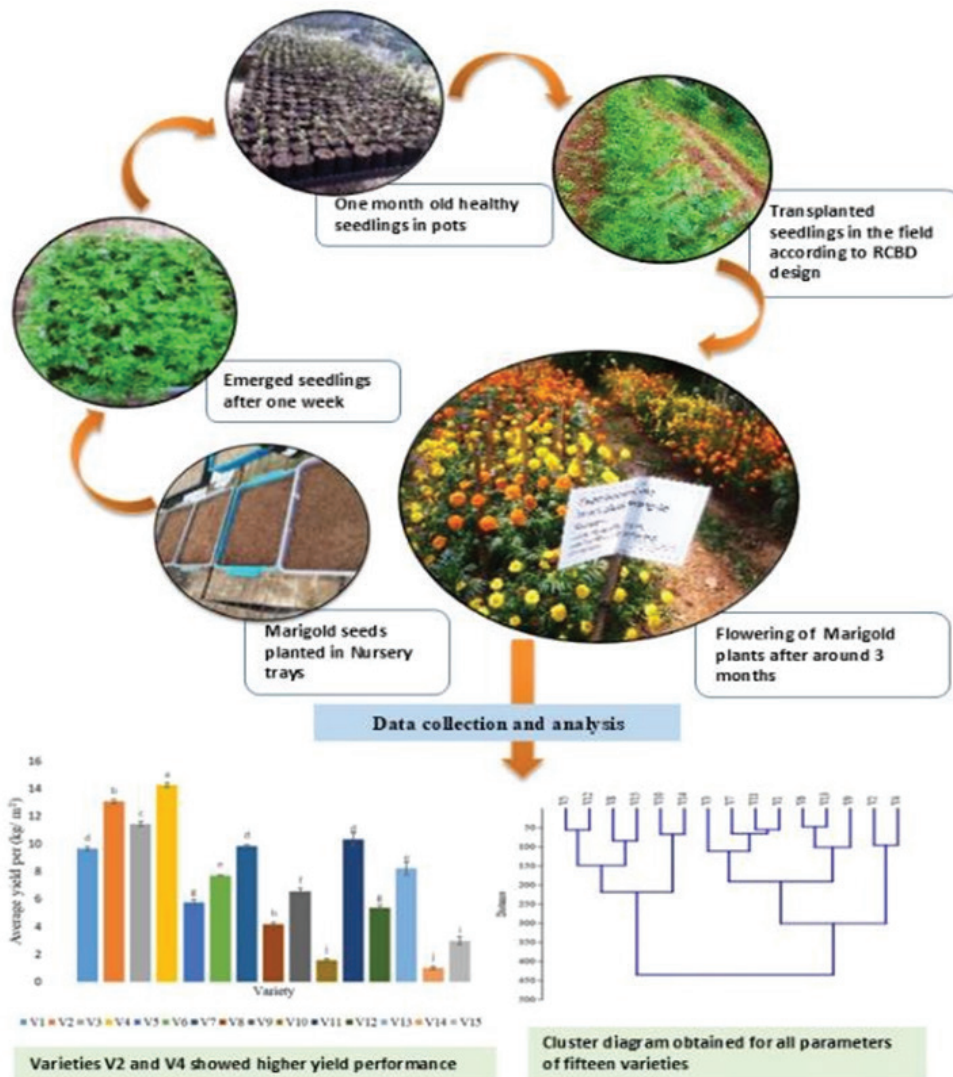


RESEARCH ARTICLE

Evaluation of Yield Performance of Local and Imported Marigold (*Tagetes erecta* L.) Varieties

S.S. Kumari*, A.M.A.S. Attanayake and J.P. Eeswara



Highlights

- Fifteen marigold varieties were compared for vegetative growth, reproductive traits, and consumer preference.
- Significant variation was observed among varieties for most growth and yield parameters.
- Multivariate analyses (PCA and cluster analysis) allowed classification of varieties based on overall performance.
- Promising varieties with high flower yield and good quality traits were identified for commercial cultivation.
- Findings provide practical recommendations for growers and strengthen the floriculture industry with locally validated varietal choices.

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Evaluation of Yield Performance of Local and Imported Marigold (*Tagetes erecta* L.) Varieties

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Abstract: Marigold (*Tagetes erecta* L.) is a multifunctional ornamental plant with considerable potential for value addition. However, growers often lack adequate knowledge about varieties with desirable vegetative and reproductive traits, high yield potential, and superior quality. The present study was therefore conducted to evaluate the yield performance and consumer preference of different marigold varieties for potential introduction into the Sri Lankan floriculture industry. A field experiment was carried out at the Royal Botanic Gardens, Peradeniya, using a Randomized Complete Block Design (RCBD) with three replicates and fifteen (15) varieties as treatments. Each block consisted of one plot per variety. Data on selected vegetative and reproductive parameters, as well as consumer preferences, were collected and analyzed. The study revealed significant differences ($P < 0.05$) among varieties for all vegetative and reproductive traits, except the number of leaves at 30 and 60 days after planting (DAP). Principal component analysis (PCA) and cluster analysis indicated a homogeneous grouping of the varieties. Among them, V2 and V4 recorded the highest number of flowers per plant, flower yield per plant (V4: 917.30 ± 9.67 g; V2: 840.71 ± 10.56 g), and flower yield per square meter, along with relatively better performance in other reproductive parameters such as flower weight and flower duration. Based on these findings, V2 and V4 can be recommended for commercial cultivation. This is the first reported varietal evaluation trial of marigold in Sri Lanka, and it successfully identified varieties with superior yield parameters suitable for large-scale cultivation. These results will be of practical value to farmers and stakeholders engaged in the commercial production of marigolds in Sri Lanka.

Keywords: Floriculture; Local and Imported Varieties; Marigold; Sri Lanka; Yield Performance

INTRODUCTION

Marigold (*Tagetes erecta* L.) belongs to the family Asteraceae, is an aesthetically pleasing flower (Malik et al., 2020). It is native to South and Central America, particularly Mexico, where it is used as an ornamental as well as a medicinal plant (Panwar et al., 2013). It is extensively grown throughout Asia, including India, China, and other tropical nations. Marigold plant requires temperatures between 20 °C and 30 °C, as well as a sufficient amount of yearly precipitation for its optimum growth (Singh et al., 2020).

The genus *Tagetes* contains numerous economically important species which are used as food, condiments, coloring, medicinal, and ornamental industries. The

highest diversity of genus *Tagetes* is found in India and Thailand, followed by France, Africa, Mexico, Myanmar, Bangladesh, and Indonesia (Singh et al., 2020). There are 33 species in the genus *Tagetes*, with *Tagetes erecta* L. ($2n = 24$) being the most widely cultivated species because of its magnificent flowers. The marigold plants grow up to 50-80 cm in height, and the leaves are mid-green, lanceolate, and between 5 and 17 cm in length. The edges of the leaves might be sparsely serrated or wavy, and the stems and leaves are covered with tiny hairs (Singh et al., 2020).

Flower yield is one of the most important characteristics for commercial flower cultivation in marigolds. Evaluation of the yield performance in flowering plants is essential for optimizing crop productivity, resource utilization, and overall profitability. It contributes to the development of sustainable and competitive practices in the floriculture industry and supports research and innovation efforts in this field.

It is necessary to increase the production of marigold flowers to cater to high demand to supply the required amounts for social and religious ceremonies, as well as for industrial activities (Pramila et al., 2011). However, the Sri Lankan growers are unaware of varieties suitable for their location or area. Varieties are selected based on fellow farmers' recommendations and completely depend on seed shops. Therefore, it is very important to study the performance of existing varieties available in the market under different agro-climatic conditions in Sri Lanka (Prashanth et al., 2018). Furthermore, it is essential to identify the best genotype with desirable characteristics for a specific location for successful commercial cultivation to achieve maximum profit and productivity (Singh et al., 2008). New, improved varieties with many desirable characters, such as high yield potential and better quality parameters, have been released in various other countries in Asia (Patokar et al., 2018). Thus, it may be possible to introduce new, improved high-yielding varieties into the floriculture sector in Sri Lanka.

The world production of marigolds stands at around 600,000 MT, of which India contributes a share of approximately 75-80%. Sri Lanka is one of the importers of Marigold from India (Gupta et al., 2020). Therefore, the present study was conducted to evaluate the yield performance of

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various imported and local varieties of Marigold (*Tagetes erecta* L.) to enhance the commercial Marigold cultivation in Sri Lanka.

MATERIALS AND METHODS

Location of the experiment

The experiment was conducted as a field experiment at the Royal Botanic Gardens, Peradeniya, which is located in the agro-ecological region WM2b (Mid Country Wet zone 7°16'05" N 80°35'47"E), 495 m above the mean sea level (MSL) of Sri Lanka from November 2023 to March 2024. Laboratory analysis was carried out at the Department of Crop Science and the Department of Agricultural Engineering, Faculty of Agriculture, University of Peradeniya, Sri Lanka.

Experimental design and treatments

The experiment was laid out as a Randomized Complete Block Design (RCBD) with three blocks. Each block consisted of fifteen plots containing three imported Indian varieties and twelve local varieties. One plot (an experimental unit) consisted of fourteen (14) plants from the specific variety.

Experimental procedure

Seeds of fifteen marigold varieties were sown in nursery trays. One-month-old (4-6 leaf stage), healthy, vigorous, and uniform seedlings were selected and transplanted for each variety at a spacing of 30 cm x 30 cm in randomly selected plots, and 0.5 m was maintained between two adjacent blocks. Plants were earthed up after one month of planting, and staking was done to avoid falling. The observations were recorded on four randomly selected plants in each plot after discarding the plants growing at the borders of each plot.

Cultural and management practices

Nursery management

Brick/tile pieces were laid in the bottom of the nursery tray. Then, the leaf litter layer was spread on top of that. Thereafter, sterilized nursery media, which contained soil: sand: composed leaf litter in a 1:1:1 was added. Marigold seeds were planted uniformly and covered with a thin soil layer. Each tray was covered with glass to keep the moist environment around the seeds, which facilitated quick germination.

Irrigation

All the plants were irrigated once (equal volume) a day during the nursery stage. After transferring to the field, irrigation was done in 3 to 4 day intervals as required to maintain the moisture condition.

Weeding

Manual weeding was done when it was necessary.

Pest and disease management

Antracol Propineb 70% (W/W) fungicide was applied to prevent damping off disease during the nursery stage. After seedlings were planted in filled pots, *Ceypetco Captan* 50%

(W/W) was applied to prevent plants infected by damping off. Insect (Beetle) damage was observed and insecticide, *Viper fipronil*, was applied. Leaf disease with brown spots and a burned appearance due to fungal invasion was observed in plants, and *Daconil* fungicide was applied.

Harvesting

Marigold flowers were plucked at 7-day intervals when they attained the full size, depending upon the variety, in either the morning or evening.

Data collection

Data collection was started 30 days after seeding. Vegetative and reproductive parameters were recorded using four randomly selected plants in each block of each variety. Plant height (cm), number of leaves per plant at 30, 90, and 60 days after planting, and number of primary and secondary branches at 90 days after planting were collected as vegetative parameters. The number of days taken to first flower bud initiation, 50 percent flowering, and flowering duration (days) was recorded. Weight (g), diameter (cm), colour (colorimeter-CS-10, China), vase life (days) of a flower, and number of flowers per plant were measured as reproductive parameters. Flower yield per plant (g) and flower yield kg m⁻² were calculated. Flower appearance and consumer acceptance were assessed using a Hedonic scale through a survey conducted with an untrained panel of 15 members to identify the most preferred variety.

Colour of the flowers was measured using a Colorimeter measurement, Lab* (CIELAB), in which color space is defined by the International Commission on Illumination (CIE). The L* coordinate indicates darkness or lightness of color and ranges from black (0) to white (100), and coordinates, a* and b*, indicate color directions. The a* coordinate indicates the color on a green to red axis, with +a* is the red direction, and -a* is the green direction. The b* coordinates represent the color on a blue to yellow axis, with +b* is the yellow direction, and -b* is the blue direction (Itle & Kabelka, 2009).

The vase life of marigold flowers was evaluated by visual observation under ambient room conditions (approximately 25 ± 2 °C, natural light). Tap water was used as the vase solution. For each variety, an equal number of flowers (n=6) with uniform stalk lengths were placed in separate clean glass bottles containing 500 ml of tap water. The water was changed daily in the morning to maintain freshness. Vase life was recorded as the number of days until at least 50% of the flowers exhibited visible wilting or petal discoloration.

Statistical analysis

Parametric (continuous) data were analyzed using Analysis of Variance (ANOVA) followed by Duncan's Multiple Range Test (DMRT) with the aid of Statistical Analysis System (SAS) software. Non-parametric (count) data were evaluated using the chi-square test, while time-related data were analyzed using survival analysis. Consumer preference was assessed with the Friedman test. For a comprehensive understanding of all measured data, Principal Component Analysis (PCA) and Cluster Analysis

were conducted using PAST software.

PCA was performed to determine the number of principal components to retain for dimensionality reduction while preserving most of the variance in the data. Sixteen vegetative and reproductive characters, excluding consumer preference, were included in the PCA. Vegetative parameters considered were plant height, number of leaves, and number of branches, measured only at 90 days after planting. Multivariate hierarchical clustering was carried out for the fifteen marigold varieties based on the Euclidean distance matrix as the similarity index using PAST software. A dendrogram (cluster diagram) was created considering all vegetative and reproductive characters, including plant height, number of leaves, number of branches, days to first flower bud initiation, days to 50% flowering, fresh flower weight of a single flower, flower diameter, flower color (colorimeter value), flower duration, vase life, number of flowers per plant, flower yield per plant, and flower yield per m².

RESULTS AND DISCUSSION

Variation in vegetative parameters

Plant heights of the fifteen marigold varieties were significantly different ($p < 0.01$). The significantly tallest plants at 30 and 60 days after planting (DAP) were observed in varieties V15 and V13, while the varieties V7 and V9 were the shortest among the fifteen varieties (Table 1). Interestingly, at the end of 3 months, the variety V4 showed the significantly highest plant height (75 cm) followed by variety V6 (70 cm), while the variety V1 (52.67 cm) showed the lowest plant height, followed by varieties V8, V11, V14, and V10, indicating differences in the rate of growth of different varieties with time. Plant height (90 DAP) ranged from 75 cm to 52.67 cm, with a mean value of 60.69 cm (Table 1).

In agreement with the results of the present study, African marigold (*Tagetes erecta*) varieties have shown significant differences in plant height ranging from 26.9 cm to 102.8 cm at 30 and 60 days after planting (Mehata, 2022). In contrast, Choudhary et al. (2014) reported 20-30 cm of height for marigold varieties examined in their study, indicating the environmental effects as well as the genetic make-up on the phenotypic expressions of plant height (Mehata, 2022).

The number of leaves was not significantly different ($p > 0.05$) until 60 days after planting. However, at 90 days after planting, a significantly higher number of leaves was observed in the variety V13, followed by V6 and V4, while the lowest number of leaves was observed in variety V10, which was followed by V8 and V14 (Table 1). In contrast to the results of the present study, the number of leaves of different varieties has shown a significant difference at 30 and 60 days after planting (Mehata, 2022).

Furthermore, the mean number of primary branches per plant as well as the mean number of secondary branches per plant were significantly different ($p < 0.05$) at 90 DAP. The highest mean number of primary branches was observed in variety V5 (18), followed by varieties V11 (14.83) and

V6 (14.67). The lowest mean number of primary branches was observed in varieties V7 (8) and V10 (8.36) (Table 1). The variety V11 (8.33) showed the highest mean number of secondary branches, while the lowest mean number of secondary branches was observed in varieties V8 (1.83) and V10 (1.67) (Table 1). However, the highest number of primary branches (18) and the secondary branches (8.33) observed in the present study was less compared to the results reported by Mane et al. (2021) for variety Patula Bonanza Bolero (22 and 49.01 for primary and secondary branches, respectively), indicating the differences in vegetative parameters among varieties.

The differences in branching and vegetative growth among marigold varieties are primarily attributed to genetic variability among the genotypes, with additional influence from environmental conditions (Poulose, 2017).

Variation in reproductive parameters

The number of days required for flower initiation was significantly different ($p < 0.01$) among fifteen marigold varieties (Table 2). The varieties V1 and V15 required the minimum time to initiate the first flower bud (61 days) followed by variety V7 (68 days), while the maximum time required was for variety V13 (88 days), followed by varieties V2 (85.33 days) and V10 (83.67 days) (Table 2). However, in Lahore, Pakistan, flower bud initiation of different marigold varieties has been reported between 20-30 days (Malik et al., 2020), indicating that under Sri Lankan conditions, marigold plants take more time for flower initiation. The number of days taken for the first flower to open is one significant genotypic characteristic of marigolds, and this trait may be predominantly controlled by the genotypes and environmental interactions (Prashanth et al., 2018).

There was a significant variation among marigold varieties for 50% flowering ($p < 0.01$). The minimum number of days to 50% flowering was observed in varieties V11 (85 days) and V9 (89 days), which are significantly different from other varieties. In contrast, the significantly longer time for 50% flowering was required by variety V2 (130 days), followed by varieties V3 (123 days), V4, and V5 (121 days) (Table 2). Mehta (2022) reported significantly lower numbers of days for 50% flowering of Marigold varieties; Sweet Cream (38) and Collosus (43), while more days (114) for the variety Moonstruck. Furthermore, Mane et al. (2021), reported 65.03 days as the maximum for 50% flowering of the marigold variety Pusa Basanti Gaiinda. However, in the present study, the shortest duration for 50% flowering (85 days) was higher than the longest duration (65 days) reported by Mane et al. (2021). These results indicate the importance of environmental factors in determining the flower initiation in different Marigold varieties.

Fresh weight of a single flower was significantly different ($P < 0.01$) among the fifteen marigold varieties. The highest mean flower weight was recorded in varieties V13 (11.65 g), V3 (10.38 g), V11 (10.32g), and V7 (10.24g), while the lowest was recorded in the variety V10 (4.49 g) (Table 2). In agreement with the results of the present study by Choudhary et al. (2014) reported that the maximum fresh

Table 1: Mean values of key vegetative parameters, including plant height, number of leaves, and number of branches, measured for the fifteen marigold (*Tagetes erecta* L.) varieties at 30, 60, and 90 days after planting.

Variety	Plant height at 30DAP (cm)	Plant height at 60 DAP (cm)	Plant height at 90 DAP (cm)	No of leaves 30 DAP	No of leaves 60 DAP	No of leaves 90 DAP	Mean No of primary branches	Mean No of secondary branches
V1	8.00±0.57 ^{ef}	19.33±0.88 ^f	52.67±3.71 ^f	8.67ns	12.67ns	58*	10.33*	6.67*
V2	8.67±0.33 ^{de}	20.67±0.67 ^{ef}	60±1.44 ^{cdef}	12.67ns	17.33ns	70*	13*	5*
V3	9.00±0.57 ^{def}	22.33±1.45 ^{def}	59.83±5.1 ^{cdef}	9.33ns	14.67ns	62*	13.67*	4.67*
V4	10.33±0.88 ^{bcd}	25±1.15 ^{bcd}	75±3.78 ^a	9.33ns	13.33ns	71.33*	13.33*	4.33*
V5	9.67±0.88 ^{de}	21±1.52 ^{ef}	67.67±4.33 ^{ab}	8.67ns	12.67ns	68*	18*	6*
V6	11.00±1.52 ^{ab}	23.33±1.76 ^{cde}	70±2.88 ^{ab}	11.33ns	15.33ns	72.67*	14.67*	6.67*
V7	7.67±0.33 ^f	21±2.08 ^{d^{ef}}	62.33±1.45 ^{bcd^e}	10ns	14.67ns	65.33*	8*	4.67*
V8	8.56±0.11 ^{def}	19.83±0.36 ^{ef}	53.52±3.27 ^{ef}	6.89ns	12.33ns	51.33*	10*	1.83*
V9	7.78±0.11 ^f	20.33±0.08 ^{ef}	58.38±2.36 ^{def}	7.22ns	11ns	53.33*	12.61*	4.5*
V10	11.44±0.72 ^{ab}	24.83±0.30 ^{bcd}	56.55±1.54 ^{ef}	6.44ns	12.33ns	42*	8.36*	1.67*
V11	10.78±0.67 ^b	26.44±1.99 ^{abc}	54.71±2.91 ^{ef}	8.22ns	12.83ns	61.33*	14.83*	8.33*
V12	10.67±0.33 ^{abc}	21.66±0.79 ^{de}	57.19±1.79 ^{ef}	6.44ns	11.83ns	67.33*	11.5*	4.33*
V13	11.55±0.22 ^a	22.67±0.72 ^{def}	59.56±2.25 ^{cdef}	6.44ns	13ns	81.67*	14.17*	6*
V14	9.08±0.08 ^{cde}	27.91±1.16 ^{ab}	56±2.08 ^{ef}	6.83ns	10ns	51*	8.83*	2.67*
V15	11.75±0.38 ^a	29.16±1.73 ^a	67±1.73 ^{abcd}	7.33ns	12.67ns	70.33*	11.17*	4.67*

Means sharing the same letter(s) within a column are not significantly different at $P < 0.05$ based on Duncan's Multiple Range Test (DMRT). "ns" indicates non-significance, and "*" indicates significance at $P < 0.05$.

weight of a flower (15.57 g) was in genotype MGH-09 27.1 g, followed by genotype MGH-09-276 (14.58 g), whereas the minimum fresh weight of a flower (2.32 g) was in genotype Hisar Beauty. However, Prashanth et al. (2018) reported very low flower weight compared to our study for variety Arka Agni (5.87 g).

The varieties differed significantly regarding the diameter of a single flower ($p < 0.05$). The maximum diameter of the flower (7.33 cm) was recorded in variety V13, followed by varieties V1 (7.07 cm), V11 (6.97 cm), and V15 (6.83 cm), while the lowest diameter was recorded in variety V10 (4.23 cm), followed by variety V5 (5.00 cm) (Table 2).

Malik et al. (2020) reported similar observations in their study, and the variety 'Bindi' (orange) recorded the maximum diameter (7.9 cm), whereas the minimum (1.15 cm) was recorded in 'Little Duck' (orange). It was explained that these variations in the diameter of fully opened flowers might be due to the variation in the genetic composition of different varieties. In a similar study, the maximum diameter (6.13 cm) of a flower was recorded in the variety 'Erecta Naana Moon' while the lowest flower diameter (4.07 cm) was recorded in the variety 'Orange Bunch' (Prashanth et al., 2018).

Flower color is important for understanding consumer preferences and market demand, aesthetic appeal, genetic insights, pollinator interactions, stress responses, and commercial success of the varieties. According to the statistical analysis, significant differences ($p < 0.001$) were observed among the varieties for flower color represented by the Lab* space values. Even though in terms of lightness of the varieties (L*), V12 and V11 were not significantly different from each other, the b* values were significantly

different. Furthermore, the varieties V9, V3, V13, and V6 with similar L* values were significantly different from each other with relation to the a* value.

The varieties V13, V2, and V10 are not significantly different from each other with respect to the a* color value, but they were significantly different from each other with respect to the b* value. Moreover, varieties V5, V14, V1, and V4 were not significantly different from each other when considering the a* value. With respect to b* value, the varieties V7, V6, V13 and

V9 were not significantly different from each other, but they have different a* values. The varieties V2 and V10 were not significantly different from each other with respect to Lab* values. However, other than V2 and V10, all other varieties were different from each other in terms of overall Lab* values, indicating that Marigold varieties were different with respect to the flower color (Figure 1).

The vase life of marigold flowers was significantly different ($p < 0.01$) among the fifteen varieties. The longest vase life was observed in variety V1 (7.67 days), followed by variety V2 (7.33 days). The minimum vase life was observed in variety V10 (2.33 days), followed by variety V8 (3.5 days).

In agreement with the results of the present study, the vase life of marigold varieties, Patula Bonenza Bolero, 'Dubloon', 'Sweet Cream (Mehata, 2022), and Pusa Narangi Gaiinda (Mane et al., 2021) was 6-7 days, while varieties such as Whooper Yellow (Mehata, 2022) and Pusa Basanti Gaiinda (Mane et al., 2021) exhibited the shortest vase life of 3-5 days.

Flowering duration of different varieties of marigolds was significantly different ($p < 0.01$). The longest flowering

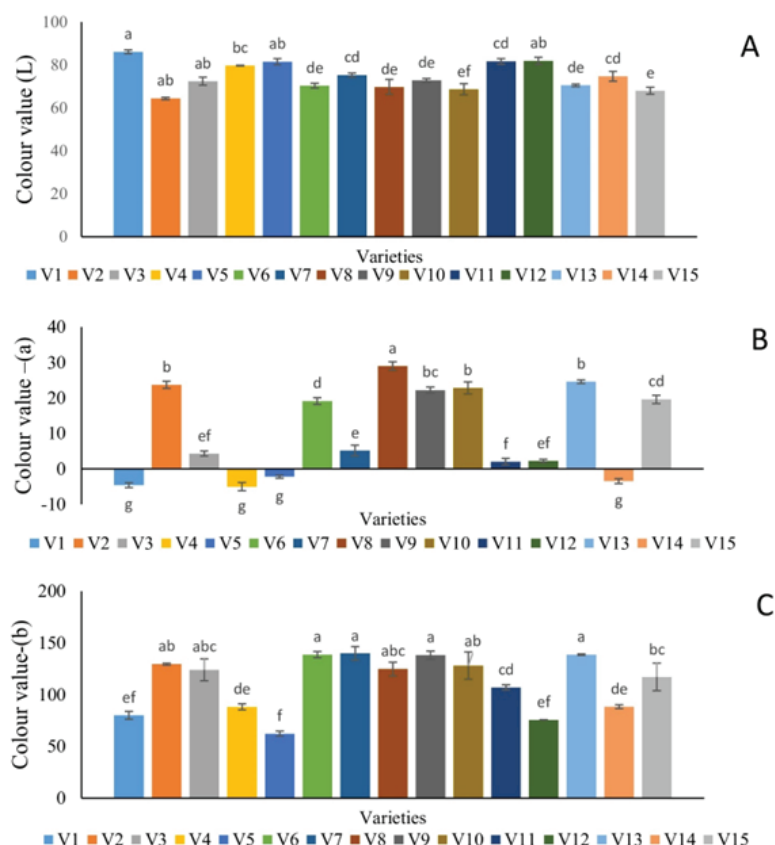


Figure 1: Variation in flower color among marigold varieties based on overall Lab* color space values. (A) L* (lightness) values, (B) a* (red, green) values, and (C) b* (yellow, blue) values.

duration was observed in variety V11 (50.67 days) followed by V9 (48.67 days) and V4 (48.33 days). The shortest flowering duration was observed in variety V14 (19.16 days), which was followed by variety V7 (28 days). Mehata (2022) reported that the flowering duration of marigold varieties was significantly different from others, and the longest flowering duration (66) was observed in the variety Dubloon, which was followed by Discovery Orange (50), while the shortest flowering duration was observed in the variety Patula Bonenza Bolero (39). In a similar study with African marigold varieties, the longest flowering duration (69.80 days) was recorded in variety T6-Orange, while the shortest (55.67 days) was recorded in variety T5-Double Orange. The possible reasons for these variations might be due to the genetic control of these characters and modification in their expression due to environmental conditions such as pests and diseases, varietal adaptability, and tolerance to unfavorable conditions (Prashanth et al., 2018; Poulouse, 2017).

There was a significant difference ($P < 0.01$) among the marigold varieties with respect to the cumulative number of flowers per plant. The highest number of flowers per plant was observed in variety V2 (103.16), which was followed by varieties V4 (96.16) and V3 (94.78). The variety V14 showed the significantly lowest number (9.67) of flowers per plant. In a study of evaluating African marigold (*Tagetes erecta* L.), a significantly higher number of flowers per plant (67.3) was recorded in the variety

'Seracole' followed by 'Cracker Jack' (57.3), while the lowest number of flowers per plant was recorded in the variety 'Inca orange' (19.4). Cell elongation and rapid cell stimulation might be the reason for the observation of the increased number of flowers per plant (Lohar et al., 2018).

In the present study, significantly ($p < 0.001$) the highest flower yield per plant was observed in variety V4 (917.30 g/plant), followed by variety V2 (840.71 g/plant). The lowest yield per plant was observed in variety V14 (64.79 g/plant), followed by variety V10 (101.85 g/plant). In agreement with the results of the present study of Srinivas and Rajasekharam (2020) the 874.9 g of flower yield per plant in genotype Astagandha followed by Vikrant Yellow (867.2 g), while the minimum (89.3 g) flower yield per plant was recorded in AW Dwarf Yellow. In a similar study, the marigold genotypes significantly differed with respect to the flower yield per plant, and the maximum (440 g) flower yield per plant was recorded in variety Arka Agni, while the lowest (270 g) was recorded in variety J. K (Prashanth et al., 2018). Choudhary et al., (2014) also reported similar findings and the maximum flower yield per plant (874.37 g) in genotype Hisar Jaffri-2, followed by MGH-09-271 (828.85 g) and MGH-09-276 (797.03 g), while the minimum (98.00 g) was in Hisar Beauty. These variations in the varieties might be due to genetic and environmental interaction (Poulouse, 2017).

Fifteen marigold varieties were significantly different from

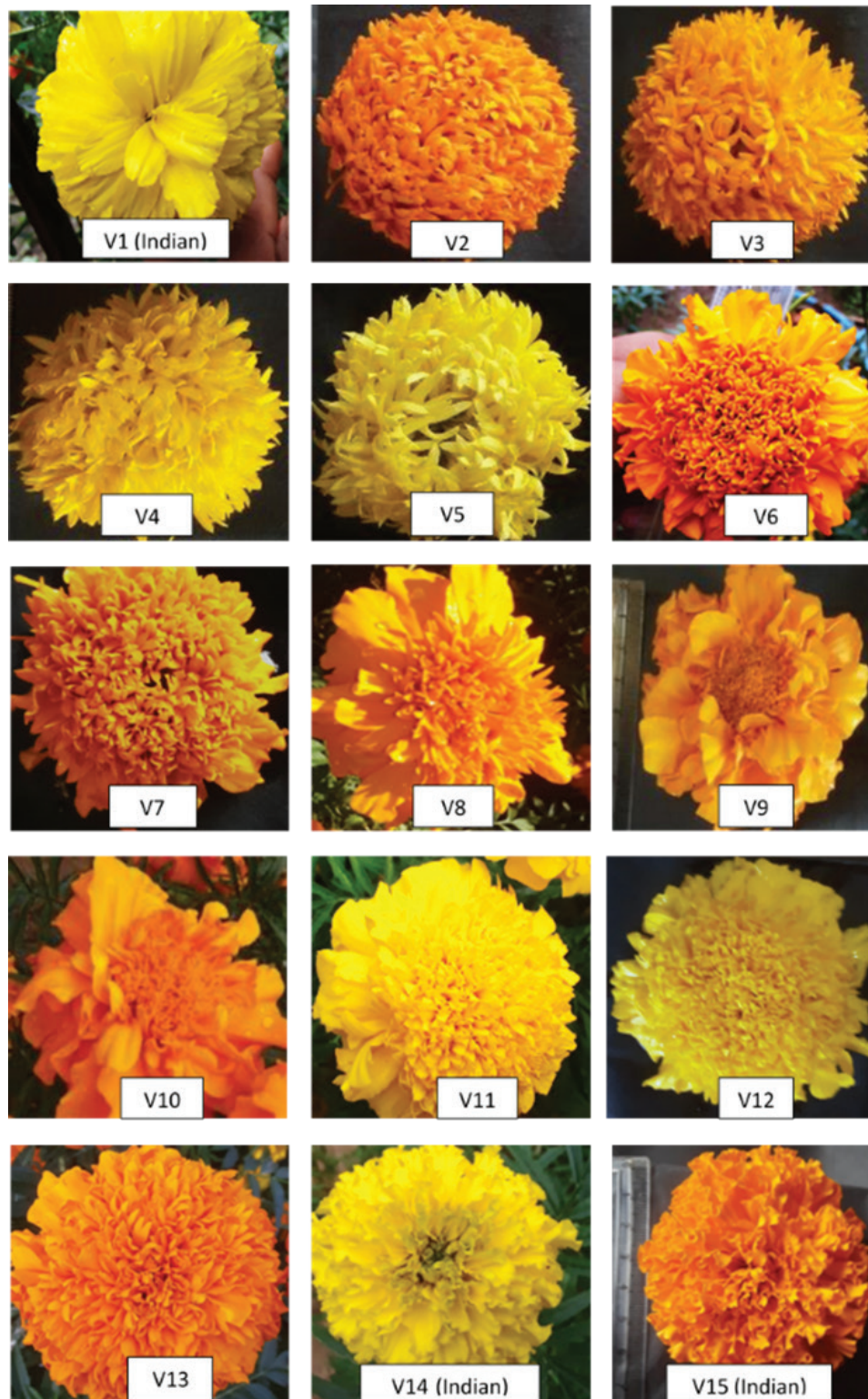


Figure 2: The appearance of representative flowers of three imported (Indian V1, V14, and V15) and twelve local (V2-V13) marigold varieties.

each other with respect to the flower yield per 1 m² ($p < 0.001$). Significantly, the highest yield per 1 m² (14.27 kg/m²) was observed in variety V4, followed by variety V2 (13.07 kg/m²). The lowest flower yield per 1 m² was observed in V14 (1.01 kg/m²) and V10 (1.58 kg/m²). Mehata et al. (2022) reported that higher yield per plot (2.9 kg/m²) for varieties Patula Bonenza, Bolero, and Antigua Orange, while the lowest yield was observed in Sweet Cream (0.81 kg/m²). Interestingly in our study, five of the evaluated varieties (V1, V2, V3, V4, and V11) showed yields above 10 kg/m², showing the possibility of obtaining higher yields in Sri Lankan conditions. The differences in yield observed may be due to the genetic potential, adaptability, and response of varieties in the specific climatic conditions. The genetic attributes of selected genotypes also affect the variations related to the growth

and yield characteristics (Singh et al., 2020). The higher flower yield may be due to proper vegetative growth, a higher number of branches, and higher reproductive parameters such as a higher number of flowers per plant, flower duration, flower diameter, and fresh flower weight (Upadhyaya et al., 2022). Flower yield expressed a highly positive correlation with the number of flowers per plant, flower diameter, and weight of the flower. During the research period, the disease susceptibility of Indian Marigold varieties, Hybrid Yellow and Hybrid Orange, was high, and it might be a reason for observable lower yield in those varieties. Local varieties were tolerant and adaptable to diseases and climatic conditions. Therefore, the highest number of flowers and highest flower yield per plant were recorded in local varieties compared to the Indian varieties.

Table 2: Mean values of key reproductive parameters, including days to first flower bud initiation, days to 50% flowering, flower weight, flower diameter, flower duration, vase life, number of flowers per plant, and flower yield per plant and per m², for the fifteen marigold (*Tagetes erecta* L.) varieties.

Variety	Days to the appearance of first flower bud	Days to fifty percent flowering	Average fresh weight of single flower (g)	Average diameter of a single flower (cm)	Vase life (days)	Flower duration (days)	No of flowers per plant	Flower yield per plant (g)	Flower yield per 1 m ² (kg/m ²)
V1	61*	98*	10.073±0.66 ^{abc}	7.06±0.06 ^{ab}	7.67*	41.33*	61.61*	620.64±9.72 ^d	9.65±0.15 ^d
V2	85.33*	130*	8.15±0.64 ^{def}	6.16±0.16 ^{de}	7.33*	47*	103.16*	840.71±10.56 ^b	13.07±0.16 ^b
V3	80.33*	123*	10.38± 0.26 ^{ab}	6.5±0.28 ^{de}	6.33*	43.67*	94.77*	735.56±11.41 ^c	11.44±0.17 ^c
V4	71*	121*	9.83± 0.45 ^{abcd}	6.16±0.33 ^{de}	5.67*	48.33*	96.16*	917.30±9.67 ^a	14.26±0.15 ^a
V5	73.67*	121*	7.02± 1.12 ^{abcd}	5±0.28 ^g	6.33*	40*	76.67*	369.58±13.15 ^g	5.75 ±0.2 ^g
V6	70*	118*	7.046± 0.40 ^f	6±0.11 ^{ef}	4.67*	33*	70.44*	496.34±2.07 ^e	7.72±0.03 ^e
V7	68*	118*	10.24±0.43 ^{abc}	5.94±0.24 ^{ef}	5.67*	28*	61.72*	632.05±7.39 ^d	9.83±0.12 ^d
V8	80.33*	108*	7.84±0.71 ^f	5.53±0.08 ^f	3.5*	39.67*	34*	266.79±11.98 ^h	4.15±0.18 ^h
V9	71.33*	89*	8.01±0.29 ^{def}	6.6±0.1 ^{bd}	4*	48.67*	52.67*	421.68±14.12 ^f	6.56±0.22 ^f
V10	83.67*	103.67*	4.50±0.36 ^g	4.23±0.15 ^h	2.33*	36.33*	22.67*	101.85±6.53 ^j	1.58±0.10 ^j
V11	69.33*	85*	10.31±1.01 ^{abc}	6.96±0.08 ^{ab}	4.67*	50.67*	64.33*	663.71±30.56 ^d	10.32±0.47 ^d
V12	78*	97.33*	9.14± 0.12 ^{bcde}	6.03±0.15 ^{ef}	4.33*	42*	37.67*	344.27±13.28 ^d	5.36±0.2 ^g
V13	88*	112*	11.65± 0.53 ^a	7.33±0.12 ^a	5.33*	32.8*	45.33*	527.98±30.32 ^e	8.21±0.47 ^e
V14	75.83*	91*	6.70± 0.19 ^f	6.03±0.08 ^{ef}	6.16*	19.16*	9.67*	1.01±0.09 ^j	7.72±0.03 ^j
V15	61*	93*	8.43± 0.12 ^{cdef}	6.83± 0.08 ^{ab}	6.67*	34*	22.67*	191.15±17.09 ⁱ	2.97±0.26 ⁱ

Means sharing the same letter(s) within a column are not significantly different at $P < 0.05$ according to the DMRT test. “ns” indicates non-significance, and “*” denotes significance at $P < 0.05$. The values of the highest-yielding varieties are highlighted.

Morphological diversity among marigold varieties

Results from principal component analysis indicated that the first five principal components (PCs) explain a substantial portion of the total variance, with PC1, PC2, PC3, PC4, and PC5 accounting for 37.07%, 19.39%, 12.27%, 9.74% and 7.44% of the variance, respectively. The first five principal components explained approximately 85.92% of the total variance. This dimensionality reduction allows for more straightforward interpretation and analysis of the data.

First Principal component - PC1 (37.07%) was heavily influenced by variables such as 'F_Y' (Flower Yield per 1m²), 'F_Y_P' (Flower Yield per plant), 'N_F_P' (Number of Flowers per plant), and 'N_S' (Number of Secondary branches). These variables significantly contributed to the PC1 with high positive loadings. This suggested that PC1 primarily represented overall flower productivity and yield. Second Principal Component - PC2 (19.39%) was influenced by high positive loadings from variables 'D_F_B' (Days taken to First flower bud initiation), 'D_50' (Days taken to 50% flowering), and 'C_a' (Colorimeter value a). It indicated that this component represents aspects related to flowering time and colorimetric characteristics. The variables, 'D' (Diameter of single flower), 'C_b' (Colorimeter value b), and Fresh Flower weight (F_W) significantly contributed to the PC3 (12.27%) with high positive loadings. It explained that PC3 primarily captures variations related to flower size and color properties. The fourth principal component, PC4 (9.74%), was mainly influenced by 'F_D' (Flower Duration) and 'C_L' (Colorimeter value L*), indicating that PC4 represents aspects related to the duration of flower and brightness/lightness of the flower color. The fifth principal component, PC5 (7.44%), had high positive loadings from 'N_P' (Number of Primary branches) and 'V_S' (Vase Life), suggesting that PC5 captures variations in the branching pattern and vase life of the flowers.

The number of leaves at 90 days after planting (NL_90) exhibited significant loadings in PC1 (0.292495) and PC2 (0.123516), indicating its considerable contribution to the overall variability. Plant height at 90 days after planting (HT_90) shows moderate loadings in PC1 (0.170917) and PC2 (0.139480), suggesting it contributes to the overall variability but to a lesser extent compared to other traits. It indicated that these variables are also important, but

not as critical as other traits in capturing specific variations related to reproductive performance and yield-related attributes. However, vegetative growth is also very important for better reproductive growth. The PCA results provide valuable insights into the identification of key traits that contribute significantly to the overall variability, which is crucial for varietal selection and breeding programs. The variables that have the highest loadings in the principal components explaining the most variance should be focused on to determine the most important traits. According to that, all the variables have to be considered when characterizing the fifteen varieties, as they contribute to the total variance.

In the cluster diagram, the varieties formed a single cluster at around 450-500 distance units, showing that while there are some distinct subgroups, all varieties have some level

of similarity to each other. The dendrogram was divided into two main clusters, and first main cluster was separated at 250-200 distance units, while the second main cluster was separated at 300 distance units. The varieties V5, V12, V8, and V15 formed a sub-cluster as they merged into the first cluster at around 150 distance units. Varieties V10 and V14 joined this cluster at around 200 distance units. These varieties showed more similar characters in terms of flower yield, days to first flower bud initiation, and days to 50% flowering. However, varieties V10 and V14 deviated from others in characters such as average weight of single flower and flower duration.

The second main cluster was further divided into two subclusters at around 300 distance units. First sub cluster included varieties V1, V3, V6, V7, V9, V11, and V13 while, the second sub cluster included the varieties V2 and V4. The varieties V1, V11, V7, and V3 form another sub-cluster, which joined the first sub-cluster at around 200 distance units. Those varieties shared more similar values for the average fresh weight of a single flower and the number of leaves. This sub-cluster included one close pair as V1 and V11, which had more similar values for the characters such as plant height, number of leaves, diameter of single flower, and flower yield per plant.

The varieties V6, V13, and V9 formed another sub-cluster at around 100 distance units. It included the close pair V6 and V13, which shared similar values for number of leaves, number of secondary branches, days to fifty percent flowering, flower duration, and flower yield per plant. However, the variety V9 deviated from the other two varieties from character, flower yield per plant.

The second sub-cluster included the close pair V2 and V4. These two varieties showed similar values for most of the characters, including number of leaves, number of primary branches, number of secondary branches, fresh weight of single flower, average diameter of single flower, flower duration, number of flowers per plant, flower yield per plant, and yield per 1 m². These two varieties were the highest-yielding varieties. The variety V9 merged with the rest of the varieties at a very high distance value, indicating it is quite different from the other varieties.

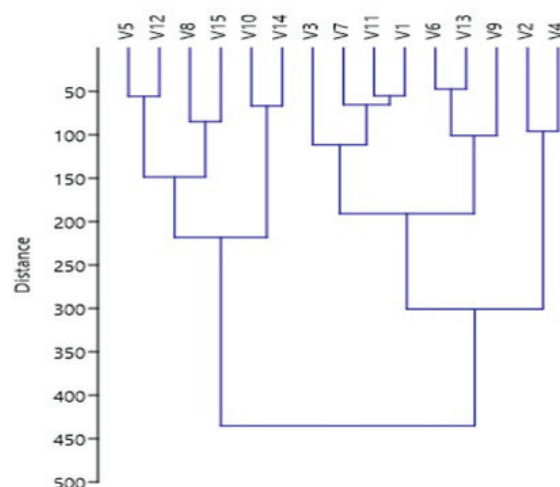
Cluster analysis revealed that certain marigold varieties have high similarity, form distinct subgroups, while others are more unique, and join the clusters at higher distance values. Therefore, this information can be used to select varieties with desired characteristics by understanding their genetic or phenotypic similarities for further studies and breeding programs.

In agreement with the results of the present study, Amma and Radhakrishna (2011) reported that 56.8% of the phenotypic variance of *Tagetes erecta* was accounted for first principal component, while 17.3% by the second principal component, followed by 8.2% by the third and 5.5% by the fourth PC based on qualitative data. It was found that leaf morphology, branching nature, and flower color contributed to the most variance on the first principal component. Furthermore, 43.3% of phenotypic variance was accounted for first principal component, while 23.2% by the second principal component, followed by 15.8 %

Table 3: Eigen-analysis of the correlation matrix for vegetative and reproductive characters of the principal components contributing most to the total variance.

Principal components (PC)						
	PC1	PC2	PC3	PC4	PC5	PC6
Eigenvalue	5.9313	3.1029	1.9633	1.5587	1.1905	0.8838
Difference	2.8283	1.1396	0.4045	0.3681	0.3067	0.2991
Proportion	0.3707	0.1939	0.1227	0.0974	0.0744	0.0552
Cumulative	0.3707	0.5646	0.6874	0.7848	0.8592	0.9144
Eigen vectors						
	PC1	PC2	PC3	PC4	PC5	PC6
HT_90	0.1709	0.1394	-0.3271	-0.4264	0.2132	-0.3529
NL_90	0.2924	0.1235	0.0821	-0.4052	0.1882	0.2349
N_P	0.2593	0.0674	-0.1757	-0.0020	0.5780	0.2819
N_S	0.3118	-0.1337	0.1663	-0.0384	0.3505	0.0161
D_F_B	-0.0897	0.3606	-0.0613	0.1970	-0.0883	0.7063
D_50	0.1754	0.3720	-0.3257	-0.1395	-0.2777	0.1036
F_W	0.2923	-0.0657	0.3729	0.0188	-0.1802	0.1971
D	0.2259	-0.1223	0.5405	-0.0894	0.0227	0.0584
C_L	0.1508	-0.4642	-0.1533	0.1838	0.0016	0.0933
C_a	-0.1641	0.4172	0.2719	0.0159	0.2521	-0.0564
C_b	-0.0672	0.4145	0.3808	-0.0136	-0.0073	-0.3016
F_D	0.2029	0.0543	-0.0501	0.5801	0.2607	-0.1749
V_S	0.2486	-0.1302	0.0216	-0.3343	-0.3302	0.0734
N_F_P	0.3457	0.1915	-0.2008	0.1696	-0.0967	-0.1159
F_Y_P	0.3665	0.1360	0.0186	0.1929	-0.2169	-0.1344
F_Y	0.3665	0.1360	0.0186	0.1929	-0.2169	-0.1344

HT_90 refers to the plant height at 90 days after planting (DAP), while NL_90 indicates the number of leaves at 90 DAP. N_P and N_S represent the number of primary and secondary branches, respectively. D_F_B denotes the days taken for the first flower bud initiation, and D_50 indicates the days taken to reach 50% flowering. F_W corresponds to the fresh weight of a single flower, and D represents the diameter of a single flower. The colorimeter values are expressed as C_L (L* for lightness), C_a (a* for the red–green axis), and C_b (b* for the yellow–blue axis). F_D indicates the flowering duration, whereas V_S refers to the vase life. N_F_P represents the number of flowers per plant, F_Y_P indicates the flower yield per plant, and F_Y corresponds to the flower yield per square meter (1 m²).

**Figure 3:** Cluster diagram obtained from all vegetative and reproductive parameters of the fifteen marigold varieties.

by the third and 10.3% by the fourth, based on quantitative data of *Tagetes erecta*. Finally, they have reported that cultivar E4 was more distant from other cultivars, while, E8 and E7 as well as E10 and E11, were close to each other in the dendrogram.

Assessment of consumer preference for marigold varieties

Consumer preference and market demand are important factors to consider when evaluating the Marigold varieties to introduce into to Sri Lankan floriculture industry. Flower color is a critical aesthetic character influencing consumer choice. Friedman test analysis indicated that there was a significant difference ($P < 0.05$) among the varieties for consumer preference based on flower color. Consumers preferred varieties V11, V13, V14, V15, and V2 over other varieties, while V10 was the least preferred variety. When evaluating the second criterion, flower size, the most preferred variety was V13, followed by varieties V11, V14, and V4, while the least preferred variety was V10 ($p < 0.05$). With respect to the flower appearance (third criterion), the varieties V11, V13, V2, V14, V3, and V4 were more preferred by panelists ($p < 0.05$) while the V10 variety was the least preferred. Analysis with respect to the overall acceptance, V11, V2, V13, V14, and V4 were the most favored varieties by panelists ($p < 0.05$), the V10 was the least preferred variety.

CONCLUSION

All vegetative and reproductive parameters, except the number of leaves at 30 DAP and 60 DAP, were significantly different among the varieties ($P < 0.05$). The PCA analysis indicated that all the evaluated characters were important in distinguishing the fifteen marigold varieties, as they contributed to the total variance. The highest-yielding varieties, V2 and V4, were clustered together in the dendrogram. Among the 15 marigold varieties, V4 and V2 recorded the highest flower yields per square

meter (14.26 kg m^{-2} and 13.07 kg m^{-2} , respectively), the highest flower yield per plant, and the greatest number of flowers. These varieties also demonstrated relatively good performance in reproductive parameters (flower weight and flower duration). The V2 had a moderate plant height (approximately 60 cm at 90 DAP), with good branching patterns (13 primary and 5 secondary branches), supporting a high number of flowers per plant. V4, although relatively taller (approximately 75 cm), and showed balanced vegetative vigor. The combination of high yield, favorable reproductive traits, acceptable branching and plant height, along with positive consumer preference, makes both V2 and V4 excellent candidates for commercial cultivation.

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DECLARATION OF CONFLICT OF INTEREST

The authors declare that there is no conflict of interest.

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AUTHOR CONTRIBUTION

All authors have accepted responsibility for the content of the manuscript, reviewed all results, and approved the final version. Conceptualization: J.P.; A.M.A.S.; data collection and analysis, S.S.; data interpretation: S.S., J.P.; writing the first draft: S.S.; Manuscript editing and reviewing: J.P.; A.M.A.S. Project administration: J.P.; A.M.A.S.

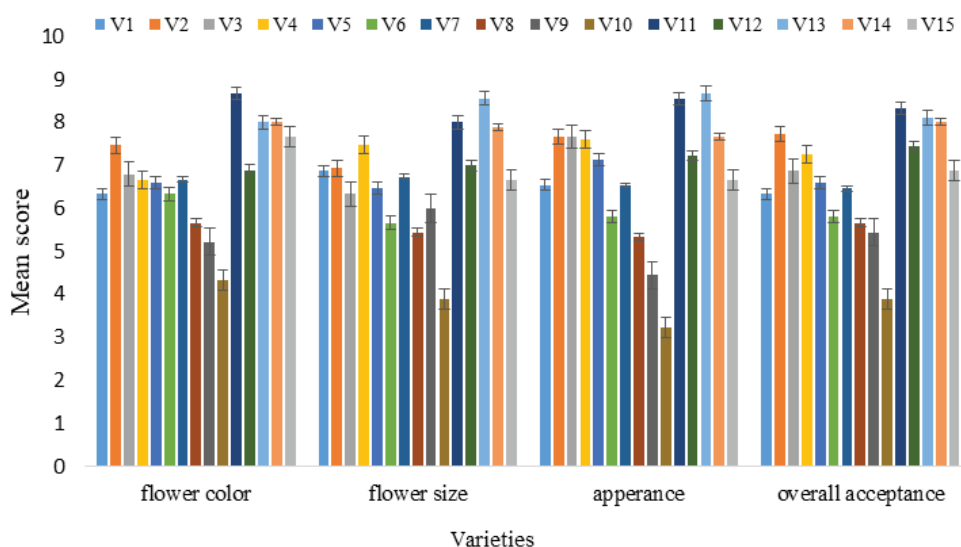


Figure 4: Variation of the mean score of consumer preference of the fifteen marigold varieties

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