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RESEARCH ARTICLE

# Regulation of flowering in marigold (*Tagetes erecta* L.) through staggered planting and growing environment in the mid-hill zone of Himachal Pradesh

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## Abstract

Regulating planting time under a congenial growing environment could improve growth, flowering and yield as well and thus the quality of crop production. A field experiment was carried out to identify appropriate planting time and growing conditions for flower regulation in marigolds (*Tagetes erecta* L.) in factorial randomized block design with 5 different planting dates, under open and naturally ventilated polyhouse conditions in two marigold cultivars (cv (s).), 'Pusa Narangi Gainda' and 'Pusa Basanti Gainda'. It was noted that planting dates, growing environments and varieties had significant effects on growth and flowering parameters. Results showed that the 10$^{th}$ of July planting under naturally ventilated polyhouse condition using marigold cv. 'Pusa Narangi Gainda' exhibited luxuriant vegetative growth, which ultimately resulted in enhanced flower yield per plant (730.43 g) and per square meter (6.89 kg) with a greater benefit-to-cost ratio (2.86) and hence, was found economically best for commercial production of marigold. However, economic flower yield was also obtained under naturally ventilated polyhouse conditions till August planting.

## Keywords

economics; naturally ventilated polyhouse; open field; staggered planting; *Tagetes erecta*

## Introduction

*Tagetes* spp. L., commonly known as marigold and belonging to the Asteraceae family, is a widely cultivated crop in India and valued for its commercial importance in loose flower production. It is indigenous to Central and South America (1). Genus *Tagetes* encompasses approximately 55 species (2), among which *Tagetes erecta* L. and *Tagetes patula* L. are the most important commercially cultivated species. It has gained popularity due to its ease of cultivation, wider adaptability, profuse flowering, short juvenility, extended blooming period, visually appealing hues with varied forms, sizes and durable keeping quality. It is one of the primevally cultivated flowering plants for ornamental purposes in tropical and subtropical regions around the world (3). India's diverse agroclimatic conditions are immensely conducive to the commercial cultivation of marigolds, leading to its widespread cultivation across many states. Among traditional loose flowers grown in India, marigold holds a prominent position in terms of both area and production (4). Marigold is being cultivated in 80980 ha with a production of 941.46 MT (5).

Marigold has huge market demand and is extensively used to make floral garlands, divine offerings and social occasions, for the beautification of landscapes, carpet bedding, potted plants and additionally for making different processed products (6). It is also being explored for the production of natural products and therapeutic components. Marigold is favoured for production of carotenoid pigments, namely lutein, zeaxanthin and xanthophylls, which aid in vision and protect the retina, skin, breast and cervical tissue (7, 8). Lutein is also being used as a food colorant and is also included in poultry feed to achieve desired pigmentation (9–12). *Tagetes* oil is the most unique and exquisite perfume used in cosmetics and as an insect repellent (13). Marigold contains thiophane compounds with medicinal and nematocidal properties, making it an effective trap crop for tomatoes and onions under an integrated pest management system to reduce the menace of fruit borer (14, 15). Its cultivation can increase farmers' income and attract industrial interest for its potential for value addition (16, 17).

Flowering can be influenced by numerous factors that include the inherent characteristics of genotype or the growing environment and cultivation aspects. To regulate flowering, various techniques can be employed *viz.*, genetic, physiological and mechanical approaches. These strategies offer an opportunity to modulate the developmental cycle by inducing or hindering plant growth and its maturation to coordinate flowering with the market demand (18). Diverse growing conditions and geographical location of the area provide distinct environmental attributes for flower cultivation (19). The growing environment for any commercial flower grower is determined by various factors, including temperature and photoperiod. Temperature plays a crucial role in cultivation which increases linearly from its base temperature to the optimum (20). The optimal temperature for marigolds range between 18 °C and 23 °C, with night temperature being 15.5–18 °C and the daytime temperature of 18–22 °C for quality flower production (21). Crops cultivated beneath polyhouses have a positive impact on their vegetative as well as reproductive phases when compared to those grown in open fields (22). Apart from other cultivation prerequisites, planting date is also an essential aspect that determines the flower quality and yield (23).

Marigold (*Tagetes* spp. L.) is cultivated year-round across India, making the availability of quality flowers essential for profitable production (24, 25). This crop is especially lucrative during the October–November festival season when demand peaks. However, there is a significant need for loose flowers from November to February, but low temperatures and frost during winter prevent open-field cultivation in regions like the mid-hill zones of Himachal Pradesh (26). Protected cultivation offers a solution by creating a favourable environment, extending the growing season and supporting consistent crop productivity. While advances in protected cultivation have shown promise, more research and public awareness are needed to optimize its use for sustainable flower production (27).

Given the crop's significance from the farmers' point of view, there is a prime need to identify a convenient planting time and appropriate growing environment for commercial cultivation for loose flower production during the winter season. This study intends to examine the impact of different planting dates and growing environments on growth as well as the flowering of the 'Pusa Narangi Gainda' and 'Pusa Basanti Gainda' cultivars of marigold.

## Materials and Methods

### *Experimental location*

The study was carried out from June 2020 to February 2021 at the Experimental Farm of the Department of Floriculture and Landscape Architecture, Dr. Yashwant Singh Parmar University of Horticulture and Forestry, Nauni, Solan, Himachal Pradesh, at a 30°52'02" N latitude and 77°11'30" E longitude and at an elevation of 1276 m above mean sea level. The region falls under the mid-hill zone of Himachal Pradesh with a sub-temperate to sub-tropical climate and is characterized by warm summers and moderate winters.

### *Planting material*

Seeds of commercially grown marigold cultivars of Himachal Pradesh, namely 'Pusa Narangi Gainda' and 'Pusa Basanti Gainda', were procured from the Indian Agricultural Research Institute, New Delhi and seedlings were raised in the nursery.

### *Experimental procedure*

The experiment was conducted in a factorial randomized block design with three replications, using 2 marigold cultivars, 'Pusa Narangi Gainda' ($V_1$) and 'Pusa Basanti Gainda' ($V_2$). Healthy, uniform seedlings (4–6 leaf stage) were transplanted at 30 cm × 30 cm spacing on 5 planting dates: 10$^{th}$ of July ($D_1$), 25$^{th}$ of July ($D_2$), 10$^{th}$ of August ($D_3$), 25$^{th}$ of August ($D_4$) and 10$^{th}$ of September ($D_5$), under 2 conditions: open field ($E_1$) and naturally ventilated polyhouse ($E_2$). Growth and flowering of marigolds are substantially influenced by temperature, which is over 4 °C more acute in naturally ventilated polyhouse than open field conditions (Fig. 1). Standard crop management practices, including irrigation, weeding, pinching, staking and crop protection, were applied throughout the course of the experiment.

Data were collected on growth, flowering and yield parameters like plant height (cm), spread (cm), number of primary and secondary branches, days to flower bud formation and flowering, flowering duration (days), flower size (cm), number of marketable flowers per plant and per square meter and yield per plant and per square meter (g). The economics of marigold cultivation were also evaluated for a 200 m$^2$ area.

## Statistical analysis

Data of various parameters were analysed through the analysis of variance (ANOVA) technique utilizing the F-test

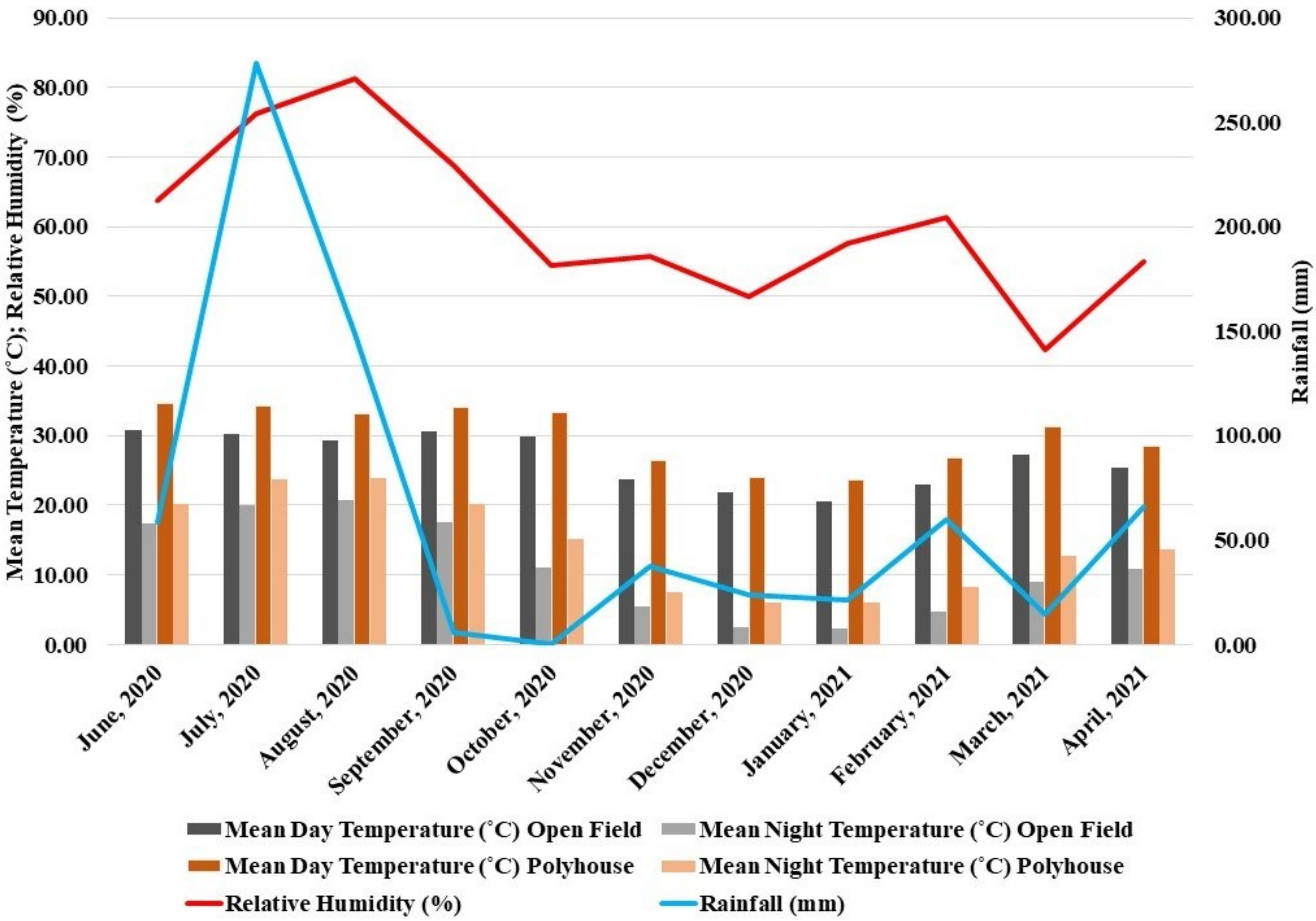


**Fig. 1.** Meteorological data during the crop period (June 2020–April 2021).

for factorial randomized block design in the program OPSTAT (28, 29). Comparisons of means have been performed because of critical differences (CD) at 5% levels of significance. The regression analysis was computed between various parameters and yield using Microsoft Excel software (30).

## Results

### *Effect of staggered planting and growing environment on growth parameters*

During the investigation period, data on various growth attributes of marigolds, namely, plant height (cm), spread (cm), number of primary branches and number of secondary branches per plant were documented. From the data, it is evident that there was a significant effect of staggered planting on the growth of marigold cultivars, 'Pusa Narangi Gainda' and 'Pusa Basanti Gainda', under open and naturally ventilated polyhouse conditions (Table 1). July planting favoured the maximum vegetative growth. The 10$^{th}$ of July planting resulted in the most vigorous vegetative growth, with the highest plant height (159.65 cm), plant spread (61.70 cm), several primary branches (4.71) and secondary branches per plant (55.04).

There was a significant increase in plant growth of marigolds in terms of plant height (116.71 cm), plant spread (55.34 cm), number of primary branches (3.94) and secondary branches per plant (45.15) was observed under naturally ventilated polyhouse condition as compared to open condition. Between cultivars, more plant height (107.01 cm), number of primary branches (3.89) and secondary branches (42.90) were recorded in 'Pusa Narangi Gainda' in comparison to 'Pusa Basanti Gainda', but more plant spread was observed from 'Pusa Basanti Gainda' (51.39 cm) than Pusa Narangi Gainda' (48.44 cm) (Fig. 2 & 3).

### *Effect of staggered planting and growing environment on flowering parameters*

The flowering attributes of marigold cvs., 'Pusa Narangi Gainda' and 'Pusa Basanti Gainda', showed a significant difference concerning different planting dates and growing environments (Table 1). The earliest planting (10$^{th}$ of July) took the maximum time for bud formation (55.61 days) whereas the earliest flower bud formation was noted in the crop planted on 25$^{th}$ of August (39.85 days). As regards flowering, the earliest flowering was noted in the crop planted on the 25$^{th}$ of July (68.90 days), followed by the 10$^{th}$ of August planting, which took 69.85 days. Whereas the 25$^{th}$ of August planting took the maximum time (76.38 days). A delay in flowering was noted with further extending the date of planting to the 25$^{th}$ of August (76.38 days) and the 10$^{th}$ of September (74.50 days).

Crop grown under open conditions produced early buds (43.48 days) and consequently they flowered earlier (65.44 days) as compared to polyhouse conditions. Further, early bud formation was observed in 'Pusa Basanti Gainda' (46.47 days) which also produced early flowering (69.85 days) in comparison to 'Pusa Narangi Gainda'. The

**Table 1.** Effect of planting dates, growing environment and cultivars on growth, flowering and yield parameters

| Particulars | Growth parameters | | | | Flowering parameters | | | | Yield parameters | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Plant height (cm) | Plant spread (cm) | Number of primary branches per plant | Number of secondary branches per plant | Days taken for flower bud formation (days) | Days taken to flowering (days) | Duration of flowering (days) | Size of flower (cm) | Number of marketable flowers per plant | Number of marketable flowers per square meter | Marketable flower yield per plant (g) | Marketable flower yield per square meter (kg) |
| **$D_1$** | 159.65 | 61.70 | 4.71 | 55.04 | 55.61 | 74.79 | 107.89 | 7.01 | 100.27 | 943.75 | 537.36 | 5.30 |
| **$D_2$** | 137.45 | 58.54 | 4.14 | 46.01 | 48.81 | 68.90 | 101.36 | 6.78 | 69.78 | 695.08 | 422.86 | 4.47 |
| **$D_3$** | 101.66 | 50.43 | 3.65 | 42.08 | 43.15 | 69.85 | 91.40 | 6.33 | 54.40 | 465.50 | 309.90 | 3.08 |
| **$D_4$** | 67.96 | 39.68 | 3.19 | 25.71 | 39.85 | 76.38 | 82.27 | 5.92 | 27.22 | 272.00 | 155.90 | 1.71 |
| **$D_5$** | 57.08 | 39.22 | 3.28 | 23.17 | 47.33 | 74.50 | 77.04 | 5.46 | 20.00 | 201.50 | 101.10 | 1.18 |
| **Mean** | **104.76** | **49.91** | **3.79** | **38.40** | **46.95** | **72.88** | **91.99** | **6.30** | **54.33** | **515.57** | **305.43** | **3.15** |
| **SE(m) ±** | **2.41** | **1.01** | **0.08** | **1.07** | **0.29** | **0.26** | **0.22** | **0.02** | **1.72** | **13.67** | **11.83** | **0.11** |
| **$CD_{(0.05)}$** | **6.89** | **2.88** | **0.24** | **3.06** | **0.82** | **0.75** | **0.62** | **0.07** | **4.92** | **39.16** | **33.88** | **0.31** |
| **$E_1$** | 92.81 | 44.50 | 3.65 | 31.66 | 43.48 | 65.44 | 79.04 | 5.86 | 41.16 | 392.17 | 210.97 | 2.19 |
| **$E_2$** | 116.71 | 55.34 | 3.94 | 45.15 | 50.42 | 80.33 | 104.94 | 6.73 | 67.51 | 638.97 | 399.88 | 4.11 |
| **Mean** | **104.76** | **49.91** | **3.79** | **38.40** | **46.95** | **72.88** | **91.99** | **6.30** | **54.33** | **515.57** | **305.43** | **3.15** |
| **SE(m) ±** | **1.52** | **0.64** | **0.05** | **0.68** | **0.18** | **0.16** | **0.14** | **0.02** | **1.09** | **8.65** | **7.48** | **0.07** |
| **$CD_{(0.05)}$** | **4.36** | **1.82** | **0.15** | **1.93** | **0.52** | **0.47** | **0.39** | **0.04** | **3.11** | **24.77** | **21.42** | **0.20** |
| **$V_1$** | 107.01 | 48.44 | 3.89 | 42.90 | 47.43 | 75.92 | 93.83 | 6.59 | 52.46 | 501.37 | 324.97 | 3.31 |
| **$V_2$** | 102.52 | 51.39 | 3.70 | 33.91 | 46.47 | 69.85 | 90.15 | 6.01 | 56.21 | 529.77 | 285.88 | 2.99 |
| **Mean** | **104.76** | **49.91** | **3.79** | **38.40** | **46.95** | **72.88** | **91.99** | **6.30** | **54.33** | **515.57** | **305.43** | **3.15** |
| **SE(m) ±** | **1.52** | **0.64** | **0.05** | **0.68** | **0.18** | **0.16** | **0.14** | **0.02** | **1.09** | **8.65** | **7.48** | **0.07** |
| **$CD_{(0.05)}$** | **4.36** | **1.82** | **0.15** | **1.93** | **0.52** | **0.47** | **0.39** | **0.04** | **3.11** | **24.77** | **21.42** | **0.20** |

$D_1$-10th of July, $D_2$-25th of July, $D_3$-10th of August, $D_4$-25th of August, $D_5$-10th of September
$E_1$-Open condition, $E_2$-Naturally ventilated polyhouse condition
$V_1$-Pusa Narangi Gainda, $V_2$-Pusa Basanti Gainda

longest flowering duration (107.89 days) with maximum flower size (7.01 cm) was observed when the marigold was planted on the 10th of July. Crop grown under naturally ventilated polyhouse condition rendered large flowers (6.73 cm) with extended duration (104.9 days) as compared to open condition. In addition, the crop of cv. 'Pusa Narangi Gainda' flowered for longer duration (93.83 days) with larger flower size (6.59 cm) in comparison to cv. 'Pusa Basanti Gainda' (90.15 days) (Fig. 2 & 3).

### *Effect of staggered planting and growing environment on yield parameters*

The highest number of marketable flowers per plant (100.27) and per square meter (943.75) was recorded with planting on the 10th of July (Table 1). In the case of the growing environment, more marketable flowers per plant (67.51) and per square meter (638.97) were recorded from the crop grown under naturally ventilated polyhouse conditions than in open field. Marigold cv. 'Pusa Basanti Gainda' produced a greater number of marketable flowers per plant (56.21) and per square meter (529.77) as compared to cv. 'Pusa Narangi Gainda'.

The highest marketable flower yield per plant (537.36 g) and per square meter (5.30 kg) was observed on the 10th of July planted crop, whereas the 10th of September planting had the lowest yield (Table 1). The crop grown under naturally ventilated polyhouse conditions produced maximum yield per plant (399.88 g) and per square meter (4.11 kg) compared to open conditions. 'Pusa Narangi Gainda' imparted more flower yield per plant (324.97 g) and per square meter (3.31 kg) 'Pusa Basanti Gainda' (Fig. 2 & 3).

### *Interaction effect of staggered planting and growing environment on growth, flowering and yield parameters*

The interaction effect between planting date and marigold cultivar (D×V), planting date and growing environment (D×E) and growing environment and marigold cultivar (E×V) exhibited significant differences for all the parameters (Table 2). Significant differences were also recorded due to interaction between planting dates, growing environment and cultivars for growth, flowering and yield parameters (Table 3). Plant height (168.31 cm) and number of secondary branches (66.39) were


**Fig. 2.** Superior performance of marigold cv. 'Pusa Narangi Gainda' was planted on the 10th of July, 25th of July and 10th of August at peak flowering. (Left Column: Open Field; Right Column: Naturally Ventilated Polyhouse Conditions).

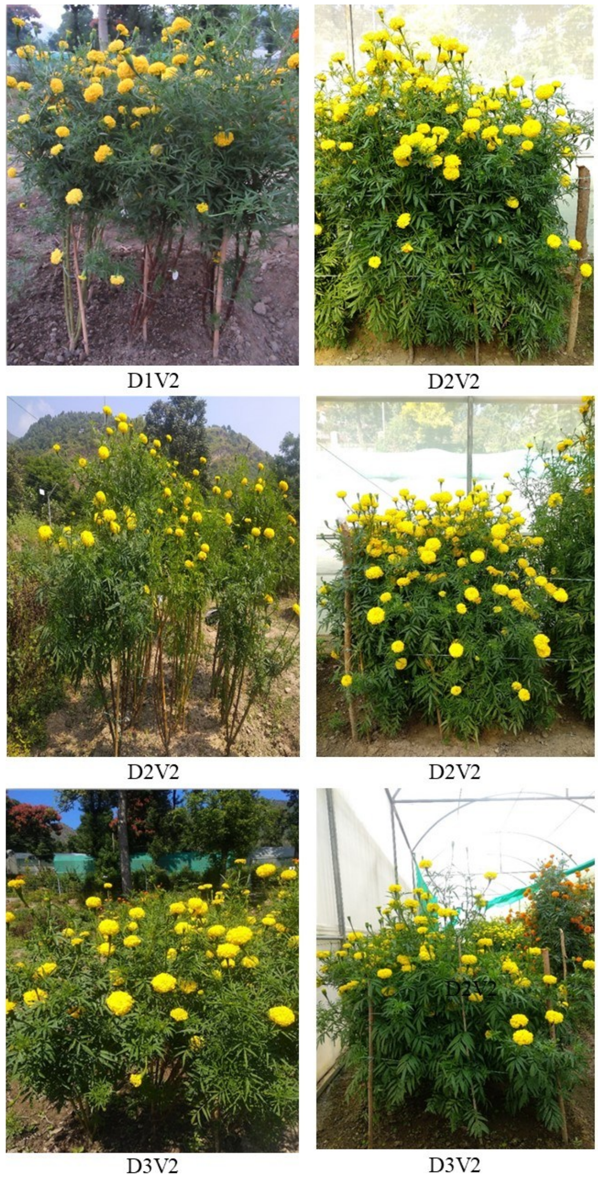


**Fig. 3.** Superior performance of marigold cv. 'Pusa Basanti Gainda' was planted on the 10th of July, 25th of July and 10th of August at peak flowering. (Left Column: Open Field; Right Column: Naturally Ventilated Polyhouse Conditions).

significantly higher when marigold cv. 'Pusa Narangi Gainda' was planted on the 10th of July under naturally ventilated polyhouse condition. Similarly, duration of flowering (123.67 days), flower size (7.66 cm), number of marketable flowers per plant (117.78) and per square meter (1074.00) and marketable flower yield per plant (730.43 g) and per square meter (3.31 kg) were maximum on 10th of July planted a crop of cv. 'Pusa Narangi Gainda' under naturally ventilated polyhouse condition (Fig. 2 & 3).

### Economics of marigold cultivation for flower production under open and naturally ventilated polyhouse conditions for an area of 200 m2

Data depicted in Table 4 illustrate that the marigold cv. 'Pusa Narangi Gainda' planted on the 10th of July under naturally ventilated polyhouse condition gained net returns of Rs. 50248.97 per 200 $m^2$ with a benefit-to-cost ratio of 2.86, followed by 'Pusa Basanti Gainda' planted on the 10th of July under polyhouse condition that gave a benefit-to-cost ratio of 2.43 with net returns of Rs. 42035.66 per 200 $m^2$. However, economic flower yield was also obtained by extending the planting time up to August 25th under open field conditions, whereas it can be extended up to the 10th of September under polyhouse conditions with both the cultivars of marigold.

### Regression analysis of growth and flowering attributes with yield of marigold cultivars as influenced by staggered planting and growing environments

The regression analysis computed for growth and flowering attributes with yield revealed a strong to weak correlation (Fig. 4). The regression analysis related to the flowering attribute, duration of flowering along with growth attributes, namely, plant height, number of secondary branches and plant spread implying a substantially stronger correlation with marketable flower yield per plant with an $R^2$ value of 0.867, 0.848, 0.805 and 0.780, respectively. In contrast, the days taken for flower bud formation and days taken to flowering were found to have a weak correlation with marketable flower yield per plant by obtaining the $R^2$ values of 0.368 and 0.069 respectively.

**Table 2.** Interaction effect of planting dates and growing environment (D×E), planting dates and marigold cultivars (D×V) and growing environment and marigold cultivars (E×V) on growth, flowering and yield parameters

| Particulars | Growth parameters | | | | Flowering parameters | | | | Yield parameters | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Plant height (cm) | Plant spread (cm) | Number of primary branches per plant | Number of secondary branches per plant | Days taken for flower bud formation (days) | Days taken to flowering (days) | Duration of flowering (days) | Size of flower (cm) | Number of marketable flowers per plant | Number of marketable flowers per square meter | Marketable flower yield per plant (g) | Marketable flower yield per square meter (kg) |
| $D_1E_1$ | 153.24 | 57.89 | 4.81 | 47.56 | 52.28 | 69.67 | 95.42 | 6.66 | 93.53 | 839.33 | 447.50 | 4.21 |
| $D_1E_2$ | 166.07 | 65.50 | 4.61 | 62.53 | 58.94 | 79.92 | 120.36 | 7.36 | 107.00 | 1048.17 | 627.23 | 6.40 |
| $D_2E_1$ | 128.30 | 55.07 | 4.28 | 42.44 | 47.31 | 61.22 | 86.86 | 6.50 | 47.25 | 497.67 | 271.31 | 2.98 |
| $D_2E_2$ | 146.61 | 62.01 | 4.00 | 49.58 | 50.31 | 76.59 | 115.86 | 7.06 | 92.31 | 892.50 | 574.41 | 5.96 |
| $D_3E_1$ | 87.68 | 44.00 | 3.47 | 35.11 | 41.72 | 65.83 | 75.11 | 5.83 | 37.36 | 305.33 | 181.79 | 1.80 |
| $D_3E_2$ | 115.64 | 56.87 | 3.83 | 49.06 | 44.58 | 73.86 | 107.69 | 6.83 | 71.45 | 625.67 | 438.01 | 4.37 |
| $D_4E_1$ | 52.72 | 34.57 | 2.89 | 18.42 | 38.95 | 61.86 | 71.14 | 5.29 | 16.86 | 208.17 | 101.40 | 1.36 |
| $D_4E_2$ | 83.19 | 44.80 | 3.50 | 33.00 | 40.75 | 90.89 | 93.39 | 6.55 | 37.58 | 335.83 | 210.41 | 2.07 |
| $D_5E_1$ | 42.09 | 30.95 | 2.81 | 14.75 | 37.14 | 68.61 | 66.67 | 5.04 | 10.81 | 110.33 | 52.85 | 0.61 |
| $D_5E_2$ | 72.07 | 47.50 | 3.75 | 31.59 | 57.53 | 80.39 | 87.42 | 5.88 | 29.20 | 292.67 | 149.36 | 1.75 |
| **Mean** | **104.76** | **49.91** | **3.79** | **38.40** | **46.95** | **72.88** | **91.99** | **6.30** | **54.33** | **515.57** | **305.43** | **3.15** |
| **SE(m) ±** | **3.40** | **1.42** | **0.19** | **1.51** | **0.40** | **0.37** | **0.31** | **0.03** | **2.43** | **19.34** | **16.73** | **0.15** |
| **CD $_{(0.05)}$** | **9.74** | **4.07** | **0.34** | **4.32** | **1.16** | **1.06** | **0.87** | **0.10** | **6.96** | **55.38** | **47.91** | **0.44** |
| $D_1V_1$ | 161.90 | 62.60 | 5.06 | 61.06 | 58.83 | 78.78 | 110.36 | 7.21 | 99.89 | 902.33 | 583.50 | 5.55 |
| $D_1V_2$ | 157.41 | 60.79 | 4.36 | 49.03 | 52.39 | 70.81 | 105.42 | 6.81 | 100.64 | 985.17 | 491.23 | 5.05 |
| $D_2V_1$ | 145.67 | 59.79 | 4.13 | 54.83 | 50.81 | 71.00 | 102.78 | 6.96 | 72.00 | 707.67 | 467.59 | 4.75 |
| $D_2V_2$ | 129.23 | 57.29 | 4.14 | 37.19 | 46.81 | 66.81 | 99.94 | 6.60 | 67.56 | 682.50 | 378.13 | 4.19 |
| $D_3V_1$ | 106.19 | 48.68 | 3.75 | 48.53 | 43.50 | 72.28 | 94.11 | 6.68 | 48.97 | 459.83 | 328.44 | 3.37 |
| $D_3V_2$ | 97.13 | 52.18 | 3.56 | 35.64 | 42.81 | 67.42 | 88.70 | 5.98 | 59.83 | 471.17 | 291.36 | 2.80 |
| $D_4V_1$ | 62.55 | 34.02 | 3.08 | 25.17 | 39.78 | 79.50 | 83.92 | 6.32 | 20.95 | 220.50 | 138.59 | 1.55 |
| $D_4V_2$ | 73.36 | 45.34 | 3.31 | 26.25 | 39.92 | 73.25 | 80.61 | 5.51 | 33.50 | 323.50 | 173.22 | 1.87 |
| $D_5V_1$ | 58.72 | 37.12 | 3.42 | 24.89 | 44.25 | 78.03 | 78.00 | 5.76 | 20.47 | 216.50 | 106.73 | 1.31 |
| $D_5V_2$ | 55.44 | 41.33 | 3.14 | 21.45 | 50.42 | 70.97 | 76.08 | 5.16 | 19.53 | 186.50 | 95.47 | 1.05 |
| **Mean** | **104.76** | **49.91** | **3.79** | **38.40** | **46.95** | **72.88** | **91.99** | **6.30** | **54.33** | **515.57** | **305.43** | **3.15** |
| **SE(m) ±** | **3.40** | **1.42** | **0.19** | **1.51** | **0.40** | **0.37** | **0.31** | **0.03** | **2.43** | **19.34** | **16.73** | **0.15** |
| **CD $_{(0.05)}$** | **9.74** | **4.07** | **0.34** | **4.32** | **1.16** | **1.06** | **0.87** | **0.10** | **6.96** | **55.38** | **47.91** | **0.44** |
| $E_1V_1$ | 97.88 | 44.19 | 3.82 | 35.13 | 44.26 | 69.19 | 79.91 | 6.17 | 37.59 | 364.27 | 212.83 | 2.23 |
| $E_1V_2$ | 87.73 | 44.80 | 3.48 | 28.18 | 42.70 | 61.69 | 78.17 | 5.56 | 44.73 | 420.07 | 209.10 | 2.15 |
| $E_2V_1$ | 116.13 | 52.70 | 3.96 | 50.66 | 50.61 | 82.64 | 107.76 | 7.00 | 67.32 | 638.47 | 437.11 | 4.38 |
| $E_2V_2$ | 117.30 | 57.97 | 3.92 | 39.64 | 50.23 | 78.01 | 102.13 | 6.47 | 67.69 | 639.47 | 362.66 | 3.83 |
| **Mean** | **104.76** | **49.91** | **3.79** | **38.40** | **46.95** | **72.88** | **91.99** | **6.30** | **54.33** | **515.57** | **305.43** | **3.15** |
| **SE(m) ±** | **2.15** | **0.90** | **0.07** | **0.95** | **0.26** | **0.23** | **0.31** | **0.02** | **1.54** | **12.23** | **10.58** | **0.10** |
| **CD $_{(0.05)}$** | **6.16** | **2.58** | **0.21** | **2.73** | **0.73** | **0.67** | **0.87** | **0.06** | **4.40** | **35.02** | **30.30** | **0.28** |

$D_1$-10$^{th}$ of July, $D_2$-25$^{th}$ of July, $D_3$-10$^{th}$ of August, $D_4$-25$^{th}$ of August, $D_5$-10$^{th}$ of September
$E_1$-Open condition, $E_2$-Naturally ventilated polyhouse condition
$V_1$-Pusa Narangi Gainda, $V_2$-Pusa Basanti Gainda

## Discussion

The present study indicates that regulation of planting time and growing environment significantly influenced the vegetative, floral and yield attributes that affect decisive economic returns. Results demonstrate that among the different planting dates, the 10$^{th}$ July planting showed superior performance over others. Additionally, amidst growing environments, naturally ventilated polyhouse

**Table 3.** Interaction effect of planting dates, growing environment and cultivars on growth, flowering and yield parameters

| | Growth parameters | | | | Flowering parameters | | | | Yield parameters | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Particulars** | **Plant height (cm)** | **Plant spread (cm)** | **Number of primary branches per plant** | **Number of secondary branches per plant** | **Days taken for flower bud formation (days)** | **Days taken to flowering (days)** | **Duration of flowering (days)** | **Size of flower (cm)** | **Number of marketable flowers per plant** | **Number of marketable flowers per square meter** | **Marketable flower yield per plant (g)** | **Marketable flower yield per square meter (kg)** |
| **$D_1E_1V_1$** | 155.48 | 60.12 | 5.22 | 55.72 | 56.61 | 76.17 | 97.05 | 6.76 | 82.00 | 730.67 | 436.57 | 4.21 |
| **$D_1E_1V_2$** | 150.99 | 55.66 | 4.39 | 39.39 | 47.94 | 63.16 | 93.78 | 6.56 | 105.06 | 948.00 | 458.43 | 4.20 |
| **$D_1E_2V_1$** | 168.31 | 65.08 | 4.89 | 66.39 | 61.05 | 81.39 | 123.67 | 7.66 | 117.78 | 1074.00 | 730.43 | 6.89 |
| **$D_1E_2V_2$** | 163.82 | 65.92 | 4.34 | 58.66 | 56.83 | 78.45 | 117.05 | 7.05 | 96.22 | 1022.33 | 524.03 | 5.90 |
| **$D_2E_1V_1$** | 137.38 | 56.75 | 4.55 | 48.44 | 48.56 | 63.89 | 85.45 | 6.57 | 52.72 | 560.33 | 305.92 | 3.04 |
| **$D_2E_1V_2$** | 119.21 | 53.38 | 4.00 | 36.44 | 46.06 | 58.55 | 88.28 | 6.44 | 41.78 | 435.00 | 236.69 | 2.92 |
| **$D_2E_2V_1$** | 153.96 | 62.82 | 3.72 | 61.22 | 53.06 | 78.11 | 120.11 | 7.35 | 91.28 | 855.00 | 629.25 | 6.46 |
| **$D_2E_2V_2$** | 139.26 | 61.20 | 4.28 | 37.94 | 47.55 | 75.06 | 111.61 | 6.76 | 93.33 | 930.00 | 519.56 | 5.45 |
| **$D_3E_1V_1$** | 92.90 | 40.13 | 3.22 | 35.83 | 41.16 | 68.56 | 75.94 | 6.20 | 27.89 | 274.67 | 164.19 | 1.87 |
| **$D_3E_1V_2$** | 82.46 | 47.87 | 3.72 | 34.39 | 42.28 | 63.11 | 74.28 | 5.45 | 46.83 | 336.00 | 199.39 | 1.73 |
| **$D_3E_2V_1$** | 119.47 | 57.24 | 4.28 | 61.22 | 45.83 | 76.00 | 112.28 | 7.16 | 70.06 | 645.00 | 492.69 | 4.86 |
| **$D_3E_2V_2$** | 111.80 | 56.49 | 3.39 | 36.89 | 43.33 | 71.72 | 103.11 | 6.50 | 72.83 | 606.33 | 383.34 | 3.87 |
| **$D_4E_1V_1$** | 57.19 | 33.91 | 3.11 | 20.22 | 38.11 | 64.56 | 74.11 | 5.77 | 16.84 | 177.00 | 104.50 | 1.37 |
| **$D_4E_1V_2$** | 48.25 | 35.23 | 2.67 | 16.61 | 39.78 | 59.17 | 68.11 | 4.80 | 16.89 | 239.33 | 98.29 | 1.35 |
| **$D_4E_2V_1$** | 67.91 | 34.14 | 3.05 | 30.11 | 41.44 | 94.44 | 93.67 | 6.87 | 25.05 | 264.00 | 172.67 | 1.73 |
| **$D_4E_2V_2$** | 98.47 | 55.46 | 3.95 | 35.89 | 40.06 | 87.33 | 93.11 | 6.22 | 50.11 | 407.67 | 248.14 | 2.40 |
| **$D_5E_1V_1$** | 46.45 | 30.02 | 3.00 | 15.45 | 36.83 | 72.78 | 66.94 | 5.56 | 8.50 | 78.67 | 52.97 | 0.66 |
| **$D_5E_1V_2$** | 37.74 | 31.87 | 2.61 | 14.06 | 37.44 | 64.44 | 66.39 | 4.52 | 13.11 | 142.00 | 52.72 | 0.56 |
| **$D_5E_2V_1$** | 70.99 | 44.22 | 3.83 | 34.34 | 51.67 | 83.28 | 89.06 | 5.95 | 32.45 | 354.33 | 160.50 | 1.96 |
| **$D_5E_2V_2$** | 73.15 | 50.78 | 3.67 | 28.84 | 63.39 | 77.50 | 85.78 | 5.80 | 25.95 | 231.00 | 138.22 | 1.53 |
| **Mean** | **104.76** | **49.91** | **3.79** | **38.40** | **46.95** | **72.88** | **91.99** | **6.30** | **54.33** | **515.57** | **305.43** | **3.15** |
| **SE(m) ±** | **4.81** | **2.01** | **0.17** | **2.13** | **0.57** | **0.52** | **0.43** | **0.05** | **3.44** | **27.35** | **23.66** | **0.22** |
| **CD $_{(0.05)}$** | **13.77** | **5.76** | **0.45** | **6.11** | **1.64** | **1.49** | **1.24** | **0.14** | **9.84** | **78.32** | **67.53** | **0.62** |

$D_1$-10$^{th}$ of July, $D_2$-25$^{th}$ of July, $D_3$-10$^{th}$ of August, $D_4$-25$^{th}$ of August, $D_5$-10$^{th}$ of September
$E_1$-Open condition, $E_2$-Naturally ventilated polyhouse condition
$V_1$-Pusa Narangi Gainda, $V_2$-Pusa Basanti Gainda

**Table 4.** Effect of staggered planting on the economics of marigold cultivation for flower production under open and naturally ventilated polyhouse conditions for an area of 200 $m^2$

| Treatments | Total cost of cultivation/200 $m^2$ (Rs) | Net flower yield per 200 $m^2$ (kg) | Gross returns/200 $m^2$ (Rs) | Net return/200 $m^2$ (Rs) | B:C ratio |
|---|---|---|---|---|---|
| **$D_1E_1V_1$** | 10,604.81 | **599.46** | 35,967.60 | 25,362.79 | 2.39 |
| **$D_1E_1V_2$** | 10,525.99 | 598.96 | 35,937.60 | 25,411.61 | 2.41 |
| **$D_1E_2V_1$** | 8,656.63 | 981.76 | 58,905.60 | 50,248.97 | 2.86 |
| **$D_1E_2V_2$** | 8,420.14 | 840.93 | 50,455.80 | 42,035.66 | 2.43 |
| **$D_2E_1V_1$** | 10,208.42 | 432.44 | 25,946.40 | 15,737.98 | 1.54 |
| **$D_2E_1V_2$** | 10,129.53 | 416.01 | 24,960.60 | 14,831.07 | 1.46 |
| **$D_2E_2V_1$** | 8,378.48 | 920.96 | 55,257.60 | 46,879.12 | 2.71 |
| **$D_2E_2V_2$** | 7,882.23 | 776.83 | 46,609.80 | 38,727.57 | 2.31 |
| **$D_3E_1V_1$** | 9,469.70 | 266.17 | 13,308.50 | 3,838.80 | 0.41 |
| **$D_3E_1V_2$** | 9,469.70 | 245.96 | 12,298.00 | 2,828.30 | 0.30 |
| **$D_3E_2V_1$** | 7,977.59 | 693.33 | 34,666.50 | 26,688.91 | 1.58 |
| **$D_3E_2V_2$** | 7,169.03 | 551.16 | 27,558.00 | 19,738.07 | 1.18 |
| **$D_4E_1V_1$** | 7,011.37 | 246.88 | 12,344.00 | 5,332.63 | 0.34 |
| **$D_4E_1V_2$** | 8,937.04 | 192.21 | 9,610.50 | 673.46 | 0.08 |
| **$D_4E_2V_1$** | 7,011.37 | 246.88 | 12,344.00 | 5,332.63 | 0.34 |
| **$D_4E_2V_2$** | 6,807.56 | 342.13 | 17,106.50 | 9,937.47 | 0.62 |
| **$D_5E_1V_1$** | 8,772.64 | 94.89 | 3,895.60 | -4,977.20 | -0.57 |
| **$D_5E_1V_2$** | 8,733.22 | 80.56 | 3,222.40 | -5,510.82 | -0.63 |
| **$D_5E_2V_1$** | 6,846.97 | 237.03 | 9,481.20 | 2,634.05 | 0.18 |
| **$D_5E_2V_2$** | 6,610.48 | 218.06 | 8,722.40 | 1,914.84 | 0.13 |

$D_1$-10$^{th}$ of July, $D_2$-25$^{th}$ of July, $D_3$-10$^{th}$ of August, $D_4$-25$^{th}$ of August, $D_5$-10$^{th}$ of September
$E_1$-Open condition, $E_2$-Naturally ventilated polyhouse condition
$V_1$-Pusa Narangi Gainda, $V_2$-Pusa Basanti Gainda
B:C ratio- Benefit:Cost Ratio

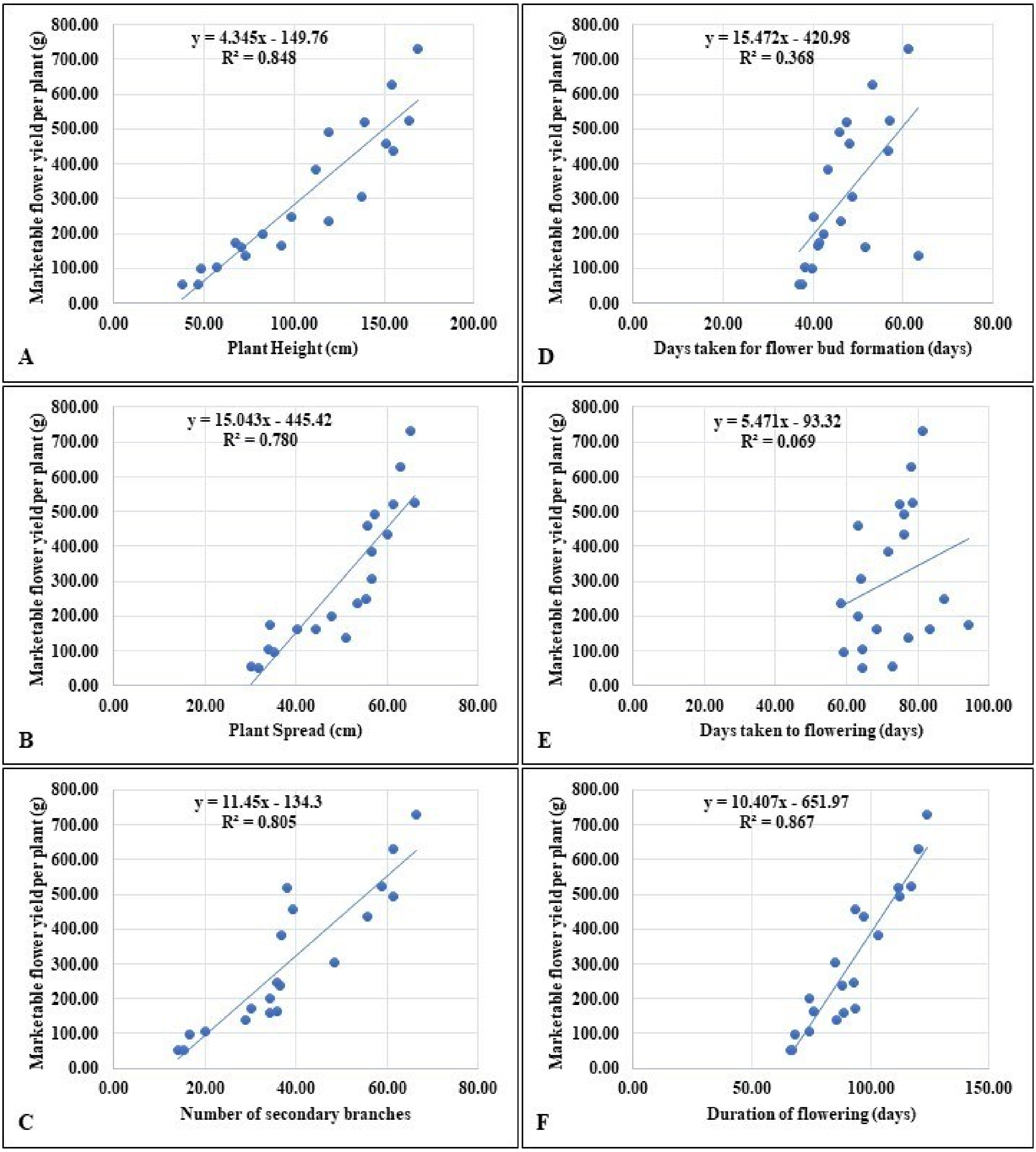


**Fig. 4.** Regression analysis of growth and flowering attributes with yield of marigold cultivars as influenced by staggered planting and growing environments.

conditions induced exceptional results. Further, among marigold cultivars, 'Pusa Narangi Gainda' stood out as the most superior.

From the outcome of the experiment, it was observed that planting marigolds on 10th July resulted in remarkable plant growth, flowering and yield outcomes. It could be attributed to the fact that these plants may have been exposed to the prevailing congenial environmental conditions for appropriate growth. Rapid meristematic activity, most likely owing to rapid cell division and elongation during the tender development stage, might explain the increased plant height, wider plant spread and profuse branching in African marigolds (31). However, the meteorological data (Fig. 1) shows that planting done in September and onwards was exposed to decreased night temperatures during the rapid period of growth, resulting in reduced plant metabolism, similarly reported in *Arabidopsis* (32). Hence, a significant reduction in different vegetative parameters was noticed when planting dates were extended till September. The varietal intrinsic genetic composition and rates of growth and development across marigold cultivars may also explain the variance in the expression of morphological traits (33). Additionally, maintenance of ideal temperature and optimum intensity of photosynthetic light might be the principal factors for elevated plant growth within the naturally ventilated polyhouse condition (34). These findings align with previous studies indicating that a comparatively profuse plant growth was obtained from early planting of marigold (35–39).

With reference to the flowering parameter data, it is evident that the 10th of July planted crop took the maximum number of days to develop buds and flowers. It could be acknowledged that early planting had ample time to build up vegetative growth due to congenial environmental conditions and therefore, it took comparatively more time for bud formation and flowering. On the other hand, later plantings (25th of July and 10th of August) were exposed to shorter day conditions accompanied by lower night temperatures, which imposed them to stress conditions triggering early bud formation followed by the earliest flowering. A delay in flowering was noticed in further extending the date of planting to the 25th of August and 10th of September due to unfavourable temperatures, particularly during night, which hindered bud development. Furthermore, flowering duration is a very important parameter since it signifies the duration of availability of flowers in the market. These variations have an economic benefit in terms of selecting cultivars and planting dates that offer consistent yield of flowers for an extended duration of time, ensuring profitable returns. Flower size is the criterion that shall define the quality and suitability of variety as loose flowers. The variation in the size of the flower is mostly linked to the genetic composition of the specific variety, as well as optimal foliage growth and crop health management. In this study, the July planting of the crop has resulted in larger blooms with extended flowering duration in comparison to late plantings. Likewise, crops grown under polyhouse conditions had a prolonged flowering period with increased flower size, which could be attributed to prevailing congenial environmental conditions during the cropping period, leading to the translocation of a greater amount of photosynthates to the flower, resulting in larger flowers. These results are in concurrence with previous studies (40–44).

The superlative yield performance from the 10th of July planting could be associated with the presence of favourable environmental conditions inducing luxuriant vegetative growth that might have hastened the process of photosynthesis, the synthesis of carbohydrates and the accumulation of food in vegetative parts causing a rapid transition to reproductive structures and amplified number of marketable flowers. In conformity with previous findings, the total cumulative impact of ambient conditions has led to a quantitative increase in yield attributes (40–46). In addition, this paramount yield performance has ultimately fetched higher market value, resulting in the highest gross as well as net returns. Thus, it culminated in the highest benefit-to-cost ratio. The regression analysis convincingly illustrated the significance and influence of the duration of flowering and growth attributes of marigolds to obtain the yield of marigolds (47, 48).

## Conclusion

This study successfully demonstrated that the regulation of planting dates and growing environments significantly influences the growth, flowering and yield of marigold (*T. erecta*) cultivars, specifically ‘Pusa Narangi Gainda’ and ‘Pusa Basanti Gainda’. Planting marigolds on July 10th in naturally ventilated polyhouse conditions in the mid-hill zone of Himachal Pradesh promoted superior vegetative growth, extended flowering and a high yield of 730.43 g per plant (6.89 kg/m$^2$), with a benefit-to-cost ratio of 2.86, proving its commercial viability. Extending planting up to July 25th in open fields or August 25th in polyhouses ensures a continuous flower supply from October to early February, aligning production with peak demand and enhancing profitability. Furthermore, the findings underscore the importance of selecting appropriate planting times and environments to meet market demand and improve crop profitability, particularly in the challenging climatic conditions of the mid-hill zone of Himachal Pradesh.

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## Authors’ contributions

PSH and SRD were involved in framing out the research work and designing the experiment. PS carried out the field experiment. PS and VB documented the data, performed the statistical analysis and drafted the manuscript. All listed authors have thoroughly reviewed and endorsed the final version of the manuscript, indicating their collective agreement with its content and findings.

## Compliance with ethical standards

**Conflict of interest:** Authors do not have any conflict of interest to declare.

**Ethical issues:** None

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