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Planting time and spacing effects on marigold (*Tagetes erecta* L.) NK1 orange: a comprehensive study in Nangarhar, Afghanistan

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ABSTRACT
Marigolds are widely valued for their ornamental beauty and versatility in landscaping, yet optimal horticultural practices for their cultivation under specific local agro-climatic conditions still need to be determined. This study aimed to elucidate the effects of cultivation time and spacing on growth, flower yield, and flowering duration of Marigolds. A field experiment was conducted on the marigold NK1 orange variety based on a factorial randomized block design. The planting times were February 4th (P1), February 21st (P2), and March 8th (P3), while the spacings were 30 cm × 30 cm (S1), 30 cm × 45 cm (S2), 45 cm × 45 cm (S3), and 45 cm × 60 cm (S4). The P2 treatment significantly ($p<0.05$) increased plant height, with no differences among the spacing treatments. The number of primary branches per plant and stem diameter varied significantly with planting time and spacing. Stem diameter positively correlated ($r = 0.41$) with plant spread under different timings. The P2-S2 treatment influenced the most significant flower size, and the maximum length of the ray floret was also observed in the P2 treatment. Flower size had a positive correlation ($r = 0.48$) with the length of the ray floret. Additionally, the highest significant ($p<0.05$) flower fresh weight and flower yield per plant were observed in the P2 treatment. Furthermore, the P2 and P3 treatments had a longer flowering duration than the P1 treatment, with the highest duration of 76 days observed in the P2 treatment. The planting time influences the vegetative growth and flower attributes which is the best time to recommend cultivation for marigold producers in the context of Afghanistan.

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Introduction

Ornamental plants are cultivated for their decorative purposes in gardens and landscape designs, as houseplants, cut flowers, and specimen displays. With the recent focus on agricultural diversification, floriculture has been considered an enterprise that can give farmers higher income per unit area [1]. Among the many ornamental plants grown worldwide, marigold (*Tagetes* spp L.) stands out as a significant commercial flower belonging to the Compositae/Asteraceae family [2]. Native to South and Central America, especially Mexico [3]. It is highly popular in tropical and subtropical regions as a garden plant, potted plant, and for creating herbaceous borders to enhance the beauty of gardens and landscapes [4]. The plants of *Tagetes erecta* are tall, but their height varies depending on the species. The plant canopy is mostly erect and features numerous branches, large flowers, and a variety of colors [5], [6]. The most common colors of marigolds are yellow and orange, with multiple shades such as bright yellow, light yellow, golden yellow, bright orange, and dark orange [3]. Moreover, the Tagetes varieties are adaptable to diverse environmental conditions and can be grown in any soil with good drainage. Growers prefer marigolds due to their accessible cultural practices, short juvenility, profuse flowering, considerable blooming period, attractive color, shape, size, and good quality [7]. Marigold is also a potential source of pharmaceutical components for natural color preparation, oil extraction, etc. [8].

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In marigold plants, the planting times and plant spacing are considered as important factors that affect plant growth, yield, flowering duration, and oil production [9]. The cultivation of marigold in May caused a substantial increment of plant height and plant spread [10]. According to [11], planting time, spacing, and pinching at 60 DAT showed significant effect on the number of days to first flowering and the number of flowers per plant.

The successful commercial production of marigolds depends upon many factors, such as variety, planting time, fertilizer, spacing, irrigation, etc. Planting time and spacing are important factors that affect yield and flower-related parameters. In the context of Afghanistan, no information is available on the time of planting, i.e., seed sowing/transplanting of seedlings and spacing for transplanting to determine optimum plant density in marigolds to raise a better crop. Also, the agroclimatic conditions are favorable, offering significant potential for the commercial cultivation of marigolds for flowers, landscaping, and other ornamental uses. However, horticultural practices under local conditions have yet to be standardized to ensure high-quality flower production. Therefore, this study was conducted in 2021 at the Experimental Farm of the Faculty of Agriculture, Nangarhar University, Nangarhar, Afghanistan, to determine this region's optimal cultivation time and spacing.

Material and Methods

Cultivation condition

This experiment was conducted in 2021 at the Experimental Farm of Agriculture Faculty, Nangarhar University (Nangarhar, Afghanistan). Geographically, Nangarhar province is located in the eastern region of Afghanistan. Mainly, Nangarhar University is located at latitude 34° 28' 20" N and longitude 70° 22' 9" E, with a 599 m elevation above sea level. Its climate is semi-arid with hot summers, and the hottest months are June, July, and August, as shown in Fig 1. This experiment was laid out in a factorial randomized block design (FRBD) with three replications. Seeds of marigold NK1 Orange variety were sown in the nursery at three planting times and subsequently cultivated in a four-planting space. The planting times were February 4th (P1), February 21st (P2), and March 8th (P3), while the spacings were 30 cm × 30 cm (S1), 30 cm × 45 cm (S2), 45 cm × 45 cm (S3), and 45 cm × 60 cm (S4). One seedling per hill was transplanted in all plots. The field was thoroughly ploughed and properly leveled, and all grasses, stubbles, and crop residues were removed. During bed preparation, chemical fertilizers were applied at 50 kg per hectare of Urea (containing 46% N) and 100 kg per hectare of DAP (Diammonium phosphate). Additionally, 150 kg per hectare of Urea was applied one week before the flowering stage. The first irrigation was provided immediately after transplanting, followed by regular watering when the soil became sufficiently dry.

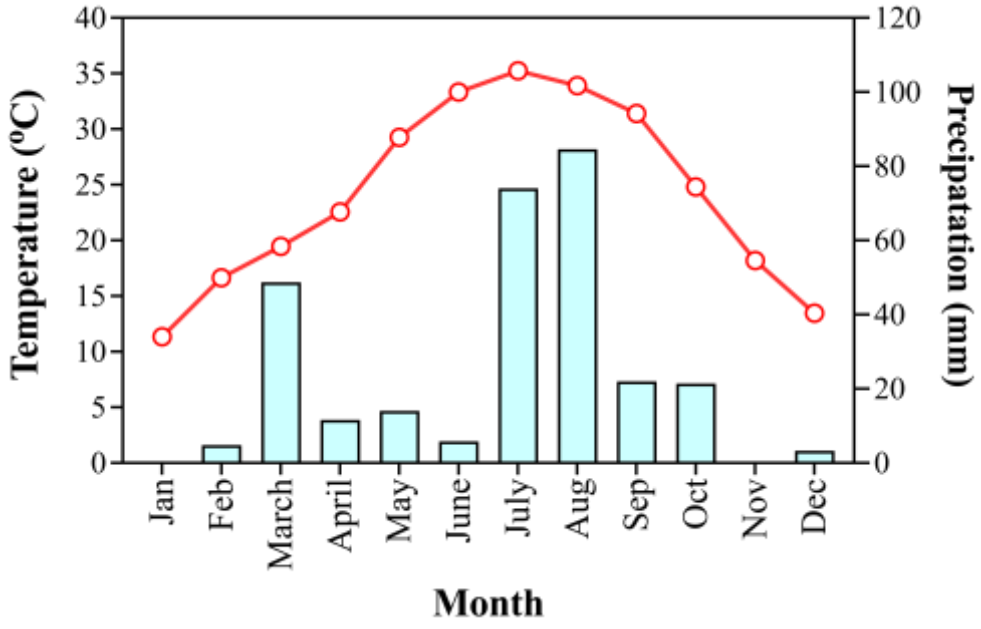

Fig 1. The experimental location's temperature and precipitation (mm) during the marigold growing season (Meteoblue, 2023).

Pinching and weeding

Pinching was performed one month after transplanting in the P1 and P2 treatments, while it was done 40 days after transplanting in the P3 treatment. Weeding was carried out as needed across all treatments.

Growth and flowering parameters

Growth parameters; plant height (cm), plant spread (cm), number of primary branches per plant, stem diameter (mm), and length and width of leaf (cm). Parameters related to the flowers included flower size (cm) (measured using Digital Vernier Calliper), length and width of the ray floret (cm), number of flowers per plant, fresh weight of the single flower (g), flower yield per plant (g), flower yield per plot (kg), dry weight of the single flower (g), and days to bud initiation and first flowering. The flower yield per plot was measured using the following formula.

Flower yield per plot = flower yield per plant × total number of plants per plot

Statistical analysis

The data were analyzed using the two-way analysis of variance (ANOVA) and Pearson's correlation analysis with language R 3.6.2 statistical software. The means were considered using Tukey's test at the 0.05 level.

Results

Growth attributes

Planting time significantly ($p<0.01$) affected plant height, whereas no significant differences were observed among the spacings. The P2 treatment resulted in the tallest plants compared to the other treatments. In the P2 treatment, the highest plant height was 48.72 cm in S1, followed by 47.13 cm in S2 and 46.52 cm in S4 (Fig 2). No significant differences ($p>0.05$) in plant height were found among the planting spacings in the P1 and P3 treatments. The planting time significantly affected the plant spread ($p<0.01$). P2 had a higher plant spread than P1 and P3 treatments, as shown in Table 1. In P2 treatment, S4 had a higher plant spread (42.94 cm) compared to other treatments, followed by S1, S2, and S3, sequentially. The highest value of plant spread was 42.38 cm in S2 of P3 treatment. Furthermore, the results presented in Table 1. revealed that spacing had no significant influence ($p>0.05$) on plant spread. However, the plant spread was comparatively affected by higher spacing.

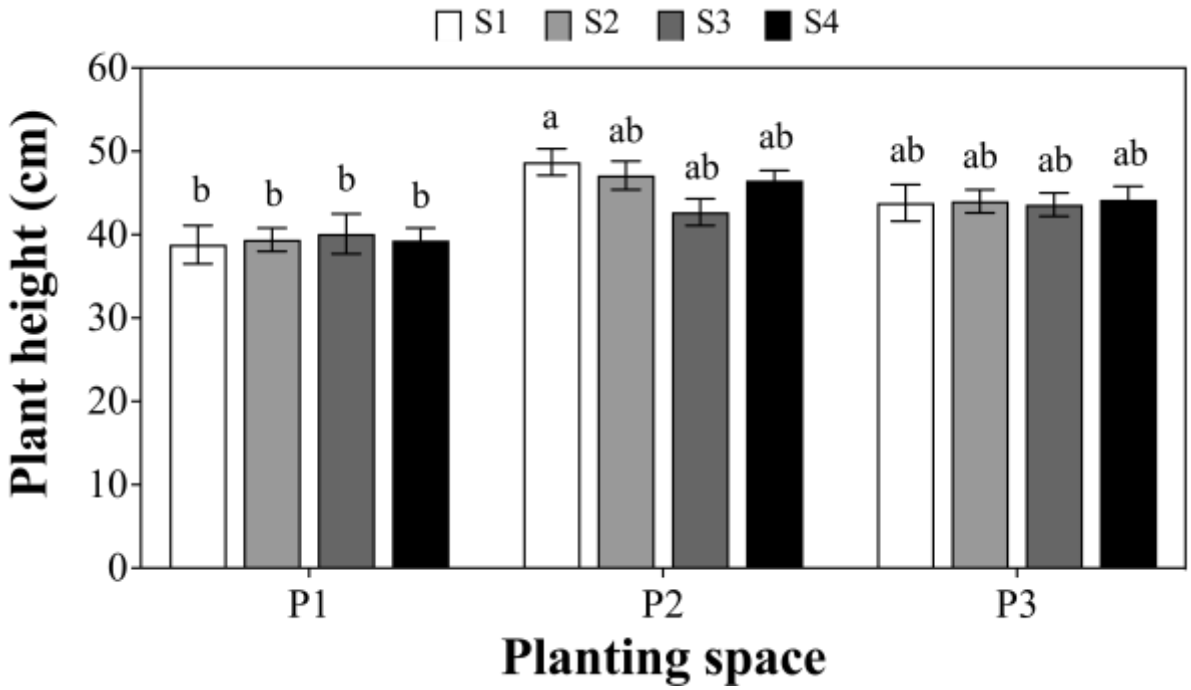

Fig 2. Effect of planting time and spacing on plant height of marigold (n = 10). According to Tukey's test, different letters are shown on bars at 0.05 level.

The number of primary branches per plant was significantly influenced ($p<0.01$) by planting time and planting space. Among the different planting times, the highest value of the number of primary branches per plant (7.66) was observed in the P1-S2 treatment. Also, the production of primary branches was suppressed in P3 compared to P1 and P2. After S2 (7.66) and S1 (6.88) in the P1 treatment, S2 (6.77) and S1 (6.66) had a higher value in the P2 treatment (Table 1). The results revealed that stem diameter was significantly different ($p<0.01$) in planting time and planting space ($p<0.05$) treatments. The data for stem diameter is in accordance with plant spread between planting time treatments and had a positive correlation ($r = 0.41$) between plant spread and stem diameter. The highest values of stem diameter were observed in P2 as compared to P1 and P3 treatments. In the P2 treatment, stem diameter's highest value (18.17 mm) was in S4

and followed by S3 (16.88 mm), S1 (15.23 mm), and S2 (14.12 mm), Sequentially (Table 1). The effect of planting time revealed that during plants' growth in P2 treatment, due to appropriate climatic conditions, the growth of plant spread and stem diameter was enhanced, as shown in Table 1.

Marigold's transplanting at the third week of P2 treatment is the proper time for transplanting for the better physical appearance of the plant's canopy. Statistically, there was no significant difference ($p>0.05$) in the leaf length under different planting times and spacing. At the same time, there was a difference among planting treatments, as shown in Table 2. The results revealed that the width of leaves showed a significant difference ($p<0.01$) between planting times, while there was no significant difference between spacing. The highest values were observed sequentially in the P1 treatment, followed by P3 and P2. In the P2 treatment, planting space S3 (6.77 cm) showed the highest value, followed by S4 (6.50 cm), S1 (6.44 cm), and S4 (6.44 cm), as shown in Table 2.

Flower characteristics

The results of this experiment revealed that different planting times had a significant ($p<0.05$) effect on the flower size of the marigold plant (Fig 3A). Comparing the mean values between treatments, P2-S2 (9.01 cm) had the highest flower size values, while the flower size was lower (6.21 cm) in the P3-S3 treatment. The higher plant spread and stem girth observed in the P2 treatment resulted in larger flower size, as shown in Fig 3A.

The length of florets showed a significant difference ($p<0.05$) between planting times, while there was no significant difference ($p>0.05$) between spacings and their interaction with planting time. The maximum length of the ray floret (4.8 cm) was found in the P2 treatment, and the minimum (3.73 cm) was recorded in the P3 treatment. As shown in Fig 3B, the longest floret length was observed in the P2 treatment at the S2 spacing, followed by the S3 and S1 spacings. The flower size was directly influenced by the length of the floret, with a positive correlation ($r = 0.48$) between the length of the ray floret and flower size. Similarly, there was a significant difference ($p<0.05$) in the width of the ray floret among planting times but no significant difference between spacings. However, spacing had a comparatively minor effect on the ray floret width in marigold plants. There was a positive correlation between the width of the ray floret and flower size ($r = 0.62$) and between the width and length of the ray floret ($r = 0.65$). The highest width of the ray floret was observed in the P2-S2 treatment (1.70 cm), followed by S3 (1.61 cm) and S1 (1.52 cm), as shown in Fig 3C.

The statistical analysis revealed that different planting times and spacings had a significant ($p<0.05$) effect on the number of flowers per marigold plant. The highest number of flowers per plant was observed in P3, followed by P2 and P1, respectively (Fig 3D). In the P3 treatment, S2 spacing resulted in the highest number of flowers (53.00) compared to other treatments. In contrast, the second-highest number of flowers per plant was recorded in S4 spacing (49.82) of the P2 treatment (Fig 3D). This study also demonstrated a positive correlation between plant spread and the number of flowers (Fig 4). According to Fig 4D, the highest plant spread was observed in the S2 and S4 spacings of the P3 and P2 treatments. Therefore, in marigold plants, a wider spread leads to more flowers per plant. Compared to planting time, the influence of planting time on flower production was greater. Additionally, the wider plant spread observed in the P2 treatment contributed to a higher number of flowers per plant, aligning with the primary objective of the experiment.

The highest fresh weight of a single flower was recorded in the P2 treatment compared to other treatments. Within the P2 treatment, the highest fresh weight of a single flower was observed in S2 (13.41 g), while the lowest was in S4 (12.82 g). Additionally, even the lowest fresh weight of a single flower in the P2 treatment's subgroup (planting space) was higher compared to the other spacings in the P1 and P3 treatments. Sowing and transplanting times directly affect plant growth and flower parameters in marigold plants. The results of this experiment indicate that early (P1) and late (P3) planting of marigold plants can decrease the fresh weight of flowers (Table 3).

Flower yield per plant increased significantly ($p<0.01$) with the P2 treatment. The flower yield per plant showed a positive relationship with flower size ($r = 0.62$), length of the ray floret ($r = 0.44$), width of the ray floret ($r = 0.47$), number of flowers per plant ($r = 0.35$), and fresh weight of a single flower ($r = 0.35$). The highest flower yield per plant was observed in the P2 treatment (639.91 g), while the lowest values were recorded in the P3 treatment (328.21 g). Within the P2 treatment, the maximum flower yield per plant was observed in S4 (639.91 g), followed by S2 (598.31 g), S3 (566.83 g), and S1 (566.61 g), respectively (Table 3). Planting time and planting space had a significant effect on flower yield per plot ($p < 0.01$). The number of plants per plot is the most important factor for total flower yield in a specific area.

Table 1. Effect of planting of planting time and spacing on plant spread, number of primary branches, and stem diameter.

Treatments	Plant spread (cm)					Number of primary branches per plant					Stem diameter (mm)				
	S1	S2	S3	S4	Spacing Mean	S1	S2	S3	S4	Spacing Mean	S1	S2	S3	S4	Spacing Mean
P1	36.88	38.72	38.44	35.44	37.37	6.88	7.66	6.44	6.44	6.86	12.28	13.10	13.92	13.52	13.20
P2	41.50	41.33	40.55	42.94	41.58	6.66	6.77	6.22	6.00	6.41	15.23	14.12	16.88	18.17	16.10
P3	37.50	42.38	36.72	39.83	39.11	5.11	5.44	4.55	4.88	5.00	12.66	16.14	14.57	15.43	14.70
Planting time mean	38.62	40.81	38.57	39.40		6.22	6.62	5.74	5.77		13.39	14.45	15.12	15.71	
SD	2.50	1.88	1.91	3.76		0.96	1.11	1.03	0.80		1.60	1.54	1.55	2.34	
P	**					***					***				
S	ns					***					*				
P × S	ns					ns					ns				

The data is represented as mean (n = 9). SD means standard deviation. Significant differences at the 0.05% level are shown above in the table. *** p<0.001, ** p<0.01, *p<0.05, and ns: not significant. The P and S stand for planting time and spacing, respectively.

Table 2. Effect of planting time and spacing on the length and width of the leaf.

Treatments	Length of leaf (cm)					Width of leaf (cm)				
	S1	S2	S3	S4	Spacing Mean	S1	S2	S3	S4	Spacing Mean
P1	11.00	12.27	12.32	10.94	11.63	7.22	8.22	7.55	7.05	7.51
P2	11.22	11.88	11.00	12.11	11.55	6.44	6.44	6.77	6.50	6.54
P3	11.61	12.44	11.57	12.38	12.00	6.72	7.11	6.50	7.44	6.94
Planting time mean	11.27	12.20	11.63	11.81		6.79	7.25	6.94	7.00	
SD	0.30	0.28	0.66	0.76		0.39	0.89	0.54	0.47	
P	ns					**				
S	ns					ns				
P × S	ns					ns				

The data is represented as mean (n = 9). SD means standard deviation. Significant differences at the 0.05% level are shown above in the table. ** p<0.01, and ns: not significant. The P and S stand for planting time and spacing, respectively.

Among the planting time treatments, the highest yield was observed in P2, followed by P1 and P3. The number of plants per plot is determined by spacing, with S1 (36 plants per plot) having the highest value compared to S2 (24 plants per plot), S3 (16 plants per plot), and S4 (12 plants per plot) (Table 3). Flower yield per plot significantly increased with decreasing planting space between plants. Different spacings S1 (30 cm × 30 cm), S2 (30 cm × 45 cm), S3 (45 cm × 45 cm), and S4 (45 cm × 60 cm)-resulted in decreasing flower yields per plot as spacing increased. However, decreasing plant spaces negatively affected the number of flowers per plant, flower size, length of the ray floret, and width of the ray floret (Table 3).

Table 3. Effect of planting time and spacing on fresh weight of the single flower, flower yield per plant, and flower yield per marigold plot.

Treatments	Fresh weight of the single flower (g)					Flower yield per plant (g)					Flower yield per plot (kg)				
	S1	**S2**	**S3**	**S4**	**Spacing Mean**	**S1**	**S2**	**S3**	**S4**	**Spacing Mean**	**S1**	**S2**	**S3**	**S4**	**Spacing Mean**
P1	11.95	12.22	12.54	12.45	12.29	433.41	496.11	459.82	484.72	468.53	15.66	11.90	7.35	5.81	10.17
P2	12.90	13.41	13.16	12.82	13.07	566.61	598.31	566.83	639.91	592.92	20.39	14.36	9.07	7.67	12.87
P3	8.55	7.60	7.811	7.78	7.93	359.01	380.62	328.21	353.10	355.21	12.92	9.13	5.25	4.23	7.88
Mean Planting	11.1	11.0	11.1	11.0		453.0	491.7	451.6	492.6		16.30	11.80	7.22	5.91	
SD	2.28	3.06	2.92	2.80		105.1	108.9	119.5	143.5		3.78	2.61	1.91	1.72	
P	***					***					***				
S	ns					ns					***				
P × S	ns					ns					ns				

The data is represented as mean (n = 9). SD means standard deviation. Significant differences at 0.05% level are shown above in the table. *** $p<0.001$ and ns: not significant.

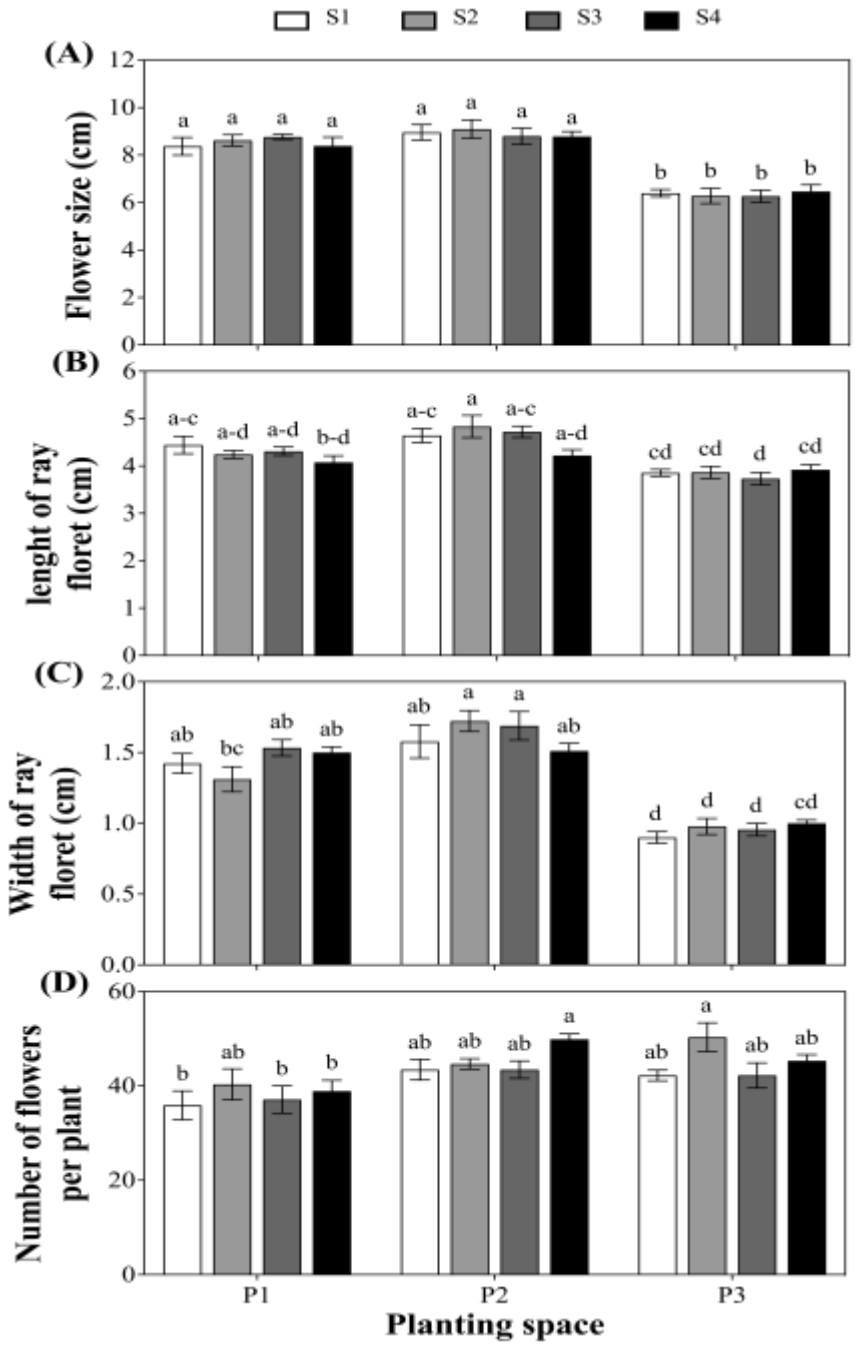

Fig 3. Effects of planting space and sowing time on flower size, length of ray floret, width of ray floret, and number of flowers per plant of marigold shown in (A), (B), (C), and (D), respectively. The letters on the bars are shown differently among treatments based on Tukey's test at 0.05% level. S indicates sowing and P planting time.

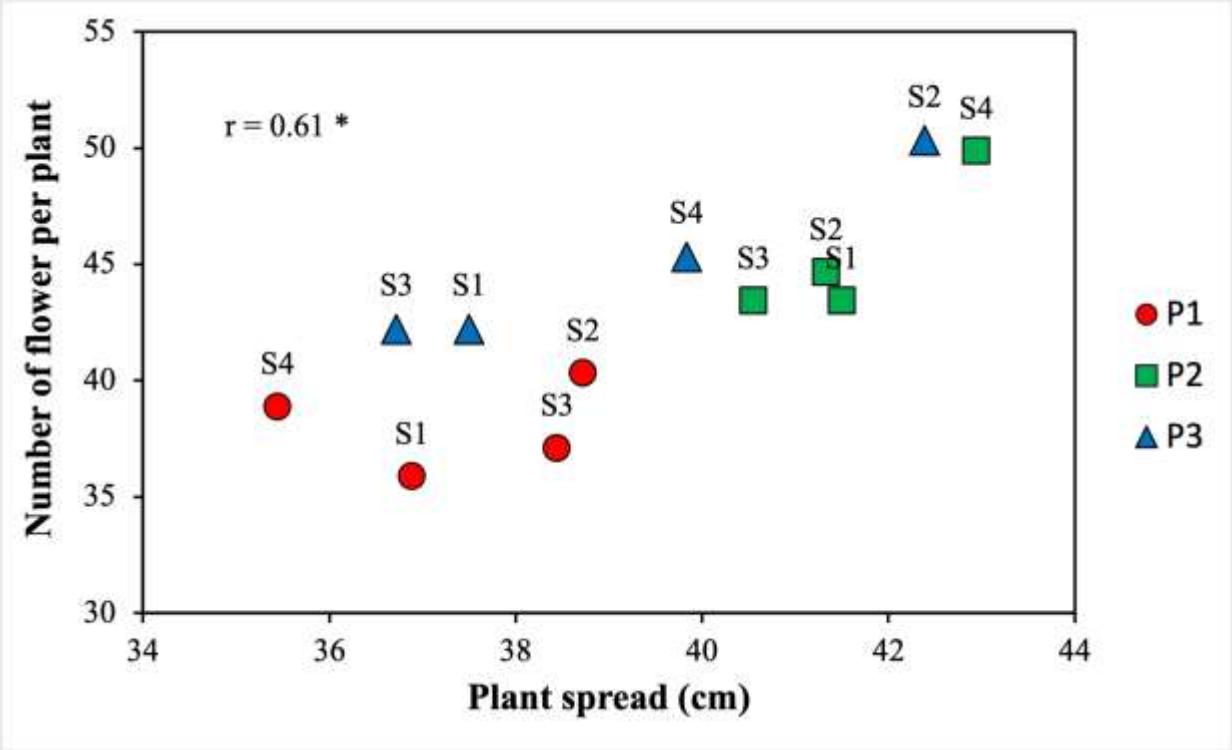

Fig 4. The relationship of plant spread with the number of flowers per plant under different planting times and spacing of marigolds.

The maximum dry weight of marigold flowers was observed in the P2 treatment compared to other treatments. Within the P2 treatment, the highest value was recorded in S2 (2.37 g), followed by S1 (2.33 g), S3 (2.16 g), and S4 (2.14 g). The increase in the dry weight of a single flower varied significantly ($p<0.001$) between planting times. However, there was no significant difference ($p>0.05$) due to planting spacing or the interaction between planting time and spacing, as shown in Table 4.

Table 4. Effect of planting time and spacing on the dry weight of marigold flowers.

Treatments	Flower dry weight (g)				
	S1	**S2**	**S3**	**S4**	**Spacing Mean**
P1	2.06	2.07	2.13	2.25	2.13
P2	2.33	2.37	2.16	2.14	2.25
P3	1.72	1.53	1.44	1.58	1.57
Planting time mean	2.03	1.99	1.91	1.99	
SD	0.30	0.42	0.40	0.35	
P	***				
S	ns				
P × S	ns				

Effect of planting time and planting on flower attributes

The effect of different planting times on the days taken to reach various phenological stages of marigold is presented in Table 5. The results revealed that marigolds differed in the days taken to bud initiation, flowering, and the duration of the flowering period. P1 cultivation had the maximum days to bud initiation (56 days), significantly higher than P2 and P3 treatments. The days taken to flowering corresponded with the days taken to bud initiation.

The most important parameter of this experiment was the duration of flowering. The results showed that the P2 and P3 treatments had longer flowering durations than the P1 treatment. Among all treatments, P2, with 76

days of flowering duration, was the most favorable for cultivating marigolds in the Nangarhar province of Afghanistan (Table 5).

Table 5. Effect of planting time on days to bud initiation, days taken to flowering, and duration of flowering.

Treatments	Days to bud initiation	Days taken to flowering	Duration of flowering days
P1	56.2	63.4	69.2
P2	48.3	54.4	76.7
P3	40.1	47.2	70.1

Discussion

This study investigates the impact of different cultivation times and plant spacing on the growth, floral yield, and phenology of marigold plants under the climatic conditions of Nangarhar province, Afghanistan. Plant height is a crucial growth component representing a crop's growth behavior and influencing the marigold plant's physical appearance. It results from genetic makeup and environmental conditions, particularly temperature and plant-to-plant competition during growth. The results indicated significant variation among treatments under different cultivation dates and plant spacing, as shown in Fig 2. Plant height was noticeably affected by plant spacing across all three cultivation dates, with the highest plant height observed in P2 treatments. In the P2 treatment, plant heights increased sequentially with spacings of 30 × 30 cm, 30 × 45 cm, and 45 × 60 cm. In contrast, P1 and P3 treatments showed no substantial difference between spacing treatments, but different spacing relatively affected plant height due to adjacent crop competition. These findings align closely with those of [13] who reported that closer spacing (30 × 30 cm) resulted in greater plant height compared to other spacing treatments (30 × 45 cm, 45 × 45 cm, and 45 × 60 cm) in marigolds. Similar results were also observed in marigold plants by [14]. Various spacing treatments showed a significant difference in plant spread, while planting dates did not significantly affect plant spread. However, there is still a substantial difference between planting space treatments. The maximum plant spread (42.9 cm) was recorded in the P2 treatment of the cultivation date and S4 (45 × 60 cm) of planting space, followed by S2 (30 × 45 cm) of P3 and P2, as shown in Table 1. The increased plant spread can be attributed to a greater number of flowers per plant and a higher number of branches per plant, which results in a wider plant canopy. These findings are supported by [9], who reported that marigold cultivation after February decreased plant spread. Conversely, wider spacing increases plant spread due to reduced competition for water, light, and available nutrients in the growing area. Similar results have been reported by [10], [15], [16], [17] in marigold plants. The results of this experiment revealed that the effect of planting date and plant spacing on the number of branches per plant of *Tagetes erecta* was significantly different. Still, the interaction of the aforementioned treatment effect was not significant. The number of branches per plant varied based on the planting dates. There were more branches in the February cultivation than in the March cultivation, but it was relatively close to the late February cultivation. The branching process of marigolds tended to be faster in P1, P2, and P3 sequentially (Table 1). Increasing spacing did not affect the number of branches per plant, as there was more planting space. The plant spread showed good results in providing a wider canopy and utilizing the nutrients to proliferate produced branches. The maximum number of branches in Tagetes erecta was produced in 30 × 45 cm spacing in all cultivation dates. These results are in accordance with the [10], [15], [18], [19], [20] in marigold plants. The stem diameter differed significantly in all cultivation dates and spacing. The stem diameter positively correlated with the plant spread in all cultivation dates. The highest value of stem diameter (18.1 mm) was in the P1 cultivation date with 45 × 60 cm, while the closer spaces (30 × 30 cm) showed less stem diameter in all three cultivation dates. The variation of stem diameter of different genotypes was also revealed by [21]. The results of this experiment for stem diameter of marigold plants under different spacing are supported by the same result of [22].

The size of flowers was significantly different between cultivation dates, while not significant in between spacing. Among cultivation dates, the P2 treatment showed a wider flower size diameter than the P1 and P3 treatments. The maximum flower size (9.0 cm) was recorded in P2 treatment, while a minimum (6.2 cm) was observed in P3. This decrease is due to late cultivation in P3, as the days from cultivation to harvest were shorter than other treatments. Moreover, in the interaction of cultivation dates and spacing, P2 showed the maximum flower size (30 × 45 cm) in the S2 planting space and followed by S3 (45 × 45 cm), S1 (30 × 30 cm), and S1 (45 × 60 cm). The diameter of flower size can always be affected by the length of the floret ray; herein, the length of the floret ray showed a positive correlation with the flower size. Similar results were reported by

[1], [11], [23] in African marigolds. The various cultivation dates and spacing significantly influenced the floral parameters, particularly the length and width of the ray floret. The length of the ray floret was in line with the flower size; this means if the size of the ray floret is affected by the cultivation date and spacing, many flowers can be affected. The maximum length of ray floret was found in P2 and followed by P1 and P3 treatments (Fig 4.4). The planting space of S2 (30 × 45 cm) showed the longest floret length compared to other spacing treatments. Reduced spacing might increase competition during vegetative growth, resulting in shorter floret length and smaller flower size. Herein, the balanced planting space and best cultivation time for the maximum length of the floret and flower size are found in the P2 cultivation date and S2 planting space. Similar results were found by [24] in marigold and [25] in gladiolus. Likewise, regarding flower size and the length of the ray floret, the cultivation date and spacing significantly affect the width of the ray floret. The maximum width of the ray florets (1.7 cm) was observed in the P2 treatment, followed by P1 and P3 sequentially. The width of the ray floret was significantly affected by the cultivation date in P3 treatment. At the same time, this is a good confirmation of the late cultivation (after February) catastrophic effect on marigold plants. Based on the spacing, this experiment revealed that the S2 treatment showed more width of the ray florets in the P2 and P3 treatments, while in the P1, S3 (45 × 45 cm) showed wider florets in the flowers. The P1 cultivation date showed a wider ray of the florets due to the long plant growth period and relatively good weather compared to the P3 treatment. These results conform with the findings which are described by [7], [14], [26], [27], [28], [29] in marigold plant.

Different cultivation dates and planting significantly affected the number of flowers per plant. More flowers per plant were sequentially observed in P3, P2, and P1. The maximum number of flowers in the S2 of P3 was recorded and followed by S4 of P2 treatment. The wider planting space of 45 × 60 cm had a higher number of flowers as compared to other treatments in P2; this seems to be mainly due to a greater number of branches per plant and also less competition among the plants. The fewer flower plants were in P1 cultivation treatment in S1 (30 × 30 cm) planting space treatment. This is proof of the effect of high competition between plants in a closely-spacing environment in marigold plants. The plants in different cultivation dates varied between all treatments, but the effect of the environmental conditions, such as temperature, was stable on all planting space treatments. There was a strong correlation (r = 0.61*) between plant spread and the number of flowers per plant as shown in Fig 4. These results were similar to the findings of [3], [10], [30], [31], [32], [33], [34], [35], [36] in marigold plants. The flower yield per plant was greatly affected by flower size, length and width of the ray floret, number of flowers per plant, and fresh weight. There was a significant difference between cultivation dates, but no significant difference between spacing or the interaction of cultivation dates and spacing. The maximum flower yield per plant was recorded in P2 and the minimum in P3 treatment. In P2 treatment, the highest values of flower yield per plant (639.9 g) were observed in S4 (45 x 60 cm), followed by S2 (598.3 g), S3 (566.8 g), and S1 (566.6 g) sequentially (Table 3). The S4 planting space of the P2 treatment showed higher flower yield per plant due to the greater number of flowers per plant, while S2 (30 × 45 cm) showed higher fresh flower weight and better performance in other floral parameters.. The number of flowers per plot differed significantly between cultivation dates and spacing, but not in their interaction. The maximum value of flower fresh weight per plot (20.4 kg) was recorded in P1 with (30 × 30 cm), and the minimum (4.2 kg) was in P3 with (45 × 60 cm) (Table 3). In all P treatments, the treatment with the least spacing (30 × 30 cm) showed the highest values of fresh flowers per plot, which was due to the high number of plants per area.

Data recorded on flowering attributes (Table 5) showed that the earliest bud initiation occurred in P3 (40.1 days), P2 (48.3 days), and P1 (56.2 days) sequentially. The early cultivation revealed that the temperature was low and the days taken to initiate flowering were longer compared to other treatments. In contrast, later (after February, as in the P3 treatment), the temperature was higher, which caused early bud initiation in marigold plants. In this experiment, data presented in Table 5 revealed that the days taken to flowering were in line with the days taken to bud initiation in different cultivation times. In contrast, the duration of the flowering was varied among cultivation dates. The maximum number of days to keep flowers fresh in plants was recognized as P2 cultivation, while the P1 treatment with the earlier cultivation had shorter flowering periods than other treatments. From these results, we conclude that optimal timing for bud initiation and flowering can lead to a longer flowering duration in marigold plants under different cultivation dates. These results are similar to the results of [37], [38] in marigold plants. The planting time and spacing had a substantial impact on the vegetative growth and flowering attributes of marigolds in this study. However, further research is needed to examine additional marigold genotypes and gain a deeper understanding of this process and its sustainability.

Conclusion

In this experiment, we found that planting time and spacing have a significant impact on the growth and flowering attributes of marigold plants under the climatic conditions of Nangarhar, Afghanistan. The data from

the P2 cultivation and S2 (30 × 45 cm) spacing showed notable effects on plant spread and the number of primary branches per plant. The largest flower size was observed in the P2-S2 treatment. Additionally, this treatment resulted in the highest fresh flower weight and flower yield per plot. The findings revealed that cultivation time had a strong influence on the timing of bud initiation, the number of days to flowering, and, most importantly, the duration of the flowering period. For ornamental plants, the duration of the flowering period is a priority for growers compared to other parameters. The most extended flowering duration (76.7 days) was recorded in the P2 (late February) treatment, indicating that this planting time is most favorable for extending the flowering period in marigolds under the study conditions. Thus, it is advised that marigold farming in Nangarhar, Afghanistan, implement a planting schedule of late February (P2) and a spacing of 30 × 45 cm (S2) to enhance growth, flower size, yield, and particularly the duration of flowering.

Compliance with ethical standards
Conflict of interest / Çıkar çatışması
The author declare no conflict of interest.
Ethical standards
The study is proper with ethical standards.

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