



RESEARCH ARTICLE

Effect of transplanting dates and mulches on growth and flowering of African marigold (*Tagetes erecta* L.) cv. Pusa Narangi Gainda

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Abstract

The productivity and quality of flowers can be improved by using high-yielding cultivars and improved horticultural practices such as date of planting and mulching. Planting dates and mulch materials have a significant impact on the growth and flowering of marigold. Therefore, a field experiment was planned at College of Horticulture, Banda University of Agriculture and Technology, Banda, Uttar Pradesh during 2023–24. The experiment was laid out in a factorial randomised block design (FRBD) with three replications to investigate the effect of transplanting dates and mulches on the growth and flowering of African marigold. Analysis of the results revealed significant variations in plant height, plant spread, number of secondary branches per plant, duration of flowering, flower diameter, number of flowers per plant and flower yield per plant in the D1 treatment, i.e., the first fortnight of October. Among the mulch treatments, significant results were recorded for plant height, plant spread, number of primary branches per plant, duration of flowering, flower diameter, number of flowers per plant, flower yield per plant and days to first flower opening under the M3 treatment, i.e., silver black polythene mulch. Among the various treatment combinations, early bud initiation, early first flower opening, maximum flower diameter and maximum flower yield were recorded under the treatment combinations D1M2, D2M3, D3M1 and D3M1 respectively. Overall, the treatment combination D1M3 [transplanting during the first fortnight of October + polythene mulch (silver black)] showed the best results for most of the growth, flowering and yield parameters. Future research should focus on evaluating the effects of organic and inorganic mulches on plant canopy, weed population control and improving the soil biophysical properties.

Keywords: flower; marigold; mulch; plant; transplanting

Introduction

Marigold, an auspicious flower species for India, is native to North America and belongs to family Compositae (1). It possesses decorative, pharmaceutical, conventional and antimicrobial properties in addition to its application in gardening (2). As marigold has the potential for year-round growth, it can be cultivated in different seasons to ensure flower availability during festival seasons and on various occasions such as Magh Mela, when demand is high. Similarly, during New Year, Holi and Diwali, as well as at parties, functions and ceremonies such as birthdays, marriage ceremonies and political rallies, flowers are in great demand.

The productivity and quality of flowers can be improved by using high-yielding cultivars and improved horticultural practices such as date of planting and mulching. Vegetative growth and crop quality are improved by proper planting time, which also satisfies

consumer demand (3). As flowering in marigold is generally governed by day length and temperature, studying the effects of different planting dates of marigold (*Tagetes* spp.) is useful for analysing yield potential across planting dates. This helps determine the optimum time of cultivation to obtain higher yield to meet market demand during specific periods for special occasions, thereby fetching higher income.

Mulching is a very useful technique for protecting plant roots from heat and cold injury. It involves covering the soil surface around plants to create congenial conditions for plant growth and influences various aspects of the soil environment and crop requirements. Mulching also helps enhance microbial activity in the soil (4). To achieve good and healthy production of marigold flowers, both planting time and mulching are important aspects. In view of this, an experiment entitled “Effect of transplanting dates

and mulches on growth and flowering of African marigold (*Tagetes erecta* L.) cv. Pusa Narangi Gaiinda" was conducted to assess the effects of transplanting dates and mulches on vegetative growth, flowering and yield parameters in marigold.

Materials and Methods

Experimental location

The field trial was carried out at the Instructional Farm, College of Horticulture, Banda University of Agriculture and Technology, Banda. The site is situated between latitudes 24° 53' and 25° 55' N and longitudes 80°07' and 81°24' E. The region experiences a semi-arid/tropical climate characterised by hot and dry summers, a pleasant monsoon season and a satisfying winter, with an average annual rainfall of about 800 mm (Fig. 1).

Nursery preparation and seed sowing

The raised nursery beds were prepared with a fine mixture of soil and farmyard manure (FYM). Before sowing, the nursery beds were drenched with a copper fungicide to prevent fungal diseases such as damping-off. Healthy and disease-free seeds of African marigold cv. Pusa Narangi Gaiinda were sown on different dates as per technical programme, in rows at a spacing of 5 cm and at a depth of 2–3 cm on raised beds. The beds were then covered with a fine mixture of soil and FYM. The soil of the experimental site was clayey, with a pH of 7.5 and an EC of 0.56 ds m⁻¹. It contained 0.42 % available organic carbon, 94.5 kg/ha nitrogen, 13.5 kg/ha phosphorus and 165 kg/ha potassium, with uniform topography. Healthy, disease free seedlings of uniform size and vigour at the 4–5 leaf stage were transplanted in the field as per the layout. Transplanting was done on beds (1.6 × 1.6 m²) at a spacing of 40 × 40 cm.

Experimental details

The experiment was laid out in a factorial randomised block design (FRBD). The treatment combinations included three planting dates (D1: first fortnight of October, D2: second fortnight of October and D3: first fortnight of November) and four mulching treatments [M1: control (no mulch), M2: black plastic mulch, M3: silver plastic mulch and M4: local grass (*Saccharum spontaneum*)]. All intercultural

operations were performed from time to time. Irrigation was applied when the soil moisture content fell below the optimum level.

Statistical analysis

Data on various vegetative, flowering and soil parameters were recorded from five selected plants from each plot. The data were analysed using analysis of variance (ANOVA) with the F-test for an FRBD, employing the OPSTAT software (5, 6). Mean comparisons were performed using critical difference (CD) at the 5 % level of significance.

Results

Effects of transplanting dates and mulches on vegetative parameters

The perusal of data appended in Table 1 indicated that there was a significant effect of planting dates and mulching on vegetative parameters. Plant height, plant spread and number of primary branches per plant were significantly influenced by transplanting dates and mulch treatments. Among the different transplanting dates, the maximum plant height (60.20 cm), plant spread (51.02 cm) and number of primary branches per plant (9.93) were recorded in the D1 treatment (transplanting during the first fortnight of October), whereas the minimum values (42.20 cm, 35.69 cm and 8.13 respectively) for these parameters were observed in the D3 treatment (transplanting during the first fortnight of November). In the case of different mulch treatments, the maximum plant height (51.94 cm), plant spread (44.44 cm) and number of primary branches per plant (10.07) were recorded in the M3 treatment i.e., silver black plastic mulch, while the minimum values (47.49 cm, 40.05 cm and 8.84 respectively) were observed in the M1 treatment i.e., control. However, the interaction effect between transplanting dates and mulching was found to be non-significant for these parameters.

Effect of transplanting dates and mulches on flowering parameters

Among the various flowering parameters, days taken to bud initiation and first flower opening were highly influenced by planting dates and mulching and their interaction also had a

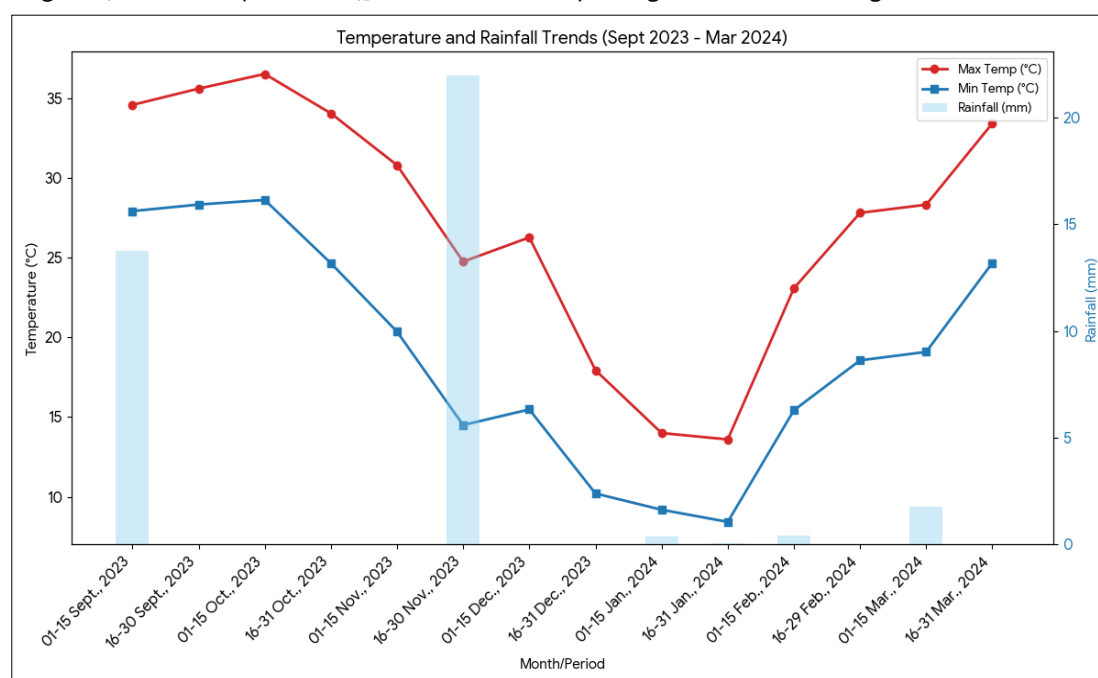


Fig. 1. Weather parameters prevailed during crop period.

Table 1. Effect of transplanting dates, mulching and their interaction on vegetative and floral parameters of African marigold (*Tagetes erecta* L.) cv. Pusa Narangi Gainda

Treatments	Plant height (cm)	Plant spread (cm)	Number of primary branches	Number of secondary branches	Days taken to bud initiation	Days to first flower opening	Days taken to 50 % flowering	Duration of flowering (days)	Flower diameter (cm)	Number of flowers per plant	Flower yield per plant (g)
Date of transplanting (Factor I)											
First fortnight of October (D1)	60.20	51.02	9.93	44.00	24.77	32.98	38.91	77.82	6.62	41.00	260.53
Second fortnight of October (D2)	46.95	40.58	9.88	28.38	22.52	31.32	35.75	71.50	5.55	36.33	226.59
First fortnight of November (D3)	42.20	35.69	8.13	26.78	21.02	29.28	35.52	71.05	5.42	36.05	199.31
CD at 5 %	2.54	1.85	0.71	4.37	1.12	0.98	0.52	1.04	0.32	4.06	13.95
SE (m)	0.99	0.76	0.28	1.71	0.44	0.38	0.20	0.41	0.12	1.59	5.46
Mulching treatments (Factor II)											
Control (M1)	47.49	40.05	8.84	32.53	24.78	33.38	38.02	71.47	5.42	28.38	176.13
Black plastic mulch (M2)	49.66	42.87	9.11	32.62	22.09	30.38	36.53	73.07	5.94	37.13	223.86
Silver black plastic mulch (M3)	51.94	44.44	10.07	36.18	22.04	29.98	35.73	76.04	6.45	47.82	309.03
Local grass (<i>Saccharum spontaneum</i> L.) (M4)	50.05	41.15	9.24	30.84	22.16	31.04	36.62	73.24	5.64	37.84	206.22
CD at 5 %	2.93	2.14	0.8	NS	1.29	1.13	0.60	1.20	0.37	4.69	16.11
SE (m)	0.86	0.66	0.24	1.48	0.38	0.33	0.18	0.35	0.10	1.38	4.73
Date of transplanting × mulching treatments											
D1M1	58.37	49.30	10.07	41.73	29.00	37.07	37.90	75.80	5.72	35.07	189.52
D1M2	58.36	52.65	9.33	43.07	25.40	32.60	39.10	78.20	6.91	39.87	249.40
D1M3	65.15	53.95	10.73	48.93	24.20	32.27	39.73	79.47	7.94	50.13	367.82
D1M4	58.93	48.18	9.40	42.27	24.80	33.60	38.90	77.80	5.91	38.93	235.38
D2M1	44.46	37.44	9.27	30.00	24.67	30.33	34.90	69.80	5.37	24.80	176.38
D2M2	49.32	41.04	9.27	28.53	22.07	30.07	35.00	70.00	5.73	35.13	217.77
D2M3	45.93	41.33	11.20	31.60	21.13	33.47	37.23	74.47	5.70	47.20	299.44
D2M4	48.10	42.52	10.00	23.33	19.73	29.20	35.87	71.73	5.39	37.07	212.78
D3M1	39.64	33.42	8.00	25.87	19.40	28.27	34.40	68.80	5.17	25.27	162.50
D3M2	41.31	34.94	7.93	26.27	20.67	28.47	35.50	71.00	5.19	36.40	204.40
D3M3	44.73	38.03	8.27	28.00	21.13	29.40	37.10	74.20	5.70	46.13	259.84
D3M4	43.11	36.37	8.33	26.93	21.00	29.60	35.10	70.20	5.63	37.53	170.50
CD at 5 %	NS	NS	NS	NS	2.24	1.9	NS	NS	0.65	NS	27.89
SE (m)	1.73	1.31	0.48	2.96	0.76	0.66	0.35	0.70	0.20	2.75	9.45

significant effect on these parameters (Table 1). Among the different transplanting dates, early bud initiation (21.02 days) and first flower opening (29.28 days) were observed in the D3 treatment i.e., second fortnight of November. However, delayed bud initiation (24.77 days) and first flower opening (32.98 days) were observed in the D1 treatment, i.e., first fortnight of October. In the case of mulching treatments, the minimum days taken for bud initiation (22.04 days) and first flower opening (29.98 days) were recorded in M3, i.e., silver black plastic mulch, whereas M1, i.e., control, took the maximum days for bud emergence (24.78 days) and first flower opening (33.38 days). The interaction between planting dates and mulching was also significant for days taken to bud initiation and first flower opening. Early bud initiation (19.40 days) and first flower opening (28.27 days) were recorded in the D3M1 treatment (first fortnight of November + control) while the D1M1 treatment, i.e., first fortnight of October + control, showed late bud initiation (29.00 days) and first flower opening (37.07 days). Days taken to 50 % flowering had a significant influence of transplanting dates and mulching. Minimum days taken to 50 % flowering (35.52 days) was

recorded in D3 treatment and maximum (38.91 days) was recorded in D1 treatment. Similarly, among mulches, early 50 % flowering (35.73 days) was recorded in M2 while late 50 % flowering (38.02 days) was recorded in M1. However, interaction between transplanting dates and mulching was non-significant on days taken to 50 % flowering.

Among the different planting dates, the longest duration of flowering (77.82 days), maximum flower diameter (6.62 cm), number of flowers per plant (41.00) and flower yield per plant (260.53 g) were recorded in the D1 treatment, whereas the minimum values (71.05 days, 5.42 cm, 36.05, 199.31 g respectively) for these parameters were recorded in the D3 treatment. In the case of mulching treatments, the maximum duration of flowering (76.04 days), flower diameter (6.45 cm), number of flowers per plant (47.82) and flower yield per plant (309.03 g) were recorded in the M3 treatment. However, the minimum duration of flowering (71.47 days), flower diameter (5.42 cm), number of flowers per plant (28.38) and flower yield per plant (176.13 g) were recorded in the M1 treatment.

Effect of transplanting dates and mulches on soil parameters

The data obtained on the effect of planting dates, mulching and their interaction on soil parameters are presented in Table 2. Both planting dates and mulching showed a significant effect on soil moisture content at 30, 60 and 90 days after transplanting (DAT) and their interaction effect was also significant. The maximum soil moisture content (25.06 %, 26.35 % and 25.41 %) at 30, 60 and 90 DAT was recorded in the D3 treatment, i.e., first fortnight of November, followed by the D2 treatment, i.e., second fortnight of October. In contrast, the minimum soil moisture content (23.45 %, 25.37 % and 24.44 %) was recorded in the D1 treatment, i.e., first fortnight of October, at 30, 60 and 90 DAT. In the case of mulching treatments, the maximum soil moisture content (28.25 %, 29.28 % and 29.27 %) was recorded in the M3 treatment, i.e., silver black plastic mulch, at 30, 60 and 90 DAT, followed by the M2 treatment (black plastic mulch), while the minimum values (16.57 %, 18.88 % and 18.01 %) were recorded in the M1 treatment, i.e., control (no mulch). The interaction between planting dates and mulching was also significant for soil moisture content. The maximum soil moisture content (29.88 %, 30.15 % and 29.71 %) was recorded in the D3M3 treatment (first fortnight of November + silver black plastic mulch) while the minimum soil moisture content (16.22 %, 17.64 % and 17.29 %) was observed in the D1M1 treatment, i.e., first fortnight of October + control, at 30, 60 and 90 DAT respectively.

The planting dates, mulching and their interaction showed a significant effect on soil temperature at 30, 60 and 90 DAT. The maximum soil temperature at 30, 60 and 90 DAT was recorded in the D1 treatment, i.e., first fortnight of October, followed by the D2 treatment, i.e., second fortnight of October. In contrast, the minimum soil temperature was recorded in the D3 treatment, i.e., first fortnight of November, at 30, 60 and 90 DAT. In the case of mulching treatments, the maximum soil temperature at 30, 60 and 90 DAT (28.84 °C, 27.77 °C and 30.23 °C) was recorded in the M2 treatment, whereas the M1 treatment recorded the minimum soil temperature (21.87 °C, 20.32 °C and 24.49 °C).

The interaction between planting dates and mulching also had a remarkable effect on soil temperature at 30, 60 and 90 DAT. The maximum soil temperature (30.45 °C, 29.66 °C and 31.24 °C) was recorded in the D1M2 treatment (first fortnight of October + black plastic mulch), whereas the minimum soil temperature (20.63 °C, 18.54 °C and 22.11 °C) was observed under the D3 M1 treatment, i.e., first fortnight of November + control. Planting dates and their interaction with mulches showed a non-significant effect on the soil organic carbon percentage during the crop period, while mulching treatments had a discernible effect on organic carbon content. Among the mulching treatments, the highest organic carbon percentage was recorded in M4 (local grass *Saccharum spontaneum*), followed by M1 (control, no mulch). The lowest organic carbon percentage was observed in M2 (black plastic mulch), which did not differ significantly from M3 (silver black plastic mulch).

Planting dates showed a non-significant effect on the available nitrogen content of the soil during the crop period, whereas mulching treatments had a considerable effect on available nitrogen. Among the mulching treatments, the highest available nitrogen content was recorded in M4, i.e., local grass (*Saccharum spontaneum*), followed by M1, i.e., control (no mulch). The lowest available nitrogen was observed in M2 (black plastic mulch), followed by M3, i.e., silver black plastic mulch. Both factors, planting

dates and mulching showed a considerable effect on the available phosphorus content of the soil during the crop period, as their interaction was significant. The highest available phosphorus (22.20 kg/ha) was recorded in the D3M4 treatment interaction, i.e., first fortnight of November and local grass (*Saccharum spontaneum*), followed by the D2 M4 treatment, i.e., second fortnight of October and local grass (*Saccharum spontaneum*). In contrast, the minimum available phosphorus was recorded in the D2M2 treatment interaction, i.e., second fortnight of October and black plastic mulch.

Planting dates, mulching and their interaction showed a non-significant effect on the available potassium content of the soil during the crop period. Statistical analysis of the data revealed that planting dates had a non-significant effect on the water holding capacity of the soil during the crop period. On the other hand, among the mulching treatments, the highest water holding capacity was reported in M3, i.e., silver black plastic mulch, followed by M2, i.e., black plastic mulch, while M1 (no mulch) showed the lowest water holding capacity.

Discussion

The superiority of the D1 treatment (transplanting during the first fortnight of October) with respect to vegetative parameters might be due to the sufficient time available for marigold plants under the D1 treatment to attain maximum vegetative growth before entering the reproductive phase. Favourable growing conditions, prevailing winds, relative humidity and environmental factors such as a longer photoperiod and higher temperatures during the growth period of the October-planted crop also contributed significantly. Rapid meristematic activity, most likely owing to enhanced cell division and elongation during the initial development stages, might explain the increased plant height, wider plant spread and greater branching observed in marigold plants (7). However, meteorological data (Fig. 1) show that planting from November onwards was exposed to a shorter photoperiod and decreased night temperatures during the initial growth period, resulting in reduced plant metabolism, as similarly reported in *Arabidopsis* (8). Hence, a significant reduction in different vegetative parameters was noticed when transplanting was done in November. Further, this growth was enhanced by the M3 treatment, i.e., silver black plastic mulch which conserved moisture, regulated soil temperature and provided a more favourable microclimate for healthy plant growth. These findings are consistent with previous studies conducted on marigold (9–25).

The perusal of data with reference to flowering parameters indicated that transplanting during the first fortnight of October (D1) required the maximum number of days for bud initiation and first flower opening and also exhibited the longest duration of flowering (77.82 days), maximum flower diameter (6.62 cm), number of flowers per plant (41.00) and flower yield per plant (260.53 g). This was possibly due to favourable flowering conditions, with an average temperature of 29.35 °C, prevailing winds and relative humidity as well as environmental conditions such as a longer photoperiod during the flowering period of the October-planted crop. These conditions resulted in flowers with a better diameter, longer flowering duration, number of flowers per plant and flower yield per plant which was further backed by mulches. Among the mulching treatments, M3, i.e., silver black plastic mulch, recorded the maximum flower diameter, longer flower duration,

Table 2. Effect of transplanting dates, mulching and their interaction on soil parameters of African marigold (*Tagetes erecta* L.) cv. Pusa Narangi Gainda

Treatments	Soil moisture content (%)			Soil temperature (°C)			Organic carbon (%)	Bulk density (g/cc)	Available nitrogen (kg/ha)	Available phosphorus (kg/ha)	Available potassium (kg/ha)	Soil pH	Soil EC (dS m ⁻¹)	Water holding capacity (%)	
	30 DAT	60 DAT	90 DAT	30 DAT	60 DAT	90 DAT									
Date of transplanting (Factor I)															
First fortnight of October (D1)	23.45	25.37	24.44	27.60	26.85	29.19	0.41	1.25	158.22	15.09	467.97	8.39	1.56	69.67	
Second fortnight of October (D2)	24.31	25.98	25.25	25.89	24.51	28.16	0.41	1.29	154.82	16.93	496.94	8.36	1.82	68.98	
First fortnight of November (D3)	25.06	26.35	25.41	24.98	24.49	26.29	0.42	1.24	163.86	18.32	477.93	8.42	1.93	71.62	
CD at 5 %	0.03	0.03	0.01	0.12	0.01	0.01	NS	NS	NS	NS	NS	NS	NS	NS	
SE (m)	0.01	0.0	0.01	0.04	0.01	0.01	0.02	0.00	11.68	1.13	50.45	0.07	0.22	1.37	
Mulching treatments (Factor II)															
Control (M1)	16.57	18.88	18.01	21.87	20.32	24.49	0.45	1.31	189.56	17.54	466.02	8.40	1.80	50.47	
Black plastic mulch (M2)	27.64	28.85	28.18	28.84	27.77	30.23	0.37	1.25	109.73	15.77	548.85	8.37	1.52	78.12	
Silver black plastic mulch (M3)	28.25	29.78	29.27	28.51	27.66	30.07	0.36	1.28	131.65	15.37	462.68	8.35	1.91	79.74	
Local grass (<i>Saccharum spontaneum</i> L.) (M4)	24.63	26.08	24.68	25.41	25.37	26.73	0.46	1.20	204.94	18.45	446.22	8.43	1.84	72.12	
CD at 5 %	0.04	0.04	0.01	0.13	0.01	0.02	0.06	NS	34.47	NS	NS	NS	NS	4.06	
SE (m)	0.01	0.01	0.03	0.04	0.01	0.01	0.02	0.03	10.11	0.98	43.69	0.06	0.19	1.19	
Date of transplanting × mulching treatments															
D1M1	16.22	17.64	17.29	23.53	20.31	23.34	0.45	1.23	207.81	15.03	504.53	8.39	1.65	50.13	
D1M2	26.29	29.25	27.88	30.45	29.66	31.24	0.32	1.28	125.54	18.12	426.40	8.35	1.24	78.57	
D1M3	28.64	29.88	29.56	29.98	26.14	28.68	0.40	1.29	105.02	15.29	464.80	8.37	1.68	78.55	
D1M4	25.38	26.99	25.69	26.44	23.66	25.14	0.60	1.19	194.52	11.94	476.14	8.46	1.68	71.53	
D2M1	16.55	19.27	18.51	21.45	22.12	28.02	0.45	1.35	194.94	18.08	440.06	8.38	1.68	50.02	
D2M2	26.75	28.94	27.55	27.04	25.94	30.07	0.39	1.21	106.92	11.09	642.78	8.33	1.76	76.10	
D2M3	26.86	29.32	28.55	27.53	28.07	29.25	0.23	1.31	103.04	17.36	423.55	8.37	1.68	79.64	
D2M4	23.66	25.57	24.38	24.12	25.41	27.41	0.47	1.21	214.40	21.21	481.47	8.35	1.95	70.13	
D3M1	16.95	19.73	18.21	20.63	18.54	22.11	0.41	1.25	165.93	19.52	453.49	8.44	1.88	51.38	
D3M2	29.27	28.37	29.18	28.44	27.92	30.88	0.39	1.26	96.72	18.10	577.48	8.44	1.57	79.70	
D3M3	29.88	30.15	29.71	28.02	29.10	30.77	0.43	1.24	186.89	13.44	499.69	8.32	2.38	81.02	
D3M4	24.86	25.67	23.98	25.67	26.51	27.65	0.45	1.21	205.91	22.20	381.06	8.48	1.88	74.37	
CD at 5 %	0.07	0.06	0.02	0.23	0.02	0.03	NS	NS	NS	5.78	NS	NS	NS	NS	
SE (m)	0.02	0.02	0.01	0.08	0.01	0.01	0.04	0.06	20.22	1.96	87.38	0.11	0.37	2.38	

number of flowers per plant and flower yield per plant, followed by M2, i.e., black plastic mulch. While the M1 treatment, i.e., the control condition, reported the minimum values for these parameters. Earlier workers also reported similar findings (1, 12, 16, 19, 26–28). In other words, it can be concluded that early planting had ample time to build up vegetative growth due to congenial environmental conditions and therefore, took comparatively more time for bud initiation and flowering. However, transplanting during the second fortnight of November (D3) was exposed to shorter day conditions accompanied by lower night temperatures, which imposed stress conditions, triggering early bud formation followed by the earliest flowering (29).

Planting dates, mulching and their interaction showed a significant effect on soil moisture content at 30, 60 and 90 DAT. This might be due to climatic factors such as rainfall, relative humidity and average temperature during the crop period. The results also showed that plastic mulches captured higher soil moisture compared to organic mulch (local grass). This was probably because plastic mulches do not allow moisture to evaporate from the soil, unlike no mulch or organic mulches. Similar findings were reported earlier (30). Among the mulching treatments, the maximum soil moisture content was recorded in M2, i.e., black plastic mulch, followed by M3, i.e., silver black plastic mulch, whereas, the minimum was recorded in M1, i.e., control (no mulch). Similar observations regarding higher soil moisture retention under plastic mulches compared to organic mulch were also reported earlier (9).

Among mulching treatments, the highest percentage of organic carbon was recorded in treatment M4, i.e., local grass (*Saccharum spontaneum*) followed by treatment M1, i.e., the control condition (no mulch). In contrast, treatment M2 (black plastic mulch) showed the minimum percentage of organic carbon, with no large difference compared to treatment M3, i.e., silver black plastic mulch. This difference was probably because plastic mulches create a microclimate beneath them by suppressing weeds and conserving moisture and heat, conditions under which microorganisms do not survive as frequently as under organic mulches. Moreover, organic mulches add the required organic matter to the soil, thereby increasing the organic carbon content. This, in turn, provides a conducive environment for microorganisms and weeds. Organic mulches also maintain soil temperature effectively by moderating it in accordance with atmospheric conditions.

The highest percentage of available nitrogen was reported in treatment M4, i.e., local grass (*Saccharum spontaneum*), followed by treatment M1, i.e., the control condition (no mulch). The difference may have been due to the high mineral N content (NO_3^- and NH_4^+) in the soil, resulting from the mineralisation of organic N over time, thereby increasing the availability of soil nitrogen. The decomposition of organic matter releases soluble nutrients such as NO_3^- , NH_4^+ , Ca^{2+} , Mg^{2+} , K^+ and fulvic acids into the soil, further enhancing soil nutrient availability. In addition, mulch application effectively regulates soil temperature, thereby moderating it according to the surrounding atmosphere conditions. Researchers have also reported similar findings (31). Both factors, planting dates and mulching, showed a considerable effect on the available phosphorus content of the soil during the crop period, as their interaction was found to be significant. The highest amount of available phosphorus (22.20 kg/ha) was recorded in the D3M4 treatment, i.e., first fortnight of November with local grass (*Saccharum spontaneum*). Mulch application may also result in an

increase in the phosphorus content within the soil's available phosphorus pool. Similar results have been reported in previous studies (1, 32).

Water holding capacity was recorded as highest in treatment M3, i.e., silver black plastic mulch, followed by treatment M2, i.e., black plastic mulch, whereas treatment M1 (no mulch) showed the minimum water holding capacity. This difference was probably because plastic mulches create a favourable microclimate beneath them by suppressing weeds and conserving moisture and heat, conditions under which microorganisms do not survive as frequently as under organic mulches. In addition, organic mulches add the required organic matter to the soil, thereby increasing soil organic matter content and providing a conducive environment for microorganisms and weeds. Organic mulches also maintain soil temperature effectively by moderating it in accordance with atmospheric conditions. Similar results were reported by earlier researchers (33).

Conclusion

On the basis of the present study, it may be concluded that the D1M3 treatment (first fortnight of October + silver black plastic mulch) showed the best results for most vegetative growth, flowering and yield parameters. In terms of soil parameters, the treatment combination D3M3 (first fortnight of November + silver black plastic mulch) yielded the best result for African marigold cv. Pusa Narangi Gaiinda. Future research should focus on evaluating the effects of organic and inorganic mulches on plant canopy development, weed population control and improvement of soil biophysical properties, such as soil organic carbon, soil moisture retention and soil temperature regulation, under the Bundelkhand region. Furthermore, the findings underscore the importance of appropriate planting time and suitable environmental conditions in meeting market demand and improving crop profitability, particularly under the challenging climatic conditions of the Bundelkhand region.

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Authors' contributions

AY carried out the experiment and wrote the initial draft of the manuscript. RK was involved in the conceptualisation, planning and supervision of the experiment. AKS performed the review and editing of the manuscript. AKG performed the statistical analysis. AK and KST collected the literature and summarised relevant studies. RS participated in the design and coordination of the study. PS and PY performed statistical analysis. All authors read and approved of the final manuscript.

Compliance with ethical standards

Conflict of interest: The authors declare that they have no conflict of interest.

Ethical issues: None

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