

Evaluation of Marigold (*Tagetes erecta*) Varieties for Growth, Flowering, and Floral Attributes at Three Localities of Nepal

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Marigolds are very common in plant kingdoms used for ornamentation, religious offering, cosmetic production, medicinal purposes, and animal feed. The study was conducted to evaluate four marigold varieties, i.e., 'Karma Orange', 'Karma-I-Orange', 'Karma-555-Orange', and 'Karma-777-Orange', for their vegetative, floral, and yield attributes. The experiment was laid out on a Randomized Complete Block Design at three localities of Nepal including Kaski, Kathmandu, and Lalitpur districts and was conducted from August 2019 to January 2020. Data on predetermined parameters were collected and analyzed using R-program (version 4.0.5). The location of the varieties and the interaction between them showed significant variations for almost all parameters. Marigold production was more favorable under the Kaski conditions as plant height, plant spread, number of flowers/plant, and yield were higher than those in other locations. In addition, the number of days taken by marigold varieties for the formation of flower bloom was significantly lower in the Kaski conditions. The variety 'Karma Orange' had the maximum height (81.88 ± 5.18 cm), which is very susceptible for lodging, and had the minimum number of flowers (83.2 ± 3.78). The variety 'Karma-555-Orange' produced the highest numbers of flowers/plant (104.38 ± 9.46) and had medium-sized flowers with perfect ball shape, which is very suitable for making garlands. However, the variety 'Karma-777-Orange' had medium plant height (51.49 ± 2.67), produced not significantly different number of flowers than 'Karma-555-Orange' (101.64 ± 6.57) and yield (1.86 ± 0.1 kg/plant). It is suitable for bedding, potting, and cut flower production.

Abstract

Keywords: Bloom, Bud, Interaction, Petals.

INTRODUCTION

The marigold (*Tagetes erecta*) from the family Asteraceae is a common ornamental flower used mainly for decoration, gardening, religious offerings, cosmetic preparations, and medicines. It is native to South and Central America and Mexico, where it is used as medicine and for ornamental purposes (Mahantesh *et al.*, 2018). *T. erecta*, which are also called African marigolds, are tall marigolds that can grow up to three feet in height and produce large globe-shaped flowers. They can also be used for bedding purposes (Dixit *et al.*, 2013). Marigolds have orange to yellow colors, which is perfect for a combination of any color scheme. It is also important as a raw material of many industries since it contains high amounts of carotenoid, essential oil, and alkaloid (Pérez *et al.*, 2006). □ The flowers of African marigolds are mainly used for the extraction of 1-lemoene, ecomene, 1-linylacetate, and 1-linauol (Narsude *et al.*, 2010). Marigolds can be grown in a wide variety of soils and they require a mild climate for luxuriant growth and profuse flowering.

Seed quality and required suitable management practices can be identified by varietal characterization and identification in all horticultural crops. Improvement of the floriculture sector can have a significant impact on the economy of Nepal. With the improvement of the economic sector and development, people also started to invest in flowers and ornamentation. In the case of Nepal, marigolds are widely used at the season of wedding and festivals, especially at the time of Tihar. People use locally available varieties and some inbred varieties imported from India for plantation, but these collections used earlier were of low yield, produced flowers with poor quality, and had about 50% off-type of flower.

Therefore, it is realized that under the changing conditions and advancement of the floriculture sector, some high-yielding F1 varieties should be evaluated at the conditions of Nepal for different parameters to recommend farmers for exploitation of their production potential, which will fetch the profit to farmers. Given this high importance, four marigold varieties were assessed to evaluate the vegetative, floral, and yield attributes in the conditions of Nepal.

MATERIALS AND METHODS

Location

This research was conducted in the three localities in Nepal, i.e., Kaski, Kathmandu, and Lalitpur, from August 2019 to January 2020. The latitude, longitude, and elevation of sites are presented in Table 1.

Climate

The climate of Hemja is warm and temperate. The summers are much rainier than the winters in Hemja. The average annual temperature is 19.7 °C and the rainfall is 2693 mm/year. The remaining two experimental sites have mild and generally warm climates. In winters, there is much less rainfall than in summers. The average annual rainfall amounts to 1400 mm and the average winter temperature is around 11°C, which goes up to 27/29 °C in summers.

Table 1. Latitudes, longitudes, and elevations of the experimental sites.

Location	Latitude	Longitude	Elevation
Kaski	28° 19' 60.00" N	84° 00' 0.00" E	1058 masl
Kathmandu	27°42'59.99" N	85°26'59.99" E	1777 masl
Lalitpur	27° 40' 2" N	85° 20' 30" E	1579 masl

Soil

A composite soil sample was taken from the top (0-30 cm) layer of the experimental plot before transplanting marigold seedlings. Instrumental analysis of soil was carried out to determine soil pH and soil EC, and the general visual and feeling method was used to determine its physical properties. The information of soil analysis conducted at the Karma Groups of Companies is presented in Table 2.

Experimental details

The experiment was laid out on a Randomized Complete Block Design (RCBD). It consisted of four F1 hybrid varieties of marigold (collected from different sources) as treatments (Table 3) with six replications. The size of the individual plot was maintained at 6 m². Eighteen plants were planted in each plot. The crop was planted at a spacing of 0.5 m x 0.5 m. A 1-m distance was maintained between two adjacent replications. Similarly, the distance between two adjacent plots was maintained at 0.5 m. Randomization of treatments was done by the lottery method.

Management practice

The experimental field was prepared by deep digging a week before transplanting. The layout was done prior to transplanting. Akanee at 3 g m⁻², Karma Bio at 1.5 g m⁻², SSP at 68.3 g m⁻², and MOP at 16.7 g m⁻² were applied as a basal dose of the fertilizer during the final land preparation. The weekly spray schedule was followed as per the package of the practice of Karma Groups, which included the foliar application of NPK, micronutrients, fungicides, and insecticides. Seeds were sown on trays with 128 holes on August 2, 2019. Seedlings at two pairs of true leaf stage were transplanted at a mulched film on August 20, 2019. Transplanting was done at a PP×RR spacing of 50 cm×50 cm. Light irrigation was provided just after transplanting for the better anchorage of the marigold seedlings. Dead plants were replaced within a week after transplanting. All the inter-cultural operations like weeding and hoeing were carried out when necessary. Irrigation was provided by a water pipe on a weekly basis.

Table 2. The physical and chemical characteristics of the soil at the three experimental sites, Nepal, 2019/2020.

Location	pH	EC	Texture
Kaski	6.8	0.43 mS cm ⁻¹	Sandy loam
Kathmandu	6.0	0.21 mS cm ⁻¹	Clay
Lalitpur	6.6	0.33 mS cm ⁻¹	Sandy clay

Table 3. Description of marigold varieties used in the experiment as treatments.

Varieties	Flower color	Flower shape	Petals	Compactness	Source
Karma Orange	Deep orange	Flat	Flat	Fragile	Ameriseed International Co., Ltd.
Karma-I-Orange	Orange	Semi-ball	Flat	Compact	Ameriseed International Co., Ltd.
Karma-555-Orange	Light orange	Ball	Tube	Medium compact	Karma International Seeds
Karma-777-Orange	Orange	Semi-ball	Flat	Compact	Karma International Seeds

Observation

Three randomly selected plants were observed for twelve characters, i.e., plant height (cm), plant spread (cm), number of primary branches, number of nodes, days to first flower bud formation, days to complete bloom, number of flowers/plant, number of petals/flower, flower diameter (cm), flower depth (cm), flower weight (g), and yield (kg/plant).

Data analysis

All observed, measured, and calculated data were encoded in Microsoft excel (MAC version 16.16.15) for data curation and management. R-program (version 4.0.5) was used for data analysis. Statistical tools such as one-way ANOVA were used to check significant differences between treatments and Least Significance Difference (LSD) at 0.05 significant level was used to compare differences between treatment means.

RESULTS

The analysis of variance showed that almost all of the parameters were significantly affected the varieties, locations, and interactions between them.

Effect of location

Location exerted a significant influence ($P < 0.01$) on the parameters on plant height (cm), plant spread (cm), primary branches, number of nodes (cm), days to first flower bud formation, days to complete flower bloom, number of flowers, yield (kg/plant), number of petals/flower, flower diameter (cm), flower weight (g) and flower depth (cm).

Effect of varieties

Plant height (cm), plant spread (cm), number of nodes (cm), days to first flower bud formation, days to complete flower bloom, number of flowers, yield (kg/plant), number of petals/flower, flower diameter (cm), flower weight (g) and flower depth (cm) were significantly ($P < 0.05$) affected by varieties.

Effect of interaction of varieties and location.

The interaction between variety and location was significant ($P < 0.05$) on plant height (cm), plant spread (cm), number of nodes (cm), days to complete flower bloom, number of flowers, yield (kg/plant), number of petals/flower, flower diameter (cm), flower weight (g), and flower depth (cm).

Vegetative/ growth parameters

Plant height (82.72 ± 3.91 cm), plant spread (77.48 ± 1.57 cm), and the number of primary branches (16.75 ± 0.13) were the highest in Kaski, differing significantly from that in the other locations. Lalitpur was found to have the minimum plant height (52.58 ± 2.61 cm), number of primary branches (12.51 ± 0.28), and number of nodes (7.18 ± 0.21), being significantly different from the other two locations. Regarding varieties, 'Karma Orange' was found to be the superior variety in terms of plant height (81.88 ± 5.18 cm) and plant spread (70.47 ± 1.78 cm) so that its plant height was significantly different from that of the other three varieties. The number of primary branches ranged from 14.50 ± 0.48 in 'Karma-777-Orange' to 14.96 ± 0.57 in 'Karma-555-Orange'. However, these figures were not significantly different from each other. The number of nodes was found to be the highest in Kathmandu (8.45 ± 0.15) and it was significantly different only from that of Lalitpur (7.18 ± 0.21).

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Table 4. Analysis of variance to evaluate the effect of marigold varieties and location on different growth, flowering, yield, and floral parameters during 2019/20.

Parameters	Location	Variety	Loc × Variety
Plant height	<2e-16 ***	<2e-16 ***	<2e-16 ***
Plant spread	<2e-16 ***	<2e-16 ***	6.41e-07 ***
No. of primary branches	< 2e-16 ***	0.642	0.313
No. of nodes	1.6e-08 ***	0.034616 *	0.000798 ***
Days to flower bud formation	3.94e-09 ***	0.000894 ***	0.096417
Days to flower bloom	<2e-16 ***	4.02e-05 ***	0.000672 ***
No. of flowers	< 2e-16 ***	1.45e-06 ***	2.83e-06 ***
No. of petals	< 2e-16 ***	< 2e-16 ***	1.3e-08 ***
Flower diameter	1.32e-09 ***	2.46e-06 ***	5.06e-14 ***
Flower depth	7.42e-07 ***	0.0144 *	2.76e-08 ***
Flower weight	< 2e-16 ***	< 2e-16 ***	0.000792 ***
Yield	< 2e-16 ***	1.39e-11 ***	0.00598 **

*, **, *** and ns: Significant at P < 0.05, P < 0.01, P < 0.001 and non-significant, respectively.

Table 5. Mean values of plant height, plant spread, number of primary branches, and number of nodes of marigold varieties across locations during 2019/20.

Location	Plant height (cm)	Plant spread (cm)	Primary branches	Number of nodes
Kaski	82.72±3.91 ^a	77.48±1.57 ^a	16.75±0.13 ^a	8.45±0.15 ^a
Kathmandu	55.87±1.56 ^b	56.22±1.5 ^b	14.79±0.23 ^b	8.5±0.15 ^a
Lalitpur	52.58±2.61 ^c	57.21±1.41 ^b	12.51±0.28 ^c	7.18±0.21 ^b
LSD	1.54***	1.87***	0.64***	0.42***
Varieties				
Karma Orange	81.88±5.18 ^a	70.47±1.78 ^a	14.62±0.57 ^a	8.24±0.15 ^a
Karma-I-Orange	68.94±2.63 ^b	58.87±2.19 ^b	14.64±0.45 ^a	7.61±0.3 ^b
Karma-555-Orange	52.58±3.02 ^c	68.52±3.41 ^a	14.96±0.45 ^a	8.27±0.3 ^a
Karma-777-Orange	51.49±2.67 ^c	56.7±2.61 ^c	14.50±0.48 ^a	8.05±0.17 ^{ab}
Mean	63.73	63.64	14.68	8.04
LSD	1.78***	2.16***	0.74ns	0.49*
CV (%)	4.19	5.10	7.58	9.21

Means with similar letter (s) in each column show the lack of a significant difference at the P < 0.05 level based on the LSD test. *, *** and ns: Significant at P < 0.05, P < 0.001 and non-significant, respectively.

Interaction of location and variety (Table 6) shows that the height of 'Karma Orange' (111.67 ± 2.18 cm) at Kaski was the highest and significantly different from that of the other interactions. The plant heights of 'Karma-I-Orange' (40.76 ± 0.59 cm) and 'Karma-777-Orange' (40.20 ± 1.10 cm) at Lalitpur were not statistically different and both were the lowest. Plant spread of 'Karma-555-Orange' (87.58 ± 1.77 cm) was found to be the highest at Kaski. It was significantly different than the other values, while it was observed to be the lowest at Kathmandu (48.41 ± 1.37 cm) by not being significantly different. The number of nodes (9.22 ± 0.22) was the highest in 'Karma-555-Orange' at Kathmandu, which was significantly different only from that of the other three varieties at Lalitpur.

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Table 6. The effect of location and variety interaction on plant height, plant spread, number of primary branches, and number of nodes of marigold varieties across locations during 2019/20.

Interaction (Location × Variety)	Plant height (cm)	Plant spread (cm)	Number of nodes	Primary branches
L1×V1	111.67±2.18 ^a	79.47±2.30 ^b	8.38±0.29 ^{abc}	3.25±0.07 ^f
L1×V2	66.72±0.65 ^c	71.38±0.59 ^c	8.22±0.25 ^{abc}	3.20±0.10 ^f
L1×V3	86.33±0.68 ^b	87.58±1.77 ^a	8.61±0.43 ^{ab}	3.28±0.04 ^f
L1×V4	66.16±0.75 ^{cd}	71.50±1.07 ^c	8.61±0.32 ^{ab}	3.02±0.15 ^f
L2×V1	65.61±1.49 ^{cd}	66.25±1.07 ^{cd}	8.16±0.33 ^{abc}	7.21±0.18 ^{bc}
L2×V2	50.27±1.06 ^f	53.63±1.08 ^{fg}	8.55±0.23 ^{ab}	5.92±0.20 ^{de}
L2×V3	59.50±1.04 ^e	56.61±1.97 ^{ef}	9.22±0.22 ^a	6.63±0.17 ^{bcd}
L2×V4	48.11±0.77 ^f	48.41±1.37 ^g	8.05±0.2 ^{abc}	6.06±0.22 ^{cde}
L3×V1	68.38±0.80 ^c	65.69±1.33 ^{cd}	8.16±0.23 ^{abc}	7.49±0.30 ^b
L3×V2	40.76±0.59 ^g	51.59±0.53 ^{fg}	6.05±0.29 ^d	7.08±0.33 ^{bcd}
L3×V3	61.00±0.84 ^{de}	61.37±0.58 ^{de}	7.00±0.46 ^{cd}	9.60±0.54 ^a
L3×V4	40.20±1.10 ^g	50.18±0.73 ^g	7.50±0.20 ^{bcd}	5.00±0.28 ^e
Mean	63.73	63.64	14.69	5.65
LSD	5.23 ^{***}	6.37 ^{***}	1.46 ^{***}	1.23 ^{***}
CV (%)	3.96	4.64	7.38	9.15

Means with similar letter (s) in each column show the lack of a significant difference at the $P < 0.05$ level based on the LSD test. ***: Significance at the $P < 0.01$. L1 = Kaski, L2 = Kathmandu, L3 = Lalitpur, V1 = Karma Orange, V2 = Karma-I-Orange, V3 = Karma-555-Orange, V4 = Karma-777-Orange.

Flowering / yield parameters

Days to flower bud formation (38.15 ± 0.19) was the longest in Kaski, significantly differing from the other two locations. Contrary to this trait, days to flower bloom (56.06 ± 0.1) was the shortest in location Kaski and was also significantly different than that in the other locations. It took 61.3 ± 0.07 days for the flower bloom to form in Kathmandu, which was significantly different than that in the other locations. Among the varieties, 'Karma-777-Orange' took the shortest duration for the formation of the flower bud (35.72 ± 0.57) and bloom (58.46 ± 0.57). It differed from the other varieties significantly.

The shortest duration for flowering was related to 'Karma-777-Orange' (55.60 ± 0.33 days) in Kaski, which was statistically similar to the duration taken by other varieties in the same location. The longest duration (61.50 ± 0.29 days) for flowering was obtained from the interaction of Lalitpur and 'Karma-555-Orange' and it was statistically similar to the interaction of Kathmandu and all varieties and interaction of Lalitpur and all varieties except for 'Karma-777-Orange' (58.50 ± 0.45 days).

The number of flowers (130.29 ± 4.11) and yield/plant (2.07 ± 0.07 kg) were the highest in Kaski, which was significantly higher than that in the other locations. The lowest number of flowers per plant (76.33 ± 1.74) was found in Lalitpur, but the lowest yield/plant (1.32 ± 0.05 kg) was found in Kathmandu. The variety 'Karma-555-Orange' produced the highest number of flowers (104.38 ± 9.46), significantly differing only from 'Karma Orange' (83.20 ± 3.78) while yield/plant was found to be the highest in 'Karma-I-Orange' (1.93 ± 0.10), which was statistically similar to 'Karma-777-Orange' (1.86 ± 0.10). The lowest yield was observed in 'Karma-555-Orange' (1.37 ± 0.09) and it was statistically similar to the yield of 'Karma Orange' (1.49 ± 0.06). The highest number of flowers was produced by 'Karma-555-Orange' in Kaski (152.38 ± 4.10) and the lowest

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Table 7. The mean values of days to flower bud formation, days to flower bloom, number of flowers, and yield/plant (kg) of marigold varieties across locations during 2019/20.

Location	Days to flower bud formation	Days to flower bloom	Number of flowers	Yield/plant (kg)
Kaski	38.15±0.19 ^a	56.06±0.15 ^c	130.29±4.11 ^a	2.07±0.07 ^a
Kathmandu	36.16±0.26 ^b	61.3±0.07 ^a	85.79±3.81 ^b	1.32±0.05 ^c
Lalitpur	35.81±0.34 ^b	60.51±0.32 ^b	76.33±1.74 ^c	1.60±0.06 ^b
LSD	0.46 ^{***}	0.68 ^{***}	6.6 ^{***}	0.13 ^{***}
Varieties				
Karma Orange	37.05±0.25 ^a	59.5±0.61 ^a	83.20±3.78 ^b	1.49±0.06 ^b
Karma-I-Orange	36.75±0.35 ^a	59.44±0.61 ^a	100.64±5.38 ^a	1.93±0.10 ^a
Karma-555-Orange	37.31±0.22 ^a	59.77±0.58 ^a	104.38±9.46 ^a	1.37±0.09 ^b
Karma-777-Orange	35.72±0.57 ^b	58.46±0.57 ^b	101.64±6.57 ^a	1.86±0.10 ^a
Mean	59.30	36.71	97.47	1.67
LSD	0.53 ^{***}	0.79 ^{***}	7.63 ^{***}	0.15 ^{***}
CV (%)	1.35	3.22	11.7	13.04

Means with similar letter (s) in each column show the lack of a significant difference at the $P < 0.05$ level based on the LSD test. ^{***}: Significance at the $P < 0.01$.

Table 8. The effect of location and variety interaction on days to flower bud formation, days to flower bloom, number of flowers, and yield/plant (kg) of marigold varieties across different locations during 2019/20.

Interaction (Location × Variety)	Days to flower bud formation	Days to flower bloom	Flower/plants	Yield/plant (kg)
L1×V1	38.38±0.41	56.10±0.30 ^c	101.77±2.15 ^c	1.67±0.05 ^{bcd}
L1×V2	38.11±0.23	56.00±0.29 ^c	129.16±3.53 ^b	2.35±0.11 ^a
L1×V3	38.11±0.58	56.40±0.28 ^c	152.38±4.10 ^a	1.89±0.11 ^{bc}
L1×V4	38.00±0.37	55.60±0.33 ^c	137.83±2.26 ^{ab}	2.39±0.08 ^a
L2×V1	37.00±0.07	61.30±0.21 ^a	81.72±3.44 ^{cde}	1.29±0.13 ^{def}
L2×V2	36.94±0.46	61.20±0.14 ^a	94.55±3.45 ^{cd}	1.46±0.06 ^{de}
L2×V3	36.88±0.05	61.30±0.13 ^a	73.94±13.4 ^{de}	1.01±0.03 ^f
L2×V4	36.16±0.64	61.20±0.14 ^a	92.94±2.61 ^{cd}	1.51±0.08 ^{cde}
L3×V1	36.05±0.33	60.90±0.59 ^a	66.11±1.34 ^e	1.52±0.08 ^{cde}
L3×V2	35.83±0.42	61.10±0.4 ^a	78.22±0.94 ^{de}	1.99±0.08 ^{ab}
L3×V3	34.77±0.19	61.50±0.29 ^a	86.83±2.79 ^{cde}	1.21±0.03 ^{ef}
L3×V4	34.27±1.05	58.50±0.45 ^b	74.16±0.97 ^{de}	1.68±0.1b ^{cd}
Mean	36.71	59.30	97.47	1.67
LSD	2.32 ^{ns}	1.57 ^{***}	22.46 ^{***}	0.43 ^{**}
CV (%)	2.73	1.24	9.35	12.04

Means with similar letter (s) in each column show the lack of a significant difference at the $P < 0.05$ level based on the LSD test. ^{ns} and ^{***}: Non-significance and significance at the $P < 0.001$, respectively. L1 = Kaski, L2 = Kathmandu, L3 = Lalitpur, V1 = Karma Orange, V2 = Karma-I-Orange, V3 = Karma-555-Orange, V4 = Karma-777-Orange.

was observed in the interaction of Lalitpur and ‘Karma Orange’ (66.11 ± 1.34). The highest yield/plant obtained from the interaction of Kaski and ‘Karma-777-Orange’ (2.39 ± 0.08) which was statistically similar to the interaction of Kaski and ‘Karma-I-Orange’ (2.35 ± 0.11) and the interaction of Lalitpur and ‘Karma-I-Orange’ (1.99 ± 0.08 kg). The lowest yield/plant was observed in ‘Karma-555-Orange’ at Kathmandu (1.01 ± 0.03 kg), which was not significantly different from the interaction of Kathmandu and ‘Karma Orange’ (1.29 ± 0.13) and Lalitpur and ‘Karma-555-Orange’ (1.68 ± 0.10).

Floral traits

The number of petals/flower (442.75 ± 24.58), flower diameter (8.84 ± 0.17 cm), flower weight (23.04 ± 0.85 g), and flower depth (5.07 ± 0.07 cm) were found to be the highest in Lalitpur and were significantly different from those in the other locations. Regarding the variety, the number of petals was the highest in ‘Karma-777-Orange’ (528.96 ± 13.5) and the lowest in ‘Karma Orange’ (334.68 ± 6.88) and both were significantly different from that of the other varieties and each other. Flower diameter was found to be the highest in ‘Karma-I-Orange’ (8.60 ± 0.16 cm), but it was significantly different from only ‘Karma-555-Orange’ (7.78 ± 0.10 cm). Likewise, flower depth was the highest in ‘Karma-I-Orange’ (4.95 ± 0.10 cm), and it was statistically different from ‘Karma-555-Orange’ (4.61 ± 0.05 cm).

Table 9. Mean values of petals/flower, flower diameter, flower weight, and flower depth of marigold varieties across locations during 2019/20.

Location	Petals/flower	Flower diameter (cm)	Flower weight (g)	Flower depth (cm)
Kaski	406.51±26.36 ^b	7.85±0.15 ^c	15.71±0.38 ^b	4.58±0.09 ^b
Kathmandu	376.31±19.13 ^c	8.26±0.17 ^b	15.53±0.59 ^b	4.68±0.09 ^b
Lalitpur	442.75±24.58 ^a	8.84±0.17 ^a	23.04±0.85 ^a	5.07±0.07 ^a
LSD	10.54***	0.25***	0.90***	0.17***
Varieties				
Karma Orange	334.68±6.88 ^c	8.48±0.21 ^a	19.02±0.99 ^a	4.77±0.14 ^{ab}
Karma-I-Orange	502.77±7.12 ^b	8.60±0.16 ^a	19.82±1.02 ^a	4.95±0.10 ^a
Karma-555-Orange	267.68±5.74 ^d	7.78±0.10 ^b	13.73±0.57 ^b	4.61±0.05 ^b
Karma-777-Orange	528.96±13.5 ^a	8.41±0.28 ^a	19.81±1.09 ^a	4.77±0.11 ^{ab}
Mean	408.52	8.32	18.09	4.78
LSD	12.17***	0.29***	1.04***	0.20***
CV (%)	4.47	5.37	8.63	6.33

Means with similar letter (s) in each column show the lack of a significant difference at the $P < 0.05$ level based on the LSD test. ***: Significance at the $P < 0.001$, respectively.

The interaction of Lalitpur and ‘Karma-777-Orange’ (586.16 ± 2.15) was found to be superior in terms of the number of petals/flower and was significantly different from the other interactions while the interaction of Kathmandu and ‘Karma-555-Orange’ (260.66 ± 5.53) had lowest numbers of petals and statistically different from the other interactions except for ‘Karma-555-Orange’ at Lalitpur (295.94 ± 4.78). ‘Karma Orange’ (9.57 ± 0.11 cm) at Kathmandu produced the largest flower diameter and ‘Karma-777-Orange’ at Kaski produced the lowest one (6.86 ± 0.23 cm). The weight of flowers was the highest at Lalitpur in ‘Karma-777-Orange’ (25.69 ± 1.07 g), and it was significantly different only from ‘Karma-555-Orange’ (16.68 ± 0.57 g) at the same location. The

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lowest weight was observed at Kathmandu in ‘Karma-555-Orange’ (11.42 ± 0.35 g). The interaction of Lalitpur and ‘Karma Orange’ was related to the highest flower depth (5.46 ± 0.08 cm) whereas the lowest depth was obtained from ‘Karma-777-Orange’ (4.10 ± 0.07 cm) at Kaski.

Table 10. The effect of location and variety interaction on petals/flower, flower diameter, flower weight, and flower depth of marigold varieties across locations during 2019/20.

Interaction (Location × Variety)	Petals/flower	Flower diameter (cm)	Flower depth (cm)	Flower weight
L1×V1	323.5±10.85 ^e	8.24±0.17 ^{cde}	4.66±0.12 ^{bc}	16.55±0.43 ^b
L1×V2	513.83±1.03 ^b	8.00±0.28 ^{d^e}	4.86±0.22 ^b	17.16±0.62 ^b
L1×V3	246.44±4.85 ^g	8.32±0.13 ^{bcd^e}	4.70±0.13 ^{bc}	13.09±0.27 ^{cd}
L1×V4	542.27±12.50 ^b	6.86±0.23 ^f	4.10±0.07 ^c	16.03±0.27 ^{bc}
L2×V1	315.77±4.61 ^e	7.63±0.18 ^{ef}	4.19±0.13 ^c	15.98±0.55 ^{bc}
L2×V2	470.38±11.31 ^c	8.73±0.25 ^{abcd}	4.85±0.21 ^b	17.03±0.97 ^b
L2×V3	260.66±5.53 ^{fg}	7.51±0.08 ^{ef}	4.57±0.07 ^{bc}	11.42±0.35 ^d
L2×V4	458.44±5.28 ^c	9.18±0.19 ^{ab}	5.10±0.05 ^{ab}	17.68±0.58 ^b
L3×V1	364.77±8.19 ^d	9.57±0.11 ^a	5.46±0.08 ^a	24.52±0.72 ^a
L3×V2	524.11±7.92 ^b	9.08±0.10 ^{abc}	5.16±0.01 ^{ab}	25.26±0.63 ^a
L3×V3	295.94±4.78 ^{ef}	7.51±0.08 ^{ef}	4.57±0.07 ^{bc}	16.68±0.57 ^b
L3×V4	586.16±2.15 ^a	9.18±0.19 ^{ab}	5.10±0.05 ^{ab}	25.69±1.07 ^a
Mean	408.53	8.32	4.78	18.10
LSD	35.84 ^{***}	0.88 ^{***}	0.599 ^{***}	2.44 ^{***}
CV (%)	4.23	5.09	5.58	7.94

Means with similar letter (s) in each column show the lack of a significant difference at the $P < 0.05$ level based on the LSD test. ***: Significance at the $P < 0.001$, respectively. L1 = Kaski, L2 = Kathmandu, L3 = Lalitpur, V1 = Karma Orange, V2 = Karma-I-Orange, V3 = Karma-555-Orange, V4 = Karma-777-Orange.

DISCUSSION

The study showed significant results as to the parameters of plant height (cm), plant spread (cm), number of primary branches, number of nodes, days to flower bud formation, days to flower bloom, number of flowers/plants, number of petals/flowers, flower diameter (cm), flower depth (cm), flower weight (cm), and yield (kg/plant). Significant interactions might be observed due to the climatic variability between the locations.

Growth/vegetative parameters, like plant height (cm), plant spread (cm), number of primary branches, and number of nodes, are related to plant vigor and bushiness. In Nepal, marigold flowers require medium plant height, a greater number of primary branches, and a good spread, which can bear a greater number of flowers. It should also be resistant to lodging. The variation observed in this result is due to the genotype, environment, and their interaction. This variation agrees with the findings of Nidhi and Mohammad (2013), Umesh *et al.* (2018), Rolaniya *et al.* (2017), Kumar *et al.* (2019), Mahantesh *et al.* (2018), Netam *et al.* (2019), and Choudhary *et al.* (2014).

Flowering parameters like days to flower bud formation and days to flower bloom determine the precocity of flowers. These parameters assist to determine the planting time of marigold varieties. Variations were observed among the marigold varieties. Such variations in these attributes were also observed by Lohar *et al.* (2018), Rolaniya *et al.* (2017), Kurakula *et al.* (2018), Hemlata and Singh (2017), and Naik *et al.* (2019). Yield and yield-related traits are the most important to determine the suitability and adaptability of flower varieties. The number of flowers/plant and yield varied greatly with the location and varieties. This result is in line with the results of Umesh *et al.* (2018) and Mahantesh *et al.* (2018).

Floral attributes consist of flower weight, flower diameter, flower depth, and the number of petals/flower. Flower weight, diameter, and depth determine the shape, size, and weight of the flowers. The compactness of flowers and size can be determined through the number of petals. Floral characters were different in different varieties of the marigold and the finding is supported by Umesh *et al.* (2018), Gupta *et al.* (2014), and Naik *et al.* (2019).

CONCLUSION

Based on this experiment, Kaski is found to be the most suitable location for the cultivation of cut-type marigold varieties. This location has a lower elevation, higher temperature, and good soil structure than the Kathmandu and Lalitpur area, so all varieties performed better in terms of growth, flowering, floral, and yield-related traits at this location. Among varieties, 'Karma Orange' had the maximum height and produced fewer flowers and lower yield, so this is very susceptible to lodging and is not recommended. In the case of Nepal, marigolds are famous for making garlands that require medium or small-sized ball-shaped flowers and the requirement can be satisfied by the variety 'Karma-555-Orange'. However, the most suitable variety can be 'Karma-777-Orange', which has medium plant height and can produce high numbers of flowers/plant and more yield/plant. In addition, due to the bushy structure and medium plant height, this variety can be used for bedding purposes too.

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