Effect of maleic hydrazide and gibberellic acid on growth and yield of African marigold (*Tagetes erecta* L.) cv. Calcuttia Orange

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**Abstract**
A field experiment was carried out during the month of August – December 2020 at the Floriculture Development Center, Godawari, Lalitpur, Nepal. The experiment was conducted in randomized block design with seven treatments comprising of 3 levels each of maleic hydrazide (MH) (T2: 200 ppm, T3: 300 ppm, T4: 400 ppm) and gibberellic acid (GA3) (T5: 100 ppm, T6: 200 ppm, T7: 300 ppm) along with control (T1) replicated thrice with an objective to assess the impact of MH and GA3 on production and productivity of African marigold (*Tagetes erecta* L.) cv. Calcuttia Orange. The foliar spray of the growth regulators was applied at 30 days after transplanting (DAT). The result revealed that vegetative growth viz. plant spread (2083 cm²), stem diameter (1.2 cm), number of primary (8.13) and secondary branches (28.27) was recorded significantly maximum with the treatment of MH at 400 ppm. The plant height (56.33 cm) was found to be maximum when treated with GA3 at 200 ppm whereas MH at 300 ppm resulted in highest number of leaves (139.26). First flowering (45 d), 50% flowering (50 d), full bloom (54 d), maximum flower weight (11.33 g) and maximum flower diameter (8.10 cm) were achieved with GA3 at 200 ppm. However, the maximum number of flowers (29) was obtained by the foliar spray of MH at 400 ppm. MH at 400 ppm resulted the maximum yield of the flowers (23.528 t ha⁻¹) followed by GA3 at 200 ppm (23.079 t ha⁻¹). The experiment concluded that MH at 400 ppm and GA3 at 200 ppm contributed to increased growth, flowering and yield of the crop.

**Keywords:** African marigold, treatment, yield, foliar spray

**1 Introduction**
African marigold (*Tagetes erecta* L.) belonging to family Asteraceae is one of the most popular annual flower crop grown on a commercial scale (Sunayana et al., 2018). *Tagetes erecta* (African marigold) and *Tagetes patula* (French marigold) are popular for commercial purpose in Nepal (Dhakal, 2017). The African marigold is the tallest of all species, growing to a height of three to four feet. Its growing popularity is due to its ease of culture, adaptability, habit of free flowering, variety of colors and requires short time to produce marketable flowers, and profitable returns (Kumar et al., 2010). African marigold has been identified as a possible source of carotenoids including lutein and zeaxanthin. They are currently used in ophthalmology to combat diseases like cataract and age-related macular degeneration (ARMD), as well as food colorants, dietary nutrients, and poultry feed additives to enhance the color of egg yolks and poultry skin (Gupta, 2014). Marigold flowers have an important position during Tihar festival in Nepal. It is estimated that the Kathmandu valley alone con-
sumes around 75% of the marigolds sold across the country during Tihar (Floral Daily, 2017). The sale of marigold garland per day is 10,000-15,000 and the price of each garland is NRs. 60-70 (FAN, 2020).

Different agrochemicals have been used in recent years to ensure proper growth and flowering. Plant growth regulators (PGRs) or phytohormones are organic compounds produced naturally in higher plants other than nutrients that control growth or other physiological functions at a site remote from their source of production and are active in minute amounts (Bisht et al., 2018). Among the different plant growth regulators, some are growth promoters while others are growth retardants. Growth promoters such as GA3 play a vital role in improving the vegetative characters of the plants as it enhances the elongation and cell division by promoting the DNA synthesis in the cell (Meshram et al., 2015). Plant growth retardants such as MH are chemical compounds that regulate plant growth and development and are widely used in the floriculture industry (Sunayana et al., 2018).

Maleic hydrazide causes decrease in plant height with an increase in leaf area and chlorophyll content as well as flower diameter and results in an increase in flower weight. It might be due to accumulation of more metabolites and availability of reserve food for the reproductive growth thereby increased flower yield (Ahmad et al., 2019). On the other hand, Gibberellins reduces juvenile period and with the termination of juvenile phase, the shoot apical meristem instead of producing leaves and branches start producing buds and therefore the flowering is hastened (Kumar et al., 2014).

A study was carried out at Godawari in 2020 with an objective to access the impact of maleic hydrazide and gibberellic acid on production and productivity of African marigold in Godawari of Nepal. The output of the study will serve as valuable information to the marigold farmers as it gives them basic idea about how the crop responds to GA3 and MH.

### 2 Materials and Methods

#### 2.1 Study site and condition

The field experiment was conducted from September 2020 to December 2020 at the Floriculture Development Center, Godawari, Lalitpur, Nepal. Geographically, it is located at 27.59° N latitude and 85.39° E longitude having subtropical climate. Since, the research work was done under greenhouse condition; a psychrometer was attached to note the temperature as well as relative humidity inside the green house. It was noted each day and then the average was taken which is presented at Table 1.

#### 2.2 Treatment and design

The experiment comprised 7 treatments (Table 2) and was laid out in single factorial randomized complete block design with 3 replications. The total gross area and each plot area were found to be 112.95 m$^2$ 2.8 m $\times$ 1 m, respectively. The treatments were randomly allocated using a random number table. The foliar application of the treatments was given to the experimental marigold plants at 30 DAT by using hand atomizer at morning time. 1 mL of GA3 were dissolved in 1 L of distilled water to make 1000 ppm stock solution. Then, 200 mL, 400 mL, 600 mL of stock solution was mixed with 2 L of water each separately to obtain 100 ppm, 200 ppm and 300 ppm of the solution, respectively. Similarly, 1 g of maleic hydrazide was dissolved in 1 L of distilled water to make 1000 ppm stock solution. Then 400 mL, 600 mL, 800 mL of stock solution was mixed with 2 L of water each separately to obtain 200 ppm, 300 ppm and 400 ppm of stock solution, respectively.

### Table 1. Average temperature and relative humidity (RH) inside the green house

| Parameters | Avg. temp. (°C) | RH (%) |
|------------|----------------|--------|
| August     | 33.30          | 89     |
| September  | 30.01          | 88     |
| October    | 29.25          | 71     |
| November   | 25.50          | 62     |
| December   | 23.20          | 63     |

### Table 2. List of treatments used in the study

| # | Treatment Notation |
|---|--------------------|
| 1 | Control T1         |
| 2 | MH 200 ppm T2      |
| 3 | MH 300 ppm T3      |
| 4 | MH 400 ppm T4      |
| 5 | GA3 100 ppm T5     |
| 6 | GA3 200 ppm T6     |
| 7 | GA3 300 ppm T7     |

#### 2.3 Agronomy

The seeds of African marigold cv. Calcuttia Orange were obtained from the Floriculture Development Center (FDC), Godawari, Lalitpur. The seeds were sown in the nursery bed which was ready to be transplanted onto the poly bags within 8 days (two leaf stage). The seedlings were transplanted onto the main field at 24 days after sowing. The experimental field was divided into twenty-one plots resulting in the total net area to be 58.8 m$^2$. The experimental field was prepared with thorough ploughing followed by planking and was transplanted at a distance of 40 cm $\times$ 35 cm. It was provided with 1.5 kg of diammonium phosphate, 1.35 kg of urea and 1.35 kg of potash as basal dose and an additional 1.35 kg urea was applied.
to the plants as top dressing. Each experimental plot was applied with 70 gm of diammonium phosphate and 60 gm each of urea and potash as basal dose. In addition, each plot was provided with 60 gm of urea as top dressing at 30 DAT.

2.4 Observation and data collection

Observations on the growth and yield parameters were recorded from five plants which did not suffer from border effect and were selected per replication from each treatment. The growth parameters included plant height (cm), plant spread (cm²), number of leaves, stem diameter (cm), number of primary and secondary branches which were measured or counted at 15 DAT, 30 DAT, 45 DAT, 60 DAT, 75 DAT, and 90 DAT. The height of the plant was measured from the ground to the tip of the plant whereas plant spread was measured with measuring tape from North-South and East-West direction. Stem diameter was measured with the help of vernier caliper from 5 cm above the ground. Number of leaves, number of primary and secondary branches were counted and reported on mean basis. The flowering parameters included days to first flowering, days to 50% flowering, days to 100% flowering, number of flowers per plant, flower diameter (cm), flower weight (g) and flower yield (t ha⁻¹). The number of days taken for first flowering, 50% flowering and 100% flowering from the date of transplanting was counted and then the average was taken. Total number of flowers per plant was recorded from each tagged plant at each harvest. After the final harvest, the number of flowers of every picking was counted and then their average was worked out. The flower diameter was measured with the help of vernier caliper whereas the average flower weight was measured with the help of weighing balance and their mean was calculated. The flower yield was calculated by multiplying total number of plants and flower yield.

2.5 Data analysis

The data were collected, tabulated and processed in Microsoft Excel 2016 and statistically analyzed by using Genstat 18th edition statistical package. Means were separated using Duncan’s Multiple Range Test (DMRT) at 5% level of significance. Pearson’s correlation coefficient and regression equation were run to establish the relationship between different parameters and yield of African marigold.

3 Results and Discussion

3.1 Growth parameters

All the growth parameters were influenced significantly due to the application of various growth regulators (Table 3). The maximum plant height at 90 DAT was obtained in T6 (56.33 cm) whereas the minimum plant height was observed in T4 (46.33 cm) followed by T2 (48.63 cm). Similar findings were observed by Sarkar et al. (2018) who reported that the application of GA3 at 200 ppm recorded significantly higher plant height (85.36 cm) in African marigold. The minimum plant height of African marigold was obtained when treated with MH at 250 ppm (Sathappan, 2018). MH reduces the auxin activity thereby inhibiting cell division and elongation and as a result the height of plant is reduced (Patil, 1995). On the other hand, Meshram et al. (2015) reported that an application of GA3 in African marigold plant at different concentrations increases the growth of plant by increasing internodal length.

The treatment MH 400 ppm produced maximum plant spread (2132 cm²) followed by MH 300 ppm (2083 cm²) (Table 3). On the contrary, control (1402 cm²) recorded least plant spread followed by GA3 at 200 ppm (1719 cm²). The application of MH tends to encourage the growth of lateral branches and as a result the plant spread will be more. The stem diameter varied from 1.018 cm to 1.20 cm at 90 DAT. The maximum stem diameter was observed in MH 400 ppm whereas minimum stem diameter was observed in Control. The treatments T2, T3, T5, T6, and T7 were statistically at par.

The result showed that high significant variation in number of leaves was recorded (Table 3). T3 produced highest number (139) of leaves followed by T4 (118.3) whereas the lowest number of leaves was obtained with T1 (95) followed by T7 (103). It is evident from the findings that the number of leaves significantly increased with the spray of MH. Increase in leaf area and number might be due to the role of MH that suppresses the apical dominance and increases leaf number and area of the leaf.

Maximum number of primary (8) and secondary branches (28) were obtained with the application of MH 400 ppm (Table 3). On the other hand, control (T1) recorded minimum number of primary (6) and secondary branches (16). MH tends to cut off the basipetal flow of auxins and induce the sprouting of lateral vegetative buds to enhance the production of more number of primary and secondary branches (Goren et al., 2010).

3.2 Flowering and yield parameters

The data from Table 4 revealed that treatment GA3 at 200 ppm recorded earliest first flowering (44.67 d), earliest 50% flowering (49.67 d) and earliest full bloom (54 d). On the contrary, the maximum days taken for first flowering (54.33 d), 50% flowering (59.67 d), 100% flowering (68.67 d) was observed in Control (T1). GA3 reduces juvenile period and with the termination of juvenile phase, the shoot apical
Table 3. Effect of MH and GA3 on different growth parameters of African marigold at 90 DAT in Lalitpur, Nepal

| Treatments | Plant height (cm) | Plant spread (cm²) | Stem diameter (cm) | Number of leaves | Number of 1° branch | Number of 2° branch |
|------------|------------------|--------------------|-------------------|----------------|-------------------|-------------------|
| T1         | 52.80 abc        | 1402 a             | 1.018 a           | 94.7 a         | 5.533 a           | 16.47 a           |
| T2         | 48.63 ab         | 1761 b             | 1.027 ab          | 118.2 b        | 7.233 bc          | 20.20 ab          |
| T3         | 49.37 abc        | 2083 c             | 1.090 ab          | 139.3 c        | 7.333 bc          | 24.20 bc          |
| T4         | 46.33 a          | 2132 c             | 1.200 b           | 118.3 b        | 8.133 c           | 28.27 c           |
| T5         | 55.47 bc         | 1720 ab            | 1.098 ab          | 117.6 b        | 6.333 ab          | 21.23 ab          |
| T6         | 56.33 c          | 1719 b             | 1.167 ab          | 108.8 ab       | 7.067 bc          | 25.67 bc          |
| T7         | 56.13 c          | 1695 ab            | 1.067 ab          | 102.6 ab       | 6.467 ab          | 19.73 ab          |
| SEM (±)    | 2.16             | 96.8               | 0.05              | 5.63           | 0.41              | 1.77              |
| CV (%)     | 7.2              | 9.4                | 8                 | 10.5           | 13.8              |
| P value    | 0.031            | 0.003              | 0.187             | 0.031          | <0.001            |

Means within the column followed by the same letter are not significantly different at 5% level of significance by DMRT at 5% level of significance; 1° and 2° denote primary and secondary.

Table 4. Effect of MH and GA3 on different yield parameters of African marigold in Lalitpur, Nepal

| Treatments | Days to first flowering | Days to 50% flowering | Days to 100% flowering | Flowers no. at 105 DAT | Flower wt. (g) | Flower dia (cm) | Yield (t ha⁻¹) |
|------------|-------------------------|------------------------|------------------------|------------------------|---------------|----------------|---------------|
| T1         | 54.33 d                 | 59.67 c                | 68.67 e                | 18.09 a                | 8.333 a       | 5.630 a        | 11.293 a      |
| T2         | 50.33 c                 | 54.67 b                | 59.33 bd              | 20.78 ab               | 9.000 ab      | 6.477 b        | 13.947 ab     |
| T3         | 47 ab                   | 51.67 ab               | 55.67 a               | 27.51 cd               | 9.667 abc     | 7.143 c        | 19.834 cd     |
| T4         | 48.33 bc                | 54.33 b                | 56 ab                 | 29.34 d                | 10.667 cd     | 8.107 d        | 23.528 d      |
| T5         | 48.67 bc                | 52 ab                  | 56 abc                | 23.61 bc               | 10 bcd        | 6.710 bc       | 17.705 bc     |
| T6         | 44.67 a                 | 49.67 a                | 54 a                  | 27.15 cd               | 11.333 d      | 7.253 c        | 23.079 d      |
| T7         | 49.67 bc                | 54.33 b                | 60.33 d               | 23.32 bc               | 9.000 ab      | 6.353 b        | 15.887 bc     |
| SEM (±)    | 0.87                    | 1.12                   | 1.07                   | 1.31                   | 0.47          | 0.19           | 1369          |
| CV (%)     | 3.1                      | 3.6                    | 3.2                    | 9.4                    | 8.5           | 5              | 13.2          |
| P value    | <0.001                  | 0.001                  | <0.001                 | <0.001                 | 0.001         | <0.001         | <0.001        |

Means within the column followed by the same letter are not significantly different at 5% level of significance by DMRT at 5% Level of significance.
meristem instead of producing leaves and branches start producing buds and therefore the flowering is fastened (Kumar et al., 2014).

It is clear from the findings that the fresh flower weight was increased with the treatment of GA3 200 ppm followed by MH 400 ppm whereas the minimum flower weight was obtained with control (T1). It might be due to accumulation of more metabolites and availability of reserve food for the reproductive growth. The results are in agreement with the findings of Arshid (2009) and Haque et al. (2013) who found a significant increase in fresh and dry flower weight respectively in chrysanthemum with the application of growth retardants. The maximum flower diameter was obtained at T6 (8.10 cm) followed by T7 (7.25 cm). Minimum flower diameter was observed in Control (5.6 cm). However the maximum number of flowers at 105 DAT (27.15) was obtained with the plants that were treated with MH at 400 ppm (T4) followed by GA3 at 200 ppm (T6). The minimum number of flowers was obtained at T1 (18.09) followed by T2 (20.78).

MH resulted in reduction in plant height by suppressing the role of auxin and gibberillin which ultimately increased the number of main and secondary branches, thereby increasing flowers yield (Sharma et al., 1995; Dutta et al., 1998; Navale M U et al.). On the other hand, GA3 spray may provide better crop growth, more number of branches thus increase in number of flowers per plant. Also, the plants sprayed with GA3 had sufficient time to accumulate carbohydrate for proper flower bud differentiation due to enhanced reproductive efficiency and photosynthesis restrictive plant type.

The maximum yield (23.538 t ha\(^{-1}\)) was noted with the application of MH 400 ppm (T4) followed by GA3 200 ppm (23.079 t ha\(^{-1}\)). The minimum yield (11.293 t ha\(^{-1}\)) was recorded at control. Similar findings were obtained by Sunitha et al. (2007) and Kumar et al. (2010) in African marigold. The authors reported that, GA3 200 ppm recorded maximum flower yield in African marigold. As the apical dominance of the plant was suppressed, it allowed the lateral branches to grow more, resulting increase in the number of flowers subsequently increase in the yield.

### 3.3 Correlation with yield

All the growth and flowering parameters showed positive correlation with the yield (in kg ha\(^{-1}\)). The determination of different parameters on the yield is given in the Table 5. A positive correlation was observed between number of secondary branches and yield (kg ha\(^{-1}\)). It means that when the number of secondary branches increases, the flower yield also increases and vice-versa. The coefficient of determination 0.939 signifies that the contribution of number of secondary branches on flower yield (kg ropani\(^{-1}\)) is 93.9% and the rest of the effect was due to other factors.

| Parameters                  | R\(^2\) |
|-----------------------------|---------|
| Plant height                | 0.019   |
| Plant spread                | 0.536   |
| Stem Diameter               | 0.897   |
| Number of leaves            | 0.21    |
| Primary branches            | 0.568   |
| Secondary branches          | 0.939   |
| Days to first flowering      | 0.761   |
| Days to 50% flowering       | 0.563   |
| Days to 100% flowering      | 0.73    |
| Number of flowers           | 0.936   |
| Flower weight               | 0.886   |
| Flower diameter             | 0.884   |

### 3.4 Profitability

The result of this research and study (Table 6) shows that the benefit-cost ratio (BCR) ranged from 1.99 (control) to 5.23 (T4), which indicates that the farming of African marigold flower is financially viable. The plants treated with MH at 400 ppm (T4) had the maximum plant spread, number of secondary branches resulting in maximum number of flowers and maximum yield and therefore ultimately leading to highest BCR. Similarly the BCR was found to be 1.62 in African marigold grown in Kathmandu, Dhading and Kavre districts (Pradhan, 2016).

### 4 Conclusion

After the assessment of the response of different concentrations of GA3 and MH on marigold plant, it could be concluded that MH at 400 ppm and GA3 at 200 ppm contributed to increased growth, flowering and yield of the crop. Maleic hydrazide reduced the auxin activity resulting in decreased plant height, increased plant spread, increased leaf number, maximum primary and secondary branches and maximum number of flowers thereby resulting in maximum flower yield. GA3 on the other hand increased the inter nodal length and reduced the juvenile period resulting in maximum plant height, early flowering, maximum flower diameter and maximum flower weight. The flower yield obtained at 400 ppm MH is statistically at par with GA3 at 200 ppm. It can be concluded that though the working pathway of GA3 and MH were different, both of the hormones were able to contribute to maximum production and productivity.
### Table 6. Gross and net return of cultivating African marigold with different experimental treatments

| Treatment | Average price (NRS kg⁻¹) | Productivity (kg ha⁻¹) | Gross return (Nrs ha⁻¹) | TCP (Nrs ha⁻¹) | Net return (Nrs ha⁻¹) | B/C ratio |
|-----------|--------------------------|------------------------|------------------------|----------------|-----------------------|-----------|
| T1        | 150                      | 11293                  | 1693950                | 566263.5       | 1127687               | 1.99      |
| T2        | 150                      | 13947                  | 2092050                | 566263.5       | 1525787               | 2.69      |
| T3        | 150                      | 19834                  | 2975100                | 566263.5       | 2408337               | 4.25      |
| T4        | 150                      | 23528                  | 3529200                | 566263.5       | 2962937               | 5.23      |
| T5        | 150                      | 17705                  | 2655750                | 566263.5       | 2089487               | 3.68      |
| T6        | 150                      | 23079                  | 3461850                | 566263.5       | 2895587               | 5.11      |
| T7        | 150                      | 15887                  | 2383050                | 566263.5       | 1816787               | 3.2       |

TCP = total cost of production; B/C ratio = benefit-cost ratio

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### Conflict of Interest

The authors declare that there is no conflict of interests regarding the publication of this paper.

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