***Original Research Article***

**Climatic controls of marigold: Effect of temperature and rainfall on growth and yield of Marigold**

**ABSTRACT**

The field experiment was conducted at the experimental plot of RRTTS (OUAT) in Keonjhar, Odisha, over two consecutive years during the *rabi* seasons to investigate the impact of planting dates on the growth, yield, and productivity of various marigold varieties in the north central plateau zone of Odisha. The experiment involved comparing two varieties (BM1 and BM2) and six planting dates (1st September, 1st October, 1st November, 1st December, 1st January, and 1st February) in a factorial randomized complete block design with three replications. The results of the experiment revealed a noticeable increasing trend between the first planting date (1st September) and the second planting date (1st October), followed by a decreasing trend in subsequent planting dates in both years and for both varieties, taking into account the harvesting duration. Regarding plant height, a significant correlation of 0.67 was observed with total rainfall at a 5% level of significance. In terms of flower count, three significant correlations were established at a 5% level of significance: Accumulated GDD (0.64), Average minimum temperature (0.56), and Average mean temperature (0.55). Additionally, there was a highly significant correlation between branch count and various weather parameters, with correlations of Accumulated GDD (0.89), total rainfall (0.71), Average maximum temperature (0.79), Average minimum temperature (0.89), and Average mean temperature (0.86) for each parameter.

**Keywords:** Temperature, rainfall, phenological stages, yield, Marigold

**Introduction:**

Marigold is a widely cultivated flower in India, commonly used in religious and social functions in various forms. Known for its vibrant colors, attractive shape and long-lasting quality, marigold is a popular choice for decoration and the extraction of xanthophylls, a natural source of edible colour used in food processing and poultry feed. In India, marigold is grown commercially and is considered more profitable than other crops. This versatile flower plays a crucial role as a cash crop for small-scale farmers. In Odisha, marigold (*Tagetes erecta* L.) holds the top spot in terms of production and acreage among commercial flowers (Mohanty *et al.,* 2015). Its popularity stems from its adaptability to different soils and climates, ease of cultivation, and extended blooming period with high-quality flowers. Despite the favorable agro-climatic conditions in the state, there is a lack of standardized horticultural practices for quality marigold production. While marigold can be grown year-round, peak production occurs from October to February due to variations in weather conditions (Devi et al., 2017). To maximize yield, it is essential to use suitable cultivars, choose the right planting date, choosing improved variety and maintain optimal plant density (Mirzaei *et al.,* 2016).

Farmers often cultivate local varieties of flowers without fully understanding their potential yield and quality, resulting in lower productivity. However, there are numerous varieties of flowers available in different states that offer desirable characteristics, high yield potential, and superior quality parameters. The demand for uniform, medium-sized, compact, brightly coloured flowers with extended shelf life is particularly high in the domestic flower market. The introduction of improved varieties has played a crucial role in enhancing productivity in marigold cultivation. By selecting and cultivating these improved varieties, growers can significantly increase their yields and improve the quality of their flowers. This, in turn, leads to higher marketability and profitability for the grower. Investing in improved marigold varieties not only increases current crop yields but also ensures long-term sustainability in marigold production.

With the aforementioned facts in consideration, the present experiment was formulated to investigate the impact of planting dates on the growth, yield and productivity of various marigold varieties in north central plateau zone of Odisha.

**Materials and Methods:**

The field experiment was carried out at the experimental plot of RRTTS (OUAT) in Keonjhar, Odisha, during the year 2018-2019 and 2019-2020. The climate in this region is characterized by a mean annual precipitation of 1331.2 mm, with 87% received during the southwest monsoon season (June to September), 7% during rabi (October to January), and only 6% during summer (February to May). The soil of the experimental plot is acidic, light-textured, and of medium fertility status. The experiment involved the comparison of two varieties (V1-BM 1 and V2-BM 2) and six planting dates (D1-1st September, D2-1st October, D3-1st November, D4-1st December, D5-1st January, and D6-1st February) in a factorial randomized complete block design with three replications. Prior to planting, the plots were ploughed and disked. One-month-old seedlings were then planted in the main plot at a spacing of 40 cm × 30 cm, with all agronomic practices and plant protection measures applied uniformly across all treatments.

To assess the growth and yield of flowers, five plants were randomly selected from the middle of each plot, and their traits were measured. Statistical analysis of the data was conducted using the procedure outlined by Gomez and Gomez (1984), with significance determined at P<0.05 level, and standard error (S.E.) and critical difference (C.D.) at 5% level.

**Data and analysis**

Daily maximum (Tmax), minimum (Tmin) and mean (Tmean) air temperatures were collected from the meteorological observatory of RRTTS, Keonjhar. Average Tmax , Tmin and Tmean during different phenological stages were calculated. The accumulated growing degree day (GDD) occurring at different phenophases were evaluated (Sarkar et al., 2005). Growing degree day (GDD) = (Tm–Tb) where Tm is the mean temperature and Tb is the base temperature. For marigold crop the base temperature is considered as 5°C (Devi et al., 2017). In order to determine the effect of weather parameters on the growth and yield of marigold crop simple correlation was carried out.

**Results and discussion**

**Durations of the phenological stages**

The variation in the duration of phenological stages with different dates of planting in 2 different varieties V1 and V2 have been shown in the figure 1. There is an increasing trend observed in between 1st date of planting and 2nd dates of planting followed by a decreasing trend in the subsequent dates of planting in both the years and in both the varieties considering the duration between 1st to last harvest. The duration from 1st to last harvest is the highest at V1D2 (103), V2D1 (98) and the lowest is at V1D6 (41), V2D6 (28) in the 1st year. The maximum duration is observed in V1D2 (110), V2D1 (97) while lowest value is seen in V1D6 (48), V2D6 (30) in the next year. In the case of planting to budding considering variety 1, a decreasing pattern is observed from 1st date to 4th date of planting and with somewhat delaying the dates i.e. D5, the no. of days increased and finally decreased with further delay (D6). The highest value is observed in V1D1 (63) while the lowest value is in V1D6 (41) in 1st year and V1D1 (62) showed the highest while V1D6 (44), showing the lowest in 2nd year. On the contrary, in V 2 initially the same trend is followed as of V1 until D5 then value remains same. In the next year in both the varieties, similar trend is observed as in case of V1 in year 1. The highest value is observed in V2D1 (57) and lowest value is observed in V2D4 (38). From the period of planting to first harvest, in case of V 1, in both the years, it is observed that the number of days is decreasing with delayed dates of planting (D1 to D6). The highest and lowest durations are observed in V1D1 (75) and V1D1 (46) in 1st year; and V1D1 (68) and V1D6 (48) in 2nd year. Compared to this pattern, the pattern in case of variety 2 is similarly diminishing up to D4, and then in exception to this previous one, it is increasing from D5 to D6. The highest and lowest durations are recorded in V2D1 (63) and V2D4 (43) in 1st year and V2D2 (62) and V2D4 (39) in 2nd year respectively.

**Accumulated heat units during different phenological stages**

The Heat unit accumulated (GDD) during different phenological stages with different dates of planting in 2 different varieties V1 and V2 have been computed and the results so obtained have been presented in the figure 2. There is a decreasing trend observed in between 1st date of planting and 4th dates of planting followed by an increasing trend between 4th dates of planting to 5th date of planting and then a decreasing trend between 5th date of planting to 6th date of planting in V1. The similar trend is followed by V2 from 1st date of planting to 5th date of planting except from 5th to 6th date of planting. In case of planting to budding considering V1 a decreasing pattern is observed from 1st to 4th date of planting and then an increasing pattern from 4th to 5th date of planting then it follows a decreasing Pattern from 5th to 6th date of planting. On the contrary in V2 initially shows the same trend like V1 until D5 then value increases. In the next year, both the varieties follow the same trends in planting to budding. In the case of planting to first harvest there is a decreasing pattern from D1 to D4 then there is an increasing trend between D4 to D5.

**Air temperature during different phenological stages**

The variation in average maximum, minimum and mean air temperature during different phenological stages in two different varieties V1 and V2 have been given in the Figure 3, 4 and 5, respectively. In case of V1 there has been insignificant decrease of maximum temperature from D1 to D4 and then sudden rise in temperature from D4 to D6 during 1st harvest to last harvest. The highest maximum temperature is observed at V1D6 (30.98°C), followed by V2D6 (30.83°C) and lowest is at V1D4 (25.85°C) followed by V2D4 (24.77°C) in case of 1st year while highest value is observed in V1D6 (29.45°C) followed by V2D6 (29.29°C) and lowest value is observed in V1D4 (25.29) followed by V2D4 (24.29°C) in the next year. In case of planting to budding considering V1 and V2, from D1 to D4 there is a sharp decrease in maximum temperature followed by a sudden rise of temperature from D4 to D6. From the period from planting to 1st harvest in case of V1 and V2, in both the years, it is observed that the maximum temperature decreases from D1 to D4 followed by a rise from D4 to D6. The highest and lowest temperature are observed at V1D1 (29.28), V2D1 (29.49) and V1D4 (23.82), V2D4 (23.32) respectively in 1st year. In 2nd year V1D1 (28.69), V2D1 (28.74) shows the highest temperature and V1D4 (24.22), V2D4 (24.29) shows the lowest temperature.

In case of V1 there is a significant decrease in the minimum temperature from D1 to D3 and then a slight rise in temperature (°C) from D3 to D4, then a sudden rise in temperature from D4 to D6 during 1st harvest to last harvest in 1st year, but in year 2 temperature decreases from D1 to D4; then it rises up to D6. Considering V2 in both the year a similar pattern is followed. From the period from planting to first harvest in both V1 and V2, it is observed that the temperature decreases sharply from D1 to D4 then rises from D4 to D6 in the 1st years,. In next year, for V1, a sharp decrease in minimum temperature from D1 to D4 followed by a rise in D5 and then a sudden rise for D6 is observed. The highest and lowest minimum temperature observed at V1D1 (21.59°C), V2D1 (22.19°C) and V1D4 (11.90°C), V2D4 (11.85°C) respectively in 1st year. In 2nd year V1D1 (22.52°C), V2D1 (23.02°C) shows the highest temperature and V1D4 (13.47°C), V2D5 (13.39°C) shows the lowest temperature. In case of planting to budding considering V1 and V2, from D1 to D4 there is a sharp decreasing trend of temperature then sudden rise of temperature from D4 to D6 in 1st year. In 2nd Year same trend of temperature is followed by V1 but in V2 temperature falls up to D5 then temp rises. The peak value is observed at V1D1 (22.19°C), V2D1 (22.51°C) in 1st year and V1D1 (22.86°C), V2D1 (22.02°C) shows the highest value during 2nd year. V1D4 (11.90°C), V2D4 (11.85°C) shows the lowest temperature in 1st year and V1D4 (13.47°C), V2D5 (13.39°C) indicates the lowest temperature in 2nd year.

Considering the stage from planting to budding, mean temperature decreases from D1 to D4 and then increases up to D6 except in the 2nd year with V2 where the up rise is from D5 to D6. The highest and lowest mean temperatures are V1D1 (25.83), V2D1 (26.12) and V1D4 (17.47), V2D4 (17.56) in 1st year; and V1D1 (25.77), V2D1 (25.84) and V1D4 (18.49), V2D5 (18.52) in the 2nd year. Considering planting to first harvest stage the mean temperature decreases from D1 to D4 and increases up to D6. The highest and lowest values are observed at V1D1 (25.42), V2D1 (25.83) and V1D4 (17.68), V2D4 (17.49) in 1st year and V1D1 (25.58), V2D1 (25.88) and V1D4 (18.71), V2D4 (18.66) in 2nd year. From the 1st harvest to last harvest, initially there is a decreasing trend seen from D1 to D4 and then an increasing trend up to D6 in both the varieties in both the years. The highest and lowest values are observed at V1D1 (21.77), V2D1 (21.85) and V1D4 (19.85), V2D4 (18.56) in 1st year and V1D1 (22.06), V2D1 (22.38) and V1D4 (19.83), V2D4 (18.76) in 2nd year.

**Rainfall during different phenological stages**

In the planting to budding stage, a trend is followed in which the accumulated rainfall decreases from D1 to D5 and then increases in D6 in both varieties V1 and V2 in 1st year. The highest and lowest rainfall are observed at V1D1, V2D1 and V1D5, V2D5. In 2nd year the similar trend is followed but with different dates of planting, i.e. decreases from D1 to D3, remains constant in D4 and then rises with further delayed planting from D5 to D6. The highest rainfall is observed at V1D1, V2D1 and lowest at V1D4, V2D4. Considering the planting to first harvest stage, identical pattern is followed as that of planting to budding in both the years but the initiation point of rising rainfall is different for V1 and V2 in the 1st year. From 1st to last harvest, there is a decreasing pattern observed from D1 to D4 where from it is seen to increase up to D6 except in case of V1 in the 2nd year.

**Effect of weather parameters on growth and yield of marigold**

The correlation between weather parameters and yield attributes of marigold with different dates of planting has been given in Table 1. A positive correlation between different yield attributes and weather parameters from planting to budding is observed. Plant height exhibits significant positive correlation (0.67) with total rainfall. The number of flower shows significant positive correlation with the accumulated GDD (0.64), average minimum temperature (0.56), and average mean temperature (0.55). The number of branches also exhibits positive association with all the weather parameters. Similar type of correlation is observed in flower weight with different weather parameters. During the stage of planting to 1st harvest, high significant positive correlation is observed between branch no. and different weather parameters. A negative correlation is observed between flower diameter and total rainfall though the correlation is not found significant. From the stage of 1st to last harvest, negative correlation is observed between the yield attributes and average maximum temperature. Moreover highly significant positive correlation is observed with accumulated GDD in maximum yield attributes.

**Conclusions**

The present study concludes that the duration of the phenological stages of marigold depends on the dates of planting. Duration of the phenophases decreases gradually as the dates of planting is delayed. The crop planted in the month of February is exposed under the higher air temperature. It is evident from the results that the weather parameters positively affect the growth and yield attributes of marigold. Average maximum air temperature adversely affect the yield attributes during the 1st to last harvesting stage.

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| **Year 1** |
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| **Year 2** |
| **Fig-1: Duration of** **phenological stages of two marigold varieties** |

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| **Year 1** |
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| **Year 2** |
| **Fig-2: Heat unit accumulated during different phenological stages** |

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| **Year 1** |
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| **Year 2** |
| **Fig-3: Average maximum temperature during different phenological stages** |

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| **Year 1** |
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| **Year 2** |
| **Fig-4: Average minimum temperature during different phenological stages** |

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| **Year 1** |
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| **Year 2** |
| **Fig.-5: Average mean temperature during different phenological stages** |

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| **Year 1** |
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| **Year 2** |
| **Fig.-6: Accumulated rainfall during different phenological stages** |

**Table-1: Correlation between weather parameters and yield attributes of marigold**

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|  |  | Plant Height | Flower no. | Branch no. | Plot yield | Flower weight | Yield | Flower diameter | SPDEV | SPDNS |
| Planting to Budding | Accumulated GDD | 0.54 | 0.64\* | 0.89\*\* | 0.73\*\* | 0.81\*\* | 0.78\*\* | 0.06 | 0.68\*\* | 0.70\*\* |
| Total rainfall | 0.67\* | 0.35 | 0.71\*\* | 0.50 | 0.55\* | 0.51 | 0.02 | 0.46 | 0.53 |
| Avg. Tmax | 0.41 | 0.52 | 0.79\*\* | 0.58\* | 0.70\*\* | 0.66\* | 0.03 | 0.63\* | 0.56\* |
| Avg. Tmin | 0.49 | 0.56\* | 0.89\*\* | 0.65\* | 0.76\*\* | 0.73\*\* | 0.03 | 0.70\*\* | 0.67\* |
| Avg. Tmean | 0.47 | 0.55\* | 0.86\*\* | 0.64\* | 0.75\*\* | 0.71\*\* | 0.04 | 0.69\*\* | 0.64\* |
| Planting to first harvest | Accumulated GDD | 0.56\* | 0.67\* | 0.88\*\* | 0.72\*\* | 0.81\*\* | 0.77\*\* | 0.04 | 0.69\*\* | 0.71\*\* |
| Total rainfall | 0.69\*\* | 0.34 | 0.69\*\* | 0.47 | 0.54 | 0.50 | -0.01 | 0.43 | 0.50 |
| Avg. Tmax | 0.46 | 0.51 | 0.76\*\* | 0.58\* | 0.68\*\* | 0.63\* | 0.03 | 0.58\* | 0.54 |
| Avg. Tmin | 0.52 | 0.55\* | 0.88\*\* | 0.65\* | 0.74\*\* | 0.72\*\* | 0.03 | 0.67\* | 0.65\* |
| Avg. Tmean | 0.50 | 0.54 | 0.85\*\* | 0.64\* | 0.73\*\* | 0.70\*\* | 0.04 | 0.65\* | 0.62\* |
| 1st to last harvest | Accumulated GDD | 0.40 | 0.75\*\* | 0.90\*\* | 0.79\*\* | 0.85\*\* | 0.85\*\* | 0.01 | 0.75\*\* | 0.76\*\* |
| Total rainfall | 0.65\* | 0.37 | 0.66\* | 0.48 | 0.53 | 0.49 | -0.01 | 0.43 | 0.50 |
| Avg. Tmax | 0.21 | -0.03 | -0.12 | -0.12 | -0.07 | -0.12 | -0.16 | -0.15 | -0.18 |
| Avg. Tmin | 0.43 | 0.17 | 0.23 | 0.14 | 0.21 | 0.16 | -0.13 | 0.09 | 0.10 |
| Avg. Tmean | 0.34 | 0.10 | 0.10 | 0.05 | 0.12 | 0.06 | -0.14 | 0.01 | 0.01 |

\*. Correlation is significant at the 0.05 level \*\*. Correlation is significant at the 0.01 level

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