Pheno-thermal response of Chrysanthemum under different environments in mid hills of Himachal Himalayas

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ABSTRACT. Effects of date of transplanting, row spacing and their orientation on the pheno-thermal response of Chrysanthemum. In order to study the effect of heat, photothermal and heliothermal units on the phenology of Chrysanthemum, an experiment was conducted during 2019-2020 on Solan Shringar cultivar of Chrysanthemum at Nauni (30° 86’ N, 77° 16’ E and 1275 m amsl). The weather based indices were used for characterizing the thermal response to various phenophases of Chrysanthemum under different environmental conditions. The maturity was differed by 13 days for early, mid and late transplanting dates for which the accumulated range of growing degree days was 2278-2291, 2062-2067 and 1826-1827 °C days; photothermal unit was 11240-11366, 9266-9336 °C days under different treatments. Likewise, minimum heliothermal unit (23602 °C days) was required by the treatment with respect to 24th June of transplanting, 20×30 cm spacing and E-W orientation and maximum (29958 °C days) with respect to 25th May of transplanting, 20×30 cm spacing and N-S orientation (5.4) and 24th June of transplanting, 20x45 cm spacing and E-W orientation (2.8) treatment, respectively. The weather indices explained 73-98% variation in vegetative and 88-92 % reproductive phenophase of Chrysanthemum under different treatments.

Key words – Growing degree days, Photothermal unit, Heliothermal unit, Heat use efficiency, Flower yield and Chrysanthemum.

1. Introduction

Chrysanthemum (Dendranthema grandiflora Tzvelev) is a valuable commercial flower crops grown for its attractive flowers in all over the world. Chrysanthemums were first cultivated in China as a flowering herb as far back as the 15th century BC with a high ornamental value is one of the ten most popular
traditional flowers in China and one of the four most popular cut flowers in the world “the Queen of fall flowers” and hence, occupies a very important position in the world flower industry (Anderson, 2007). The Chrysanthemum herb used in the treatment of autoimmune diseases includes inflammation and elevated blood pressure as well as those that target the respiratory apparatus of the human body (Kato et al., 1987).

In India chrysanthemum occupies a place of pride both as a commercial and exhibition crop and one of the most important cut & loose flower (Liu et al., 2012) crops which is being cultivated and traded throughout the country. It is commonly known as Guldaudi and also known as “Queen of the East” & “Glory of the East” (Mohapatra et al., 2000; Randhava and Mukhopadhyay, 1986), Samanti in the southern states and Shevanti in the western states and ‘Bijli’ in Maharashtra. It covers areas of around 20.55 thousand hectares in which loose flower production is 188.81 thousand metric tons and cut flower production is 15.38 thousand metric tons, Himachal Pradesh ranks 5th with a total production of 11.46 thousand tons (Anonymous, 2017).

The pheno-physiological stage like bud formation, flowering, growth development and time of maturity have been reported to vary with change in site, location, topography and environment. Weather parameters have significant impact on the phenology of agricultural, horticultural and flower crops (Singh et al., 2015). The major climatic factors affecting the Chrysanthemum production are the heat accumulation, light and temperature. For vegetative growth it requires daily and temperature from 15-20 °C (Jacobsen and Amsen, 2015). The major climatic factors affecting the Chrysanthemum production are the heat accumulation, light and temperature. For vegetative growth it requires

2. Materials and methods

2.1. Location of study

The experiment was conducted during 2019-2020 at experimental farm of Department of Environmental Science, Dr. Y. S. Parmar University of Horticulture & Forestry Nauni (30° 86' N, 77° 16' E and 1275 m amsl). The climate of the area is sub-tropical to sub-temperate and semi-humid characterized by cold winters and experiences distinguished major four seasons in the year. The annual normal mean maximum temperature was 25.3 °C, minimum temperature 11.5 °C, relative humidity 64 per cent and rainfall 1118 mm, respectively. The soil is normal having pH experimental 6.8 to 7.2 with brown in color and sandy loamy texture.

2.2. Experimental details

The field experiment was conducted during 2019-2020 on Solan Shringar cultivar of Chrysanthemum. The one month old seedlings prepared from the cuttings of the chrysanthemum was transplanted at three dates D1 (25th May), D2 (9th June) and D3 (24th June) in well prepared plots at two spacing S1 (20x30 cm) and S2 (20×45 cm) with two row orientations of O1 (N-S) and O2 (E-W) with three replications making total numbers of plots 36. The recommended package of practices for the crop was adopted. When the seedlings (cuttings) well established in the field after transplanting and showed growth characteristics then the apical buds were pinched out to get maximum branching (lateral shoots) to bear increased numbers of flower for getting maximum flower production.

2.3. Observation time and method

The number of days to attain various phenophases namely pinching, bud formation, flowering and maturity were visually observed from randomly selected three plants from each treatments after transplanting.
2.4. Meteorological observation

Daily maximum (Max-T), minimum temperature (Min-T), morning (RH-m) & evening (RH-e) relative humidity, rainfall, bright sunshine hours (BSH) were recorded at Agromet observatory installed at near the experimental farm (Fig. 1). The growing degree days (GDD), photothermal units (PTU), heliothermal units (HTU) and heat use efficiency (HUE) for different phenophases of Chrysanthemum were calculated using 10°C base temperature (Tb) as per the following formulas and accumulated from the date of transplanting to date of occurrence. As the crop was taken during the Kharif season so the base temperature was taken as 10 °C.

\[ \text{GDD} = \sum \left( T_{\text{max}} + T_{\text{min}} \right)/2 - Tb \]

\[ \text{PTU} = \text{GDD} \times \text{Day Length} \]

\[ \text{HTU} = \text{GDD} \times \text{Actual bright sunshine (hours)} \]

\[ \text{HUE} = \text{Flower yield} \left( \text{gm}^{-2} \right) / \sum \text{GDD} \text{ °C day} \]

GDD : Cumulative Growing Degree days units were determined by summing the daily mean temperature above base temperature and are expressed in °C day.

PTU : Heliothermal units (HTU) for a day represent the product of heat unit and length of a day and are expressed in °C day hours. The sums of PTU for particular phenophases of interest were determined according to the above equation which gave the combined effect of temperature and sun shine duration.

HTU : Heliothermal units (HTU) for a day represent the product of heat unit and bright sunshine hours for that day and are expressed in °C day hours. The sums of HTU for particular phenophases of interest were determined according to the above equation which gave the combined effect of temperature and sun shine duration.

HUE : Heat use efficiency (HUE) was calculated as the ratio of dry matter (DM) and cumulative thermal time \( \left( \sum \text{GDD} \right) \) between any two consecutive phenological stages of the crop.

3. Results and discussion

3.1. Phenology of Chrysanthemum

Numbers of days required for commencement of different phenological events varied among different treatments (Table 1). Results of two years pooled analysis...
### TABLE 2
Thermal units required at various phenophases under different environments

| Treatments | Pinching  | Bud formation | Flowering | Maturity  |
|------------|-----------|---------------|-----------|-----------|
|            | GDD       |               |           |           |
| **D1**     |           |               |           |           |
| S1 O1      | 427.2     | 1917.5        | 2085.7    | 2278.6    |
| S1 O2      | 455.0     | 1940.1        | 2087.7    | 2280.6    |
| S2 O1      | 471.2     | 1951.2        | 2097.5    | 2291.4    |
| S2 O2      | 497.1     | 1966.5        | 2100.2    | 2290.8    |
| **D2**     |           |               |           |           |
| S1 O1      | 446.6     | 1728.9        | 1880.9    | 2062.1    |
| S1 O2      | 475.7     | 1746.1        | 1893.6    | 2067.3    |
| S2 O1      | 491.2     | 1756.3        | 1893.4    | 2062.3    |
| S2 O2      | 519.0     | 1770.9        | 1899.2    | 2065.7    |
| **D3**     |           |               |           |           |
| S1 O1      | 279.3     | 1501.1        | 1646.9    | 1827.7    |
| S1 O2      | 292.3     | 1500.3        | 1646.1    | 1826.9    |
| S2 O1      | 305.3     | 1517.4        | 1654.2    | 1827.5    |
| S2 O2      | 305.3     | 1517.4        | 1654.2    | 1827.5    |
|            | HTU       |               |           |           |
| **D1**     |           |               |           |           |
| S1 O1      | 3292.3    | 8778.7        | 10062.3   | 11317.7   |
| S1 O2      | 3468.3    | 8925.7        | 10162.7   | 11366.8   |
| S2 O1      | 3568.7    | 8998.5        | 10131.4   | 11301.3   |
| S2 O2      | 3630.4    | 9062.7        | 10100.2   | 11244.2   |
| **D2**     |           |               |           |           |
| S1 O1      | 2674.8    | 7031.9        | 8215.5    | 9336.8    |
| S1 O2      | 2702.9    | 7106.6        | 8253.3    | 9288.3    |
| S2 O1      | 2755.6    | 7214.7        | 8283.8    | 9266.8    |
| S2 O2      | 2755.6    | 7307.2        | 8381.5    | 9318.3    |
| **D3**     |           |               |           |           |
| S1 O1      | 1225.4    | 5627.5        | 6775.8    | 7789.0    |
| S1 O2      | 1231.9    | 5610.6        | 6758.8    | 7772.1    |
| S2 O1      | 1257.9    | 5706.6        | 6853.2    | 7815.5    |
| S2 O2      | 1257.9    | 5706.6        | 6853.2    | 7815.5    |
|            | PTU       |               |           |           |
| **D1**     |           |               |           |           |
| S1 O1      | 5865.2    | 25694.4       | 27646.3   | 29749.3   |
| S1 O2      | 6251.6    | 25966.3       | 27820.8   | 29958.5   |
| S2 O1      | 6477.4    | 26100.1       | 27782.7   | 29879.3   |
| S2 O2      | 6838.6    | 26273.1       | 27804.8   | 29862.5   |
| **D2**     |           |               |           |           |
| S1 O1      | 6211.3    | 23052.0       | 24798.5   | 26758.4   |
| S1 O2      | 6617.0    | 23252.2       | 24937.1   | 26810.4   |
| S2 O1      | 6833.4    | 23474.3       | 25034.2   | 26852.0   |
| S2 O2      | 7221.2    | 23648.8       | 25102.0   | 26888.5   |
| **D3**     |           |               |           |           |
| S1 O1      | 4076.0    | 20012.3       | 21673.5   | 23613.9   |
| S1 O2      | 4257.2    | 20001.1       | 21662.3   | 23602.8   |
| S2 O1      | 4438.3    | 20200.0       | 21751.8   | 23609.0   |
| S2 O2      | 4438.3    | 20200.0       | 21751.8   | 23609.0   |
depicted that number of days required by Chrysanthemum under different treatments after transplanting varied was 18-29 for pinching, 108-137 for bud formation, 125-154 for flowering and 155 to 185 for maturity/harvesting. Jacobsen and Amsen (1992) reported significant deviation in number of days from bud burst to bloom in Chrysanthemum. The number of days required for different phenophases decreased with delayed transplanting (Table 1). The effect of row spacing and orientation on number of days required to attain different growth stages was observed significant in earlier (D₁ and D₂) transplanted compared to late (D₃) transplanted Chrysanthemum. On an average the maturity (flower harvesting) was attained by the crop transplanted on 25th May, 9th June and 24 June in 184 days, 171 days and 158 days, respectively with a deviation of 13 days between each date. Sargun et al., (2019) also reported deviation in days for attaining various phenophases and maturity with delayed date of sowing. Similar results were obtained by Singh and Bhatia (2012) in apple.

3.2. Growing degree days requirement

The accumulated thermal unit requirement of Chrysanthemum to attain different phenophases varied among the various treatments adopted in the experiments (Table 2). At pinching stage, highest GDD of 519 °C days required by Chrysanthemum transplanted on 9th June in 20×45 cm spacing and E-W row orientation followed by 497 °C under D₁S₂O₂ condition whereas, lowest GDD of 279 °C days required by the crop transplanted on 24th June in 20×30 cm spacing and N-S row orientation followed by 292 °C days under D₃S₁O₂ treatment. But, to complete flowering, the accumulated GDD required in the range of 2085-2100 °C days under first date (D₁) of transplanting while, 1880-1899 under second date (D₂) and 1646-1654...
under third date of transplanting with two row spacing and orientations. The accumulated GDD was linearly associated with vegetative as well as reproductive stages of Chrysanthemum. Savita et al., (2019) reported wide variations in thermal heat requirement in pea cultivars under different dates of sowing with two row spacing and orientations at different critical phenological stages. Unit change in heat unit could affect days taken for pinching and bud formation @ 0.053 and 0.058 days, respectively (Fig. 4) and flowering & maturity stages @ 0.056 and 0.055 days, respectively (Fig. 5). Chrysanthemum transplanted at earlier date, which accumulated higher growing degree days, resulted better flower yield response. Our results were in the line with Gupta et al., (2017) who also reported lower consumption of heat units under delayed sowing. Late sowing decreased the duration of phenology.
as compared to normal sowing due to fluctuated unfavourable high temperature during the growing period.

3.3. Heliothermal unit’s requirement

Among weather parameters, duration of bright sunshine hours is considered as one of the important key factor floriculture. Temperature and bright sunshine hours in terms of Heliothermal Unit (HTU) has been adopted to evaluate the growing regions, selection of cultivars, phenological development and maturity characteristics of crops (Singh and Jangra, 2018). For different date of transplanting with two row spacing and orientation, HTU ranged from 1225-3630 °C days for pinching that was in between 5706-9062 °C days, 6853-10162 °C days and 7815-11366 °C days for bud formation, flowering and maturity stage, respectively. On an average higher HTU was required by early transplanted crop which successively decreased with delayed transplanted under all the treatments. Number of days to reach each phenophases and accumulated HTU showed a significant linear regression for both vegetative (R² = 0.73 to 0.93) and as well as reproductive (R² = 0.88 to 0.90) stages of the Chrysanthemum. Deviation in each unit of HTU may alter the commencing of pinching, bud formation, flowering and maturity stages @ 0.0042, 0.0077, 0.0075 and 0.0071 days, respectively (Figs. 4 & 5).

3.4. Photothermal unit’s requirement

The pooled analysis of two years data revealed that accumulated PTU was 4076-7221 °C days (at pinching), 20001-26273 °C days (at bud formation), 21662-27821 °C days (at flowering) and 23602-29959 °C days (at maturity). Alternately, accumulated PTU for maturity varied between 29749-29959 °C days, 26758-26888 °C days and 23602-23609 °C days respectively for first, second and third date of transplanting (Table 2). The value of PTU successively reduced for delayed transplanting. Deviation in each unit of PTU may alter the commencing of pinching, bud formation, flowering and maturity stages @ 0.0041, 0.0043, 0.0041 and 0.0040 days, respectively (Figs. 4 & 5). High significant linear relation (p ≤ 0.005) between accumulated PTU and Chrysanthemum phenophases was again proved by high values of coefficient of determination (R² between 0.95-0.98 for vegetative stages and 0.88-0.92 for reproductive stages).

3.5. Flower yield and heat use efficiency

Flower yield of Chrysanthemum was ranged from 722.5 g to 998.6 g/plant under different treatments. It was between 981.4 to 998.6 g/plant for first date of transplanting, 955.5-969.3 g/plant for second date and 722.5-740.6 g/plant for the third date (Fig. 2). The fresh and dry yield of flower was continuously decreased with delayed transplanting of the crop. Sahu et al., (2007) found that delayed sowing hastened the crop phenological development, thereby causing significant reduction in crop yields. Gupta et al., (2017) and Palasaniya et al., (2016) also reported the similar observations under delayed sowing. GDD showed linear relationship with fresh flower yield (R² = 0.84). Sargun et al., (2019) and Savita et al., (2019) also observed positive correlation between productivity and the minimum temperature in pea. The HUE was higher for first date of transplanting under 20x30 cm row spacing (5.1 to 5.4) which was at par with the second date (5.1 to 5.4) of transplanting with same row spacing. Row spacing has significant effect on HUE while, row orientation has not (Fig. 3).

4. Conclusion

Higher days of phenology with greater of GDD, HTU and PTU were observed with the longer duration Chrysanthemum. Accumulated GDD, HTU and PTU were linearly related with vegetative as well as reproductive stages of the crop. As compared to short duration, the long duration crop was more efficient to utilize the heat units to produce the better flower yield. The study confirmed the importance of various thermal units on growth, development and flower yield of Chrysanthemum. Thus it can be concluded that the early transplanted crop (25th May) recorded maximum calendar days, heat units and heat use efficiency at maturity which reduced significantly with subsequent delay in transplanting. Findings of the present study may be helpful in developing the yield prediction models of floricultural crops based on thermal indices.

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