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

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सार – **गुलदाउदी के पौधे की रोपाई की तिथि, पंक्ति की दूरी और उनके अभिविन्यास के प्रभाव इसके फीनो-थर्मल प्रतिक्रिया पर पड़ता है। गुलदाउदी के फीनोलॉजी पर गर्मी, प्रकाशीय ऊष्मा और सौर ऊष्मीय इकाइयों के प्रभाव का अध्ययन करने के लिए डॉ वाई एस परमार बागवानी और वानिकी नौनी** (30° 86' N, 77° 16' E **और** 1275 m amsl) **विश्वविद्यालय के पर्यावरण विज्ञान विभाग के प्रायोगिक फार्म में गुलदाउदी के सोलन श्रृंगार की खेती पर** 2019-2020 **के दौरान एक प्रयोगकिया गया । विभिन्न पर्यावरणीय परिस्थितियों में गुलदाउदी के विभिन्न फेनोफेज के लिए ऊष्मीय प्रतिक्रिया को चिह्नित करने के लिए मौसम आधारित सूचकांकों का उपयोग किया गया। शुरुआती, मध्य और देर से रोपाई की तारीखों के लिए परिपक्वता में** 13 **दिनों का अंतर था, जिसके लिए बढ़ते डिग्री दिनों की संचित सीमा** 2278-2291, 2062-2067 **और** 1826-1827 °C **दिन थी; विभिन्न उपक्रियाओं के तहत प्रकाशीय ऊष्मा इकाई** 11240-11366, 9266-9336 °C **दिन थी। इसी तरह,** 24 **जून की रोपाई के संबंध में** 20 × 30 **से.मी. की दूरी और** E-W **अभिविन्यास में उपक्रिया के लिए न्यूनतम सौर ऊष्मीय इकाई** (23602 °C **दिन**) **की, और** 25 **मई के रोपाई के संबंध में,** 20 × 30 **सेमी की दूरी और** E-W **अभिविन्यास में अधिकतम** (29958 °C **दिन**) **आवश्यकता थी।** 25 **मई को रोपाई,** 20 × 30 **सेमी दूरी और एन-एस अभिविन्यास** (5.4) **तथा** 24 **जून को रोपाई,** 20 × 45 **सेमी दूरी और ई-डब्ल्यू अभिविन्यास** (2.8) **उपक्रियाओं के संबंध में क्रमश: अधिकतम और निम्नतम उष्मा उपयोग दक्षता दर्ज की गई। मौसम सूचकांकों से पता चला है कि भिन्न – भिन्न उपक्रियाओं में गुलदाउदी के वानस्पतिक में** 73-98% **और प्रजनन फीनोफेज में** 88-92% **की भिन्नता रही है।**

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 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 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 E-W orientation. The highest and lowest heat use efficiency was recorded 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 5^{th} with a total production of 11.46 thousand tons (Anonymous, 2017).

The pheno-physiological stage like bud formation, flowering, flower growth and 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 long day with bright sun light and temperature ranging from 20-28 °C whereas for bud formation requires short day and temperature from 15-20 °C (Jacobsen and Amsen, 1992; Singh *et al.*, 2008). Since the chrysanthemum is a short day plant, planting should be done such that flowering coincides with short day conditions and appropriate mesoclimatic characteristics for the best growth and development (Razzaq *et al*., 1986).

Variation in weather parameters determines the inter-annual variability of plant growth and yield. Various temperature based indices like growing degree days (GDD), photothermal units (PTU) and heliothermal units (HTU) can be successfully used for describing phenological behaviour and other growth parameters like leaf area development, biomass production, yield etc. (Neog and Chakravarty, 2005). The prediction of plant behavior under a range of environmental conditions has long been an aim of plant science. This aim is driven not just by scientific curiosity, but also by the practical needs of crop cultivation, especially for floricultural plants. Although, in many crops, the main interest is fruit yield itself, in ornamental plants, such as chrysanthemum, both the flower yield and other external quality characteristics aspects are important (Kang *et al*., 2012). The concept of heat units has been applied to predict yield and physiological maturity of crops by correlating the phenological development (Singh and Jangra, 2018). Keeping the importance of weather parameters on phenology, a study was carried out to characterize the performance of Chrysanthemum grown in mid hills of Himachal Himalayas under different environmental conditions in relation to find out the climatic suitability for phenology and yield of Chrysanthemum.

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 loam 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 D_1 (25^{th} May), D_2 (9^{th} June) and D_3 (24^{th} June) in well prepared plots at two spacing S_1 (20x30 cm) and S_2 (20×45 cm) with two row orientations of O_1 (N-S) and O_2 (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.

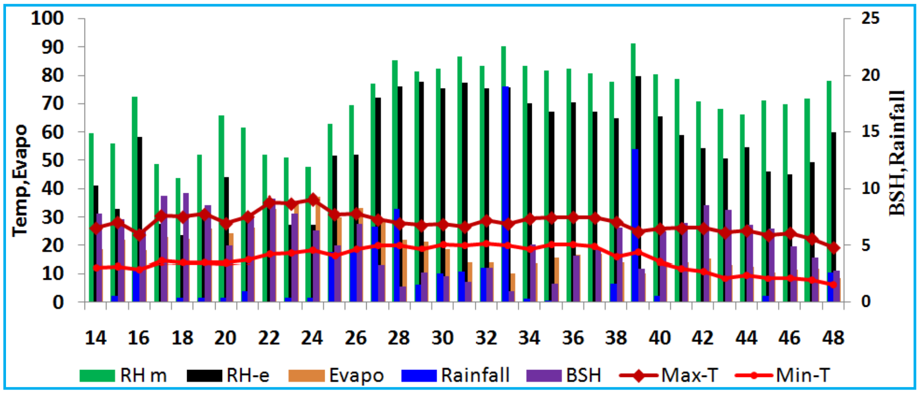

Fig. 1. Weather conditions during study period for Chrysanthemum

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.

$$\text{GDD} = \sum (T\max + T\min)/2 - Tb$$

$$\text{PTU} = \text{GDD} \times \text{Day Length}$$

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

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

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 day length.

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.

TABLE 1

Days taken to attain various phenophases in Chrysanthemum under different treatments

Treatments			Pinching	Bud formation	Flowering	Maturity/ Harvesting
D_1	S_1	O_1	26	133	151	181
		O_2	28	135	153	184
	S_2	O_1	29	137	154	185
		O_2	29	137	153	184
D_2	S_1	O_1	27	121	139	167
		O_2	29	122	139	166
	S_2	O_1	30	125	142	169
		O_2	32	131	150	179
D_3	S_1	O_1	18	108	125	155
		O_2	19	108	125	155
	S_2	O_1	20	112	130	161
		O_2	20	112	130	161

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
Growing Degree Days (GDD)						
D_1	S_1	O_1	427.2	1917.5	2085.7	2278.6
		O_2	455.0	1940.1	2087.7	2280.6
	S_2	O_1	471.2	1951.2	2097.5	2291.4
		O_2	497.1	1966.5	2100.2	2290.8
D_2	S_1	O_1	446.6	1728.9	1880.9	2062.1
		O_2	475.7	1746.1	1893.6	2067.3
	S_2	O_1	491.2	1756.3	1893.4	2062.3
		O_2	519.0	1770.9	1899.2	2065.7
D_3	S_1	O_1	279.3	1501.1	1646.9	1827.7
		O_2	292.3	1500.3	1646.1	1826.9
	S_2	O_1	305.3	1517.4	1654.2	1827.5
		O_2	305.3	1517.4	1654.2	1827.5
Heliothermal Units (HTU)						
D_1	S_1	O_1	3292.3	8778.7	10062.3	11317.7
		O_2	3468.3	8925.7	10162.7	11366.8
	S_2	O_1	3568.7	8998.5	10131.4	11301.3
		O_2	3630.4	9062.7	10100.2	11244.2
D_2	S_1	O_1	2674.8	7031.9	8215.5	9336.8
		O_2	2702.9	7106.6	8253.3	9288.3
	S_2	O_1	2755.6	7214.7	8283.8	9266.8
		O_2	2755.6	7307.2	8381.5	9318.3
D_3	S_1	O_1	1225.4	5627.5	6775.8	7789.0
		O_2	1231.9	5610.6	6758.8	7772.1
	S_2	O_1	1257.9	5706.6	6853.2	7815.5
		O_2	1257.9	5706.6	6853.2	7815.5
Photothermal Units (PTU)						
D_1	S_1	O_1	5865.2	25694.4	27646.3	29749.3
		O_2	6251.6	25966.3	27820.8	29958.5
	S_2	O_1	6477.4	26100.1	27782.7	29879.3
		O_2	6838.6	26273.1	27804.8	29862.5
D_2	S_1	O_1	6211.3	23052.0	24798.5	26758.4
		O_2	6617.0	23252.2	24937.1	26810.4
	S_2	O_1	6833.4	23474.3	25034.2	26852.0
		O_2	7221.2	23648.8	25102.0	26888.5
D_3	S_1	O_1	4076.0	20012.3	21673.5	23613.9
		O_2	4257.2	20001.1	21662.3	23602.8
	S_2	O_1	4438.3	20200.0	21751.8	23609.0
		O_2	4438.3	20200.0	21751.8	23609.0

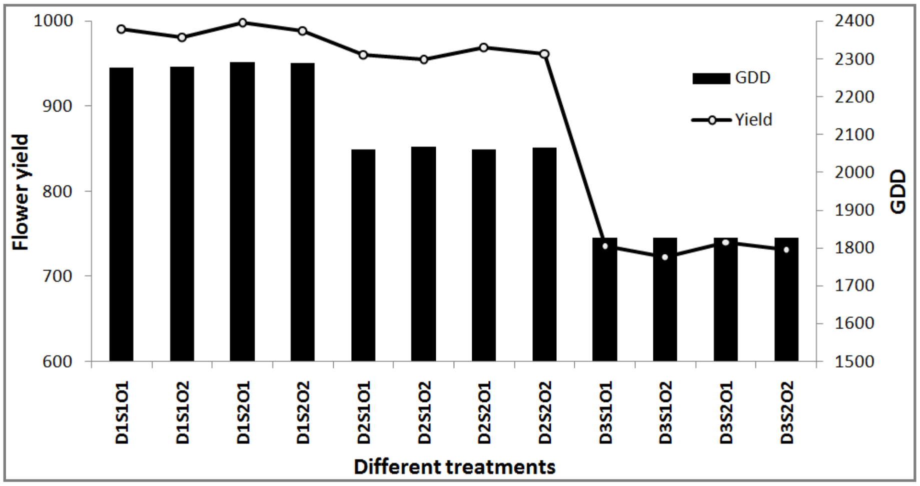

Fig. 2. Flower yield (g/plant) of Chrysanthemum under different treatments

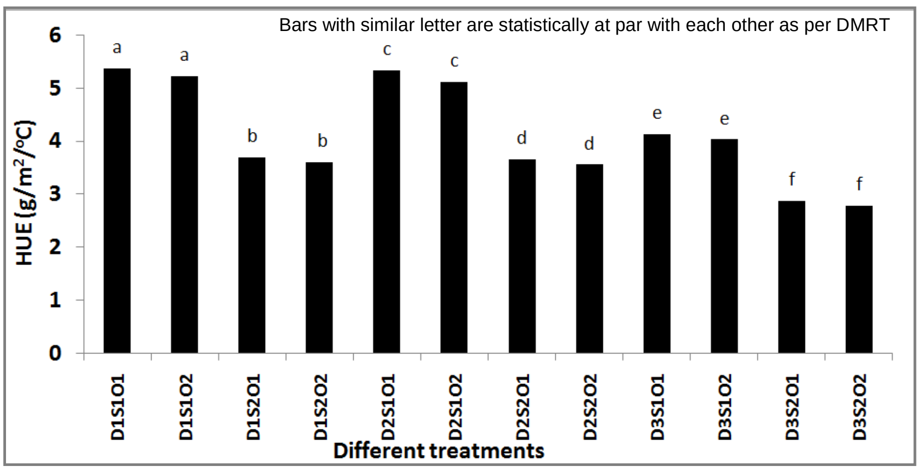

Fig. 3. Heat use efficiency of the Chrysanthemum under different treatments

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 (D_1 and D_2) transplanted compared to late (D_3) 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 $D_1S_2O_2$ 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 $D_3S_1O_2$ treatment. But, to complete flowering, the accumulated GDD required in the range of 2085-2100 °C days under first date (D_1) of transplanting while, 1880-1899 under second date (D_2) and 1646-1654

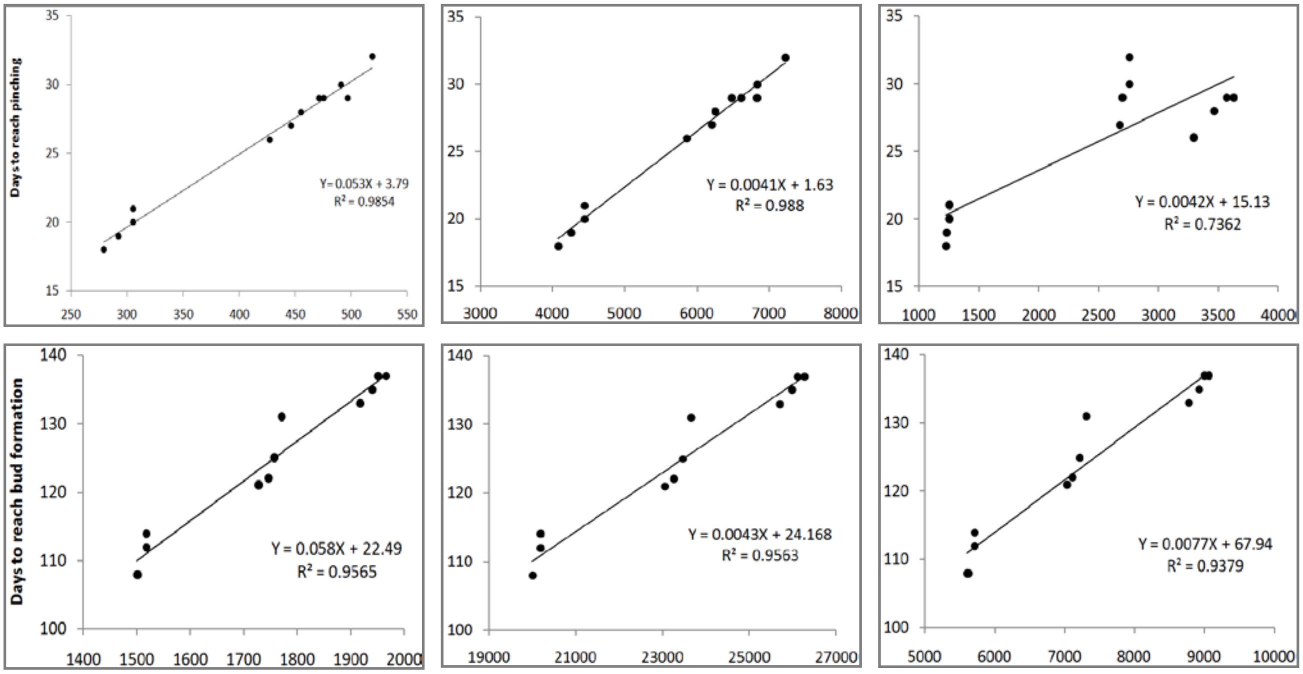

Fig. 4. Growing degree days, photothermal and heliothermal units required for different vegetative growth stage of Chrysanthemum

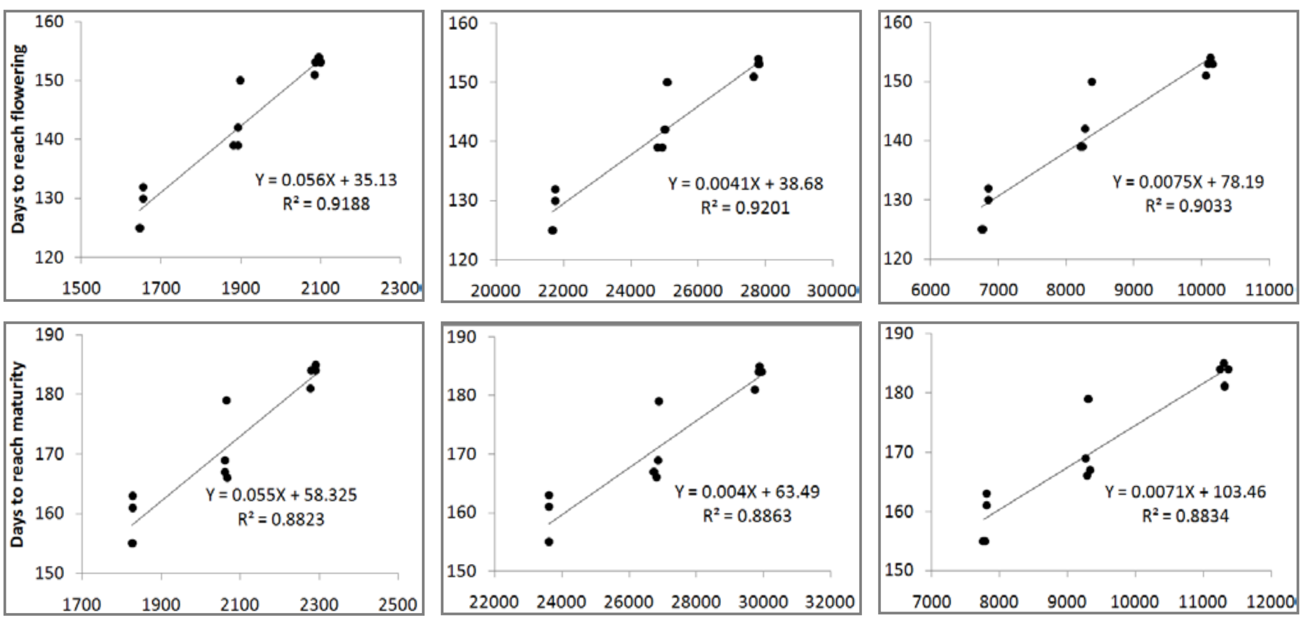

Fig. 5. Growing degree days, photothermal and heliothermal units required for different reproductive growth stage of Chrysanthemum

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 stage s 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 different phenophases and accumulated HTU showed a significant linear regression for both vegetative (R^2 = 0.73 to 0.93) and as well as reproductive (R^2 = 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 ^{o}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 ($p \leq 0.005$) between accumulated PTU and Chrysanthemum phenophases was again proved by high values of coefficient of determination (R^2 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 (R^2 = 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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