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Modulation of wild marigold (*Tagetes minuta* L.) phenophases towards the varying temperature regimes – a field study

RAKESH KUMAR[1*], K. RAMESH[1] R.D. SINGH[1] and RAJENDRA PRASAD[2]**

[1]*Institute of Himalayan Bioresource Technology (CSIR), Palampur 176 061, India*

[2]*Department of Agronomy, CSK Himachal Pradesh Agricultural University, Palampur 176 062 (HP) India*

Email: rakeshkumar@ihbt.res.in

ABSTRACT

Field experiments were conducted during 2007 and 2008 at experimental farm of Institute of Himalayan Bioresource Technology, (CSIR) Palampur (HP), India to study the performance of wild marigold (*Tagetes minuta*) under changing temperature regimes over the crop growth period. The established agroclimatic indices for temperature studied elsewhere in the domain *viz*., relative temperature disparity (RTD), growing degree days (GDD), heliothermal units (HTU) and photothermal units (PTU) were computed for different varied dates of sowing the crop. Distinct changes in weather parameters concomitant to different sowing time consequently caused significant variation in the performance of the crop. The results indicated that the early sown crop had longest crop span (224 days) than the late sown crop (102 days), from sowing to harvesting. The mean GDD accumulation from sowing to harvest ranged from 1378 to 2518°C days HTU from 6781 to 15706°C days hour and PTU from 17400 to 33052°C days hour. Total biomass, and content and yield of essential oil were correlated with different heat units calculated during the crop growth seasons. All the agroclimatic indices had positive correlations with biomass, oil content and oil yield. Thus, these indices seem to be effective in taking into account and expressing the effect of varying ambient temperature on the duration between the phenological events for comparing the crop response to the ambient temperature between different phenological stages.

Keywords : Wild marigold, temperature, photoperiod, GDD, PTU, HTU.

Crop production and climate are closely linked in terms of the crop growth, development and production, which are affected both long term meteorological factors (the climate) and short term meteorological events (the weather). The major limiting factors for higher productivity are sunlight and temperature, which are responsible for timing of biological processes and hence growth and development of living biota. Thus, air temperature based indices *viz*., growing degree-days (GDD), photothermal unit (PTU), heliothermal unit (HTU) etc. can successfully be used for describing phenological behaviour and growth parameters like leaf area development, biomass production, oil content etc. (Hundal and Kingra 2000; Neog *et al.* 2005; Singh *et al*. 2007). This GDD approach is often used in crop models (Baker and Landivar 1991; Kiniry and Bonhomme 1991; Wilhelm *et al*. 1993 and Rickman *et al*. 1995). Various forms of temperature summations, commonly referred to as heat units and expressed in 'growing degree-days' (GDD) or in 'thermal time' (Tt), have been widely used in studies to predict phenological events for various crops (Baker and Reddy, 2001). GDD and PTU have been variously used in relation to phenological events and maturity dates in crops *viz*., corn (Neild and Seeley 1977); wheat (Sastry and Chakravarty 1982; McMaster and Smika 1988; Haider *et al.* 2003); winter maize (Narwal *et al.* 1986). Relation of degree-days to phenological development of plants would provide a better understanding of crop's response to temperature. Wang (1960) reported that the duration of a particular stage of growth was directly related to temperature and this duration for particular species could be predicted using the sum of daily air temperatures.

Several agroclimatologists have documented the use of thermal indices to predict phenology (Hundal *et al.* 1997), leaf area index (Benbi 1994), growth rate (Singh *et al.* 1996) and growth and yield (Hundal *et al.* 2001 and 2003; Bazgeer *et al.* 2007). Each crop requires a definite amount of accumulated heat energy for completion of its life cycle. Crop weather relationship studies in aromatic plants are very meager and needs attention. GDD or heat unit requirement has often been used for characterizing thermal responses in crops but no attempt has been made to study its response on essential oil bearing crops like wild marigold (*Tagetes minuta*). It is native to South America and is an essential oil yielding plant used in the aromatic and flavour industries. In India, it is found in western Himalaya between altitudes of 1000 and 2500 m amsl. Essential oil obtained from wild marigold is known as "Tagetes oil" among traders and end users. The oil is a valuable commercial product largely used in compounding of high-grade perfumes. Though the agronomic aspects of wild marigold were studied in details,

[**]*Present address: Senior Scientist, Indian Institute of Soil Science (ICAR), Nabi bagh, Bhopal, India*

Table 1: Treatment details

Treatment		Date of sowing	
		2007	2008
T1	First fortnight of February	9-Feb	12-Feb
T2	Second fortnight of February	24-Feb	27-Feb
T3	First fortnight of March	11-Mar	13-Mar
T4	Second fortnight of March	26-Mar	28-Mar
T5	First fortnight of April	10-Apr	12-Apr
T6	Second fortnight of April	25-Apr	27-Apr
T7	First fortnight of May	10-May	*
T8	Second fortnight of May	25-May	*
T9	First fortnight of June	10-Jun	*
T10	Second fortnight of June	25-Jun	*

* Treatments could not be executed

Table 2 : Days taken for completion of different phenological stages of tagetes as influenced by sowing dates

Treatment	Days taken to			
	Bud initiation	50% budding	Flower initiation	Harvesting
Date of sowing	Mean	Mean	Mean	Mean
T1	203	209	217	224
T2	189	194	203	210
T3	176	179	189	196
T4	160	164	175	182
T5	151	154	164	171
T6	137	140	150	158
T7	128	132	141	145
T8	116	117	127	131
T9	100	102	111	114
T10	85	87	94	102
SEm(±)				

* Treatments could not be executed

its agrometeorological studies are missing. Modest beginning was made to study the effect of radiation on wild marigold by Ramesh and Singh (2008). The present study was undertaken to assess the effect of various weather parameter on crop growth, biomass yield, and yield and quality of oil of wild marigold.

MATERIALS AND METHODS

Field experiment

Field experiments were conducted during 2007 and 2008 at the experimental farm of Institute of Himalayan Bioresource Technology (CSIR), Palampur (1325 m amsl, 32º06´05"N, 76º34´10"E), India. The site experiences a mean annual temperature of 18° C. Rainy season accounts for 65% of the total rainfall exceeding 2500 mm and is associated with low sunshine hours. The climate is classified as sub-humid. The soil of the experimental site is clayey loam in texture, acidic in reaction (pH 5.5). Seeds of tagetes were sown at defined intervals in the nursery to suit the planting dates. During 2007, ten dates of sowing at an interval of 15 days starting from February 9 till June 25, 2007 were adopted, whereas, during 2008 only six dates of sowing could be executed starting from February 12 to April 27, 2008 as the late sown crop in 2008 could not be established due to heavy rainfall (Fig. 1). The treatments (Table 1), with three replications, were applied as per the Randomized Complete Block Design. Sixty days old seedlings of tagetes were transplanted in the main field having unit experimental plot of dimension 3.3 X 2.4 m^2.

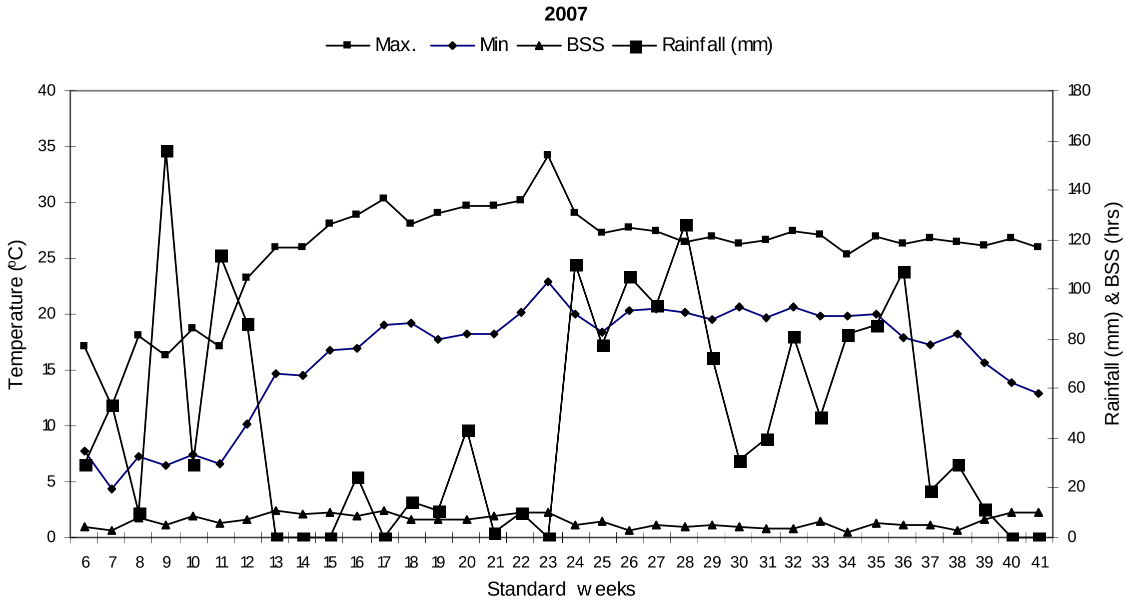
Well decomposed farm yard manure (FYM) @ 30 t ha^{-1} was thoroughly mixed in the soil before transplanting. The plant spacing was 30 x 30 cm. Periodical observations were recorded on plant biometrics. Also, data was recorded on different phenological stages *viz.*, days taken to flower bud initiation, initiation of flowering, 50 per cent flowering, and harvesting stage.

Data of weather parameters were recorded from a Class 'B' Agrometeorological observatory of CSK HP Agricultural University, Palampur, which is adjacent to the experimental site. A constant set of package of practices was adopted during both the years of study by leaving weather as only variable. The various agrometeorological indics via. GDD, HTU, PTU and RTD were determined using base temperature of 10°C and were accumulated from the date of nursery sowing to each date of sampling to give accumulated values.

RESULT AND DISCUSSION

Crop phenology

The calendar for different phenophases of tagetes observed during experimentation period is presented in Table 2. The crop took maximum number of days for bud initiation stage than for the completion of other stages in all dates of sowing. The calendar for different phenophases observed during the two crop seasons showed little variations in the number of days taken by the crop for completion of each phenophase. During 2007, the crop sown early (on February 9, 2007) took 222 days from sowing to harvesting, while late sown crop (on June 25, 2007) took 102 days for harvesting. During 2008, the early sown crop (on February 12, 2008) took 226 days, while crop sown on April 27, 2008 took 153 days. The number of days taken from sowing to harvesting was highest in the early sown crop during both the years and



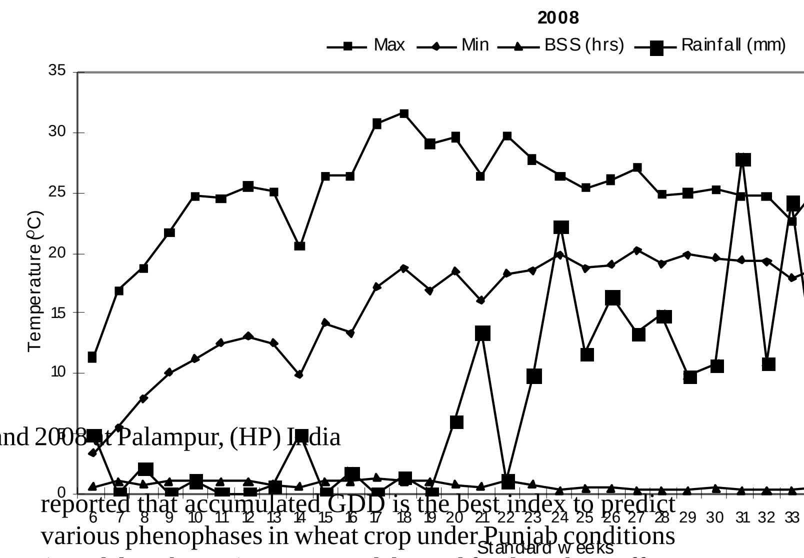


Fig. 1: Weekly meteorological data during 2007 and 2008 at Palampur, (HP) India

consistently decreased with subsequent sowing. With delay in sowing, the crop duration reduced on account of shortened vegetative and reproductive phases. In late sown crop, the duration of crop growth decreased because of forced maturity due to low temperature and lesser (BSS) (Fig. 1).

GDD and crop phenology

The heat unit or GDD - concept was proposed to explain the relationship between growth duration and temperature. This concept assumes a direct and linear relationship between growth and temperature (Nuttonson, 1955). It has been reported that accumulated GDD is the best index to predict various phenophases in wheat crop under Punjab conditions (Hundal *et al.* 1997). GDD is widely used for describing effect of temperature on growth and development of crops. GDD required for different phenophases varied with date of sowing. There was a sharp decline in GDD with delay in date of sowing during both years (Table 3). Also, in case of other pheonological stages the early sown crop had accumulated maximum growing degree days. This describes clearly the effect of temperature on phenological stages like bud initiation, 50% budding, flower initiation, and harvesting. The first sowing recorded 2518°C accumulated GDD from

Table 3 : Effect of sowing dates on weather indices at different phenological stages in tagetes

Treatment	Phenological stages	AGDD (ºC day)	AHTU (ºC day hr)	APTU (ºC day hr)
		Mean values	Mean values	Mean values
T1	Sowing to Bud initiation	2230	14119	29766
	Bud initiation to 50% budding	64	334	782
	50% budding to flower initiation	99	713	1186
	Flower initiation to harvesting	125	540	1460
	Total (Sowing to harvesting)	2518	15706	33193
T2	Sowing to Bud initiation	2215	14009	29476
	Bud initiation to 50% budding	52	274	641
	50% budding to flower initiation	105	740	1257
	Flower initiation to harvesting	113	471	1317
	Total (Sowing to harvesting)	2485	15494	32690
T3	Sowing to Bud initiation	2158	13401	28842
	Bud initiation to 50% budding	40	247	491
	50% budding to flower initiation	119	750	1426
	Flower initiation to harvesting	93	473	1077
	Total (Sowing to harvesting)	2410	14872	31836
T4	Sowing to Bud initiation	2047	12557	27436
	Bud initiation to 50% budding	47	274	578
	50% budding to flower initiation	118	767	1412
	Flower initiation to harvesting	117	575	1354
	Total (Sowing to harvesting)	2329	14174	30780
T5	Sowing to Bud initiation	1987	11879	26552
	Bud initiation to 50% budding	37	149	449
	50% budding to flower initiation	124	714	1469
	Flower initiation to harvesting	102	819	1173
	Total (Sowing to harvesting)	2250	13561	29642
T6	Sowing to Bud initiation	1817	10229	24226
	Bud initiation to 50% budding	45	154	528
	50% budding to flower initiation	111	648	1309
	Flower initiation to harvesting	92	739	1056
	Total (Sowing to harvesting)	2064	11770	27119
T7	Sowing to Bud initiation	1773	10522	23451
	Bud initiation to 50% budding	54	138	636
	50% budding to flower initiation	103	413	1187
	Flower initiation to harvesting	86	863	986
	Total (Sowing to harvesting)	2016	11935	26260
T8	Sowing to Bud initiation	1591	8892	20859
	Bud initiation to 50% budding	28	83	325
	50% budding to flower initiation	113	513	1302
	Flower initiation to harvesting	85	860	975
	Total (Sowing to harvesting)	1816	10348	23460
T9	Sowing to Bud initiation	1349	6435	17518
	Bud initiation to 50% budding	28	113	322
	50% budding to flower initiation	99	462	1143
	Flower initiation to harvesting	85	860	975
	Total (Sowing to harvesting)	1561	7870	19956
T10	Sowing to Bud initiation	1137	5047	14633
	Bud initiation to 50% budding	28	113	322
	50% budding to flower initiation	79	299	916
	Flower initiation to harvesting	134	1322	1529
	Total (Sowing to harvesting)	1378	6781	17400

Table 4 : Correlation coefficients between agro-meteorological indices and biometric observations of tagetes

Parameters	Temperature Difference (ºC)	RTD (%)	GDD (ºC days)	HTU (ºC day hr)	PTU (ºC day hr)	BSS (hr)	Day length (hr)
2007							
Total biomass (kg ha^{-1})	0.634*	0.634*	0.577	0.577	0.576	0.630	0.623
Total oil content (%)	0.351	0.235	0.509	0.490	0.515	0.378	0.386
Leaf oil yield (kg ha^{-1})	0.553	0.559	0.491	0.491	0.490	0.540	0.548
Flower oil yield (kg ha^{-1})	0.688*	0.651*	0.684*	0.682*	0.686*	0.687*	0.694*
Total oil yield (kg ha^{-1})	0.645*	0.625	0.619	0.618	0.619	0.639*	0.647*
t value at 8 df	0.632						
2008							
Total Biomass (kg ha^{-1})	0.798	0.771	0.830*	0.833*	0.828*	0.779	0.781
Total oil content (%)	0.841*	0.872*	0.795	0.774	0.780	0.865*	0.865*
Leaf oil yield (kg ha^{-1})	0.975*	0.981*	0.952*	0.947*	0.941*	0.976*	0.968*
Flower oil yield (kg ha^{-1})	0.732	0.700	0.782	0.784	0.782	0.717	0.724
Total oil yield (kg ha^{-1})	0.854*	0.843*	0.852*	0.855*	0.843*	0.839*	0.828*
t value at 4 df	0.811						

* Significant at P=0.05

sowing to harvesting while for last sowing it was 1378 °C. Every crop needs a specific amount of GDD to enter its reproductive phase from vegetative phase. Early sowing resulted in absorbing sufficient GDD in relatively less time due to prevalence of higher temperature and longer sunshine hour during post sowing period. Therefore, early sown crop recorded higher GDD as compared to the late sown crop. Similar results were also reported by Kanth *et al.* (2000) and Roy *et al.* (2005) for brassica and by Murty *et al.* (2008) for amaranth. During early dates of plantings, more GDD were accumulated from sowing to bud initiation followed by flower initiation to harvesting, 50% budding to flower initiation, and bud initiation to 50% budding.

HTU and crop phenology

HTU of different phenological stages are presented in Table 3. Like GDD, HTU also decreased with delay in sowing. Late sowing compelled the plants to complete their life cycle with a short period of time resulting in decreased HTU. These results are in agreement with those reported by Sastry and Chakravarty (1982), Masoni *et al.* (1990), and Rajput *et al.* (1987) in wheat and Rajput and Sastry (1985) in Soybean. The results revealed that the accumulated HTU ranged from 83 to 14119°C day hour during different phenological stages in all the treatments. Highest HTU were accumulated from sowing to bud initiation stage followed by 50% budding to flower initiation, flower initiation to harvesting stage, and lowest by bud initiation to 50% budding stage when the tagetes were sown from first fortnight of February to first fortnight of April. The days taken from sowing to bud initiation stage was maximum than other stages, which led to higher values of degree days and hence increased the accumulated HTU values. After sowing to bud initiation, more accumulated HTU was recorded from flower initiation to harvesting, 50% budding to harvesting, and bud initiation to 50% budding stage in order.

PTU and crop phenology

Accumulated values of PTU experienced by the crop during different phenological stages are presented in the Table 3. A cursory look at the table revealed that the accumulated PTU ranged from 322 to 29766 °C days in the completion of different phenophases of tagetes during different sowing dates. Among different phenological stages, sowing to bud initiation stage accumulated highest PTU in all the dates of sowing, which may be due to the fact that tagetes took longer duration to reach this stage than other stages (Table 2).

Correlation between agroclimatic indices and biometric observations

Attempt was made to correlate biomass, oil content and oil yield of tagetes with different agroclimatic indices (Table 4). Correlation analysis between total oil yield and daily mean weather variable at harvesting stage revealed a significant positive correlation. Significant correlations were found between total oil yield and temperature difference, day length, and BSS during both years. This indicated that temperature, day length, sunshine hours play an important role and influence oil yield of tagetes. More sunshine hours during reproductive phase might have helped in translocation of photosynthates to sink. There exist positive correlation between flower oil yield and RTD, GDD, HTU, PTU, day length and BSS during 2007. However, during 2008 these agroclimatic indices showed significant correlation with total oil yield. Based on the above correlation coefficient, it is clear that the selected weather variables have correlations with the biomass yield, oil content and oil yield.

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