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Agrometeorological indices of white clover (*Trifolium repens*) in western Himalayas

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ABSTRACT

Field experiments were conducted during 2009-2010 and 2010-2011 to study the growth performance of white clover (*Trifolium repens* L.) under different temperature regimes over the crop growth period. The agroclimatic indices for temperature *viz*., growing degree days (GDD), heliothermal units (HTU) and photothermal units (PTU) were computed for different phenological stages of the crop. Changes in weather parameters concomitant to different sowing time caused significant variation in the performance of the crop. The results indicated that the early sown crop had longer crop span (205 days) than the late sown (142 days). From emergence to seed maturity, white clover accumulated GDD of 2314±72 °C days, HTU of 17791±409 °C days hour and PTU of 29412±742 °C days hour, respectively. Positive correlations were found between fresh leaf weight, fresh stem weight and fresh root weight for GDD, HTU and PTU.

Key words: White clover, phenophases, heat units, heliothermal unit, photothermal unit.

Of the 250-300 odd species of genus *Trifolium* (family Fabaceae) (Anonymous, 2008), white clover (*Trifolium repens* L.) is the most important species in the temperate region of the world. The high forage quality and yield, besides its role in symbiotic N_2 fixation, make it a valuable forage crop. Owing to its wide adaptability under changing conditions of soil, and environmental variables, the species response to changing environmental variables has been used in several climate change models. *T. repens* is grown as a winter crop in northern India. Temperature is one of the most important climatic events that affect the growth, phenology and development of winter crop (Kalra, 2008).

Plants have a definite temperature requirement before they attain certain phenological stages. A change in optimum temperature during different phenological stages of a crop adversely affects the initiation and duration of different phenophases and finally economic yield of the crop. It is therefore indispensable to have knowledge of exact duration of phenophases in a particular environment and their association with yield attributes for achieving high yields (Kumari *et al*., 2009). Influence of temperature on phenology and yield of crop plants can be studied under field condition through accumulated heat unit system (Haider *et al*., 2003 and Pandey *et al*., 2010). Air temperature based agromet indices *viz*., growing degree days (GDD), photothermal units (PTU), heliothermal units (HTU), have been used to describe changes in phenological behaviour and growth parameters (Singh *et al*., 2007; Kumar *et al.,* 2008; Kumar *et al*., 2010). GDD or a similar linear unit system is widely used to predict crop development with air temperature. Similarly, attempts have been made to correlate phenology (Dhaliwal *et al*., 2007; Hundal *et al*., 1997) to total dry matter, growth and yield (Hundal *et al*., 2003; Murty *et al*., 2008). The selection of an appropriate base temperature is critical to the GDD or any heat unit model. The present study has been done to determine the phenological stages and heat unit requirement of *T. repens* under varied microclimate conditions.

MATERIALS AND METHODS

Field experiment

Field experiments were conducted during 2009-10 and 2010-11 in the experimental farm of CSIR- Institute of Himalayan Bioresource Technology, Palampur (1325 m amsl altitude, 32°06'05''N latitude, 76°34'10"E longitude), India. The treatment comprised of seven dates

Table 1: Effect of dates of sowing on phenological stages of T. repens (Pooled data of 2 years)

Sowing period (MSW)	Days taken to phenological stage (DAS)						
	Emergence	Bud formation	Initiation of flowering	50% flowering	100% flowering	Seed setting	Seed maturity
44	11.0	122.0	134.0	156.0	170.5	184.5	202.0
46	9.0	122.5	132.0	154.5	165.5	176.5	195.5
48	13.5	122.5	132.0	143.0	152.5	160.5	181.0
50	14.0	112.0	120.5	132.0	138.5	150.0	172.0
52	15.0	102.5	108.0	123.5	128.5	141.5	162.0
3	14.5	91.0	98.0	111.5	117.5	129.5	151.5
5	13.0	80.5	87.5	104.5	113.0	121.5	142.0
SEm±	0.8	6.4	7.0	7.6	8.6	8.8	8.4

of sowing *viz*., October 30, November 16, December 2, December 17, December 30, January 16, January 30 Periodical observations were recorded on plant biometrics *viz*. dry matter accumulation in to different plant parts, number of leaves, root length, root volume, number of lateral roots and number of spikes plant^{-1}. Data was also recorded on different phenological stages *viz.,* days taken to emergence, flower bud initiation, 50 per cent flowering, 100 per cent flowering, seed setting, and seed maturity.

Data of weather parameters *viz*., maximum and minimum temperatures, relative humidity, evaporation, bright sunshine hours and rainfall for the crop season (October 2009 to June 2010 and October 2010 to June 2011) were procured 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 taking weather as the only variable. Accumulated agrometeorological indices *viz*., GDD, HTU and PTU were determined using base temperature of 4.2°C for *T. repens* (Sakanoue, 2010).

RESULT AND DISCUSSION

Crop phenology

The calendar for different phenophases of *T. repens* observed during the experimentation period revealed (Table 1) that the crop took maximum number of days for bud formation stage compared to the completion of other stages in all dates of sowing. The number of days required to attain different phenological stages decreased with delay in sowing from 44th MSW (October 30) to 5th MSW (January 30). The crop sown early (44th MSW) took 202 days from sowing to maturity, while late sown crop (5th MSW) took 142 days for maturity. For emergence, crop sown on 52nd MSW (December 30) took significantly higher number of days as compared to other dates of sowing (Table 1) due to low temperature during this period . With delay in sowing (January 15 and January 30) took lesser number of days as compared to early sowing for bud initiation, flowering, seed setting and maturity stages. The number of days taken from sowing to maturity was highest in early sown crop and decreased consistently with subsequent sowing. *T. repens* after emergence took maximum number of days for next stage bud formation as compared to other phenological stages due to low temperature and freezing conditions. During late sowing, the duration of crop growth decreased because of forced maturity due to high temperatures. The calendar for different phenophases observed during the crop seasons showed little variations in the number of days taken by the crop for the completion of each phenophase. The crop duration reduced with delay in sowing on account of shorter vegetative and reproductive phases. It is well known that shorter days and lower temperature under delayed sowing in the initial stages of crop growth reduces photosynthesis and other physiological activities of the plant.

Growing degree days (GDD)

The accumulated thermal times presented in Table 2 revealed that GDD required for different phenophases varied with date of sowing. There was a decline in GDD with delay in sowing upto 52nd MSW and slight increase

Table 2: Effect of dates of sowing on accumulated thermal and radiation regimes at different phenophases (Pooled data of 2 years)

Sowing period (MSW)	Phenophases							
	Sowing to Emergence formation	Emergence to Bud flowering	Bud formation to Initiation of flowering	Initiation of flowering to 50%	50% flowering to 100% flowering	100% flowering to Seed setting	Seed setting to Seed maturity	Total
				GDD (°C days)				
44	150	906	145	256	259	347	409	2471
46	100	914	118	277	212	289	400	2309
48	121	926	152	201	272	165	434	2271
50	91	923	142	223	194	238	467	2278
52	90	910	105	363	107	270	422	2267
3	97	892	133	341	133	243	446	2286
5	113	872	140	414	177	178	418	2313
Mean	109	906	134	296	193	247	428	2314
SEm±	7.9	7.2	6.4	29.5	23.1	23.8	8.7	27.2
				HTU (°C days hr)				
44	1273	6325	708	1846	2510	2574	3385	18620
46	783	6198	685	2456	1982	2081	3337	17522
48	840	6297	1303	1979	1934	1342	3715	17409
50	690	6358	1377	2053	1255	2078	3950	17761
52	657	6448	953	2804	985	2266	3427	17540
3	694	6504	1264	2588	1030	1986	3655	17721
5	518	6882	1404	2894	1483	1488	3298	17967
Mean	779	6430	1099	2374	1597	1974	3538	17791
SEm±	90.7	84.3	117.9	157.6	213.9	162.2	91.1	154.6
				PTU (°C days hr)				
44	1608	9693	1634	3092	3449	4768	5684	29929
46	1031	9975	1489	3603	2894	3997	5558	28546
48	1220	10543	2034	2720	3748	2293	6027	28584
50	913	10807	1935	3029	2684	3309	6463	29139
52	913	10931	1432	4949	1479	3758	5806	29268
3	999	11030	1822	4681	1853	3377	6105	29868
5	1202	11077	1928	5718	2463	2466	5696	30550
Mean	1127	10579	1753	3970	2653	3424	5906	29412
SEm±	93.0	205.7	89.2	433.3	306.6	325.9	118.3	280.5

thereafter upto 5th MSW. The crop took 2314 GDD for maturation with a standard deviation of 72 days. Among all phenophases the crop took maximum degree of days for attaining budding stage at various dates of sowing. The accumulated GDD from sowing to seed maturity ranged from 90 to 2471 degree days at different sowing dates (Table 2). Early sowing absorbed sufficient GDD in relative less time due to prevalence of higher temperature

Table 3: Correlation coefficients between agrometerological indices and biometric observations of *T. repens* at maturity

Parameters	GDD (°C days)	HTU (°C days hr)	PTU (°C days hr)	Day length (hr)	Sunshine (hr)
Number of leaves plant^{-1}	0.72	0.72	0.84*	0.40	0.42
Fresh leaf weight (g plant^{-1})	0.86*	0.84*	0.88*	0.59	0.60
Dry leaf weight (g plant^{-1})	0.74	0.73	0.89*	0.39	0.41
Fresh stem weight (g plant^{-1})	0.84*	0.81*	0.79*	0.63	0.64
Dry stem weight (g plant^{-1})	0.50	0.44	0.76*	0.08	0.10
Fresh root weight (g plant^{-1})	0.87*	0.83*	0.85*	0.61	0.63
Dry root weight (g plant^{-1})	0.55	0.53	0.87*	0.09	0.12
Total dry weight (g plant^{-1})	0.62	0.59	0.85*	0.22	0.24
Root volume (ml plant^{-1})	0.47	0.46	0.70	0.11	0.13
Root length (cm plant^{-1})	0.72	0.62	0.74	0.47	0.49
Number of lateral roots plant^{-1}	0.22	0.28	0.44	-0.02	-0.01
Number of spikes plant^{-1}	0.73	0.70	0.39	0.81*	0.81*

* Significant at P=0.05

and longer sunshine hour during post sowing period. The shortened crop growth period (50-60 days) under late sown condition was due to the sudden drop in temperature during early vegetative phase and sharp rise in temperature during late development phases and maturity which hastened reproductive phase and maturity (Table 1).

Heliothermal units (HTU)

The HTU requirements for entire growth phase were found to decrease as the sowing was delayed up to 48th MSW and increased thereafter Table 2. Early sown crop (44th MSW) accumulated 18620 °C days hour thermal units from sowing to maturity while for late sown (3rd MSW) it was 17967 °C days hour. HTU decreased with delay in sowing as the late sown plant suffer from high temperature later in the growing season. Late sowing compelled the plants to complete their life cycle with a short period of time resulting in decreased HTU.

Photothermal units (PTU)

The PTU for different phenophases is presented in Table 2 show that PTU requirement for entire growth phase decreased as the sowing was delayed up to 48th MSW and thereafter it increased up to 5th MSW. This may be due to shorter day length, low temperature during early vegetative phase and longer day length, high temperature during late development phases. Table 2 revealed that the mean value of accumulated PTU ranged from 1127 to 10579 °C days hour in the completion of different phenophases of white clover during different sowing dates. The crop sown beyond 48th MSW required more PTU due to longer day length. PTU requirement during 100 per cent flowering to seed setting decreased with delayed sowing. This may be due to the fact that *T. repens* sown late was forced to mature early due to high temperature during reproductive phase of late sown crop so the PTU for late sown crop was also low. 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 *T. repens* took longer duration to reach this stage than other stages (Table 2).

Correlation between agroclimatic indices and biometric observations

Plant biomass was correlated with different agroclimatic indices (Table 3). Positive correlations were observed between fresh leaf weight, fresh stem weight and fresh root weight for GDD, HTU and PTU. Dry leaf weight, dry root weight and total dry weight showed a positive correlation with PTU. Numbers of lateral roots showed a negative correlation with day length and sunshine hours while numbers of spikes exhibiting a positive correlation. Based on the above correlation coefficient, it was observed that the selected weather variables have correlations with the fresh leaf weight, fresh stem weight, fresh root, dry leaf weight, dry root weight, total dry weight and numbers of spikes.

The study indicated that change in microclimate due to different sowing time is reflected during individual growth stage. The differences in the agrometeorological indices for different growth stages indicated that accumulated temperature could be utilized for studying biomass accumulation pattern at different phenological stages of *T. repens*.

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