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Thermal indices in relation to crop phenology of wheat (*Triticum aestivum* L.) and urd (*Vigna mungo* L. Hepper) at Tarai region of Uttarakhand

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सार – उत्तराखंड के तराई वाले क्षेत्र में गेहूँ और उड़द की फसलों की ऋतुजैविकी एवं जी डी डी, पी टी यू, एच टी यू एवं पी टी आई का अध्ययन करने के लिए गोविंद बल्लभ पंत कृषि एवं प्रौद्योगिकी विश्वविद्यालय पंतनगर उत्तराखंड में वर्ष 2007–2008 एवं 2008–2009 में खरीफ तथा रबी के मौसमों के समय खेतों में प्रयोग किए गए। रबी के मौसम में 18 नवम्बर 2007 और 1 नवम्बर 2008 को गेहूँ के फसल की तथा खरीफ के मौसम में 7 जुलाई 2007 एवं 20 जुलाई 2008 को उड़द के फसल की बुआई की गई। प्राप्त परिणामों से पता चला है कि गेहूँ तथा उड़द की फसलों के औसत जीडीडी, एच टी यू क्रमश: 2016, 14383, 22745 तथा 1592, 8586, 20813 थे । जी डी डी, एच टी यू पी टी यू के साथ R^2 0.98 एवं 0.99 के उपयोग के द्वारा क्रमश: गेहूँ और उड़द के कायिकी परिपक्वता का पूर्वानुमान दिया जा सकता है। वर्ष 2007-08 के दौरान गेहूँ की एच यू ई 2.28 कि.ग्रा. अन्न प्रति हेक्टेअर प्रति डिग्री दिन एवं अन्न की उपज 4250 कि.ग्रा./हेक्टेअर थी तथा वर्ष 2008-09 के दौरान एच यू ई 1.84 कि.ग्रा./हेक्टेअर प्रति डिग्री दिन एवं अन्न की उपज 3978 कि.ग्रा. हेक्टेअर थी। वर्ष 2007 के दौरान उड़द की एच यू ई 1.18 कि.ग्रा.अन्न/हेक्टेअर प्रति डिग्री दिन एवं अन्न की उपज 1878 कि.ग्रा./ हेक्टेअर थी तथा वर्ष 2008 के दौरान एच यू ई 0.99 कि.ग्रा. अन्न/ हेक्टेअर और अन्न की उपज 1584 कि.ग्रा/हेक्टेअर दर्ज की गई थी।

ABSTRACT. Field experiments were conducted during kharif and rabi seasons of 2007-08 and 2008-09 at GBPUAT Pantnagar, Uttarakhand to study phenology and GDD, PTU, HTU and PTI for wheat and urd crops at Tarai region of Uttarakhand. Wheat crop were sown on 18 November 2007 and 1 November, 2008 during rabi seasons and urd crop were sown on 7 July 2007 and 20 July 2008, during kharif season. Results revealed that mean GDD, HTU, PTU for wheat and urd crops were 2016, 14383, 22745 and 1592, 8586, 20813 respectively. Physiological maturity can be predicted for wheat and urd by using GDD, HTU, PTU with R^2 0.98 and 0.99 respectively. During 2007-08 the HUE for wheat was 2.28 kg grain/ha degree days^{-1} with grain yield 4250 kg/ha and during 2008-09 HUE was 1.84 kg grain/ha degree days^{-1} with grain yield 3978 kg/ha. During 2007 the HUE for urd was 1.18 kg grain/ha degree days^{-1} with grain yield 1878 kg/ha and during 2008 HUE was 0.99 kg grain/ha degree days^{-1} with grain yield 1584 kg/ha.

Key words – GDD, HTU, PTU, PTI, Thermal use efficiencies.

1. Introduction

Temperature plays significant role in physiological, chemical and biological processes of plants. The occurrence of different phenological events during a growing season of crop and the effect of temperature on plant growth can be explained using accrued heat units (Sunil and Sarma, 2005). Growing degree days are based on the concept that the real time to attain a phenological stage is linearly related to temperature in the range between base temperature and optimum temperature (Monteith, 1981). The heat unit concept assumes that a direct and linear relationship between growth and temperature is advantageous for the assessment of yield potential of a crop in different weather conditions. Reaumur was the first to suggest that duration of particular stages of growth is directly related to temperature summation (Patel *et al*., 1999). Hundal (2004) observed that 2 °C increase in temperature in wheat resulted in 15-17% decrease in grain yield. In India this concept has been applied to various crops like wheat, barley and mustard (Sastry and Chakravarty, 1982; Hundal *et al*., 1997; Kar and Chakravarty, 1999) and was found to be useful as an input in crop growth studies. Influence of temperature on phenology and yield of crop plants can be studied under field conditions through accumulated heat unit system (Bishnoi *et al*.,1995) The duration of each phenophase determines the accumulation

TABLE 1

Accumulated units required for attainment of phenophases and indices for wheat crop

Crop Stages	Days to attain phonological stages	GDD (ºC day)	HTU (ºC day)	PTU (ºC day)	PTI (ºC)
		2007-08			
Germination	8	87	379	887	10.9
CRI	24	250	1282	2554	10.4
Tillering	41	411	2194	4213	10.0
Jointing	70	646	3449	6724	9.2
Ear emergence	83	787	4531	8292	9.5
Anthesis	93	944	5766	10134	10.2
Milking stage	99	1014	6142	11003	10.2
Dough stage	123	1397	8937	15642	11.4
Phy-maturity	144	1865	13264	21710	13.0
		2008-09			
Germination	7	99	763	1010	14.1
CRI	27	349	2014	3560	12.9
Tillering	40	472	2601	4838	11.8
Jointing	73	843	4591	8802	11.5
Ear emergence	87	1021	6148	10789	11.7
Anthesis	96	1177	6877	11764	12.3
Milking stage	100	1244	7383	12440	12.4
Dough stage	125	1729	11328	18257	13.8
Phy-maturity	149	2168	15503	23781	14.6

and partitioning of dry matter in different parts as well as crop responses to environmental and external factors (Dalton, 1967). In the present paper thermal indices for wheat and urd have been carried out by using weather variables.

2. Data and methodology

Pantnagar is situated in the Tarai belt, foothills of the Shivalic range of Himalayas at 29°1' N latitude, 79.28° E longitude and at an altitude of 215 m above the mean sea level. The climate of Pantnagar is temperate with severe cold winter and hot summer. Annual rainfall varies between 1200-1500 mm and distributed over 55 to 60 rainy days. Wheat (*Triticum aestivum* L.), an important food grain crop in Tarai region of Uttarakhand, is sown during November/December and harvested in March/April. It is rabi season crop and amount of rainfall during this period is very low. Hence, the water requirement of the crop is fulfilled by irrigation. Urd (*Vigna mungo* L. Hepper) grown in kharif season is a very nutritious pulse crop in the Tarai belt of Uttarakhand, requiring less water for its growth and development. Field experiments were conducted during Kharif and Rabi seasons of 2007 and 2008 at Crop Research Center, GBPUAT Pantnagar, Uttarakhand with Urd variety Pant Urd-31 and Wheat UP-2565 crops. Weather data were collected form Agrometeorologcial observatory GBPUAT Pantnagar Uttrakhand, which is close to experimental site. Wheat crop growth was divided into different phenophases, germination, CRI, tillering, jointing, ear emergence, anthesis, milking, dough, and physiological maturity and for urd crop stages were germination, vegetative stage, anthesis, first pod and physiological maturity. The various thermal indices Growing Degree Days (GDD), Helio Thermal Unit (HTU), Photo Thermal Unit (PTU), Phenothermal index (PTI) and Heat Use Efficiency (HUE) were determined by using base temperature 10 °C for urd crop and 4 °C for wheat crop.

3. Results and discussion

3.1. *Wheat phenology and thermal indices*

Wheat crop were sown on 18 November, 2007 and 1 November, 2008. The crop took 70-73 days for jointing stage. Flowering occurred mostly in the last week of February. The average crop duration was 144 days. During 2007-08 ear emergence was observed at 83 days after sowing (DAS) while in 2008-09 it occurs at 87 DAS.

3.2. *Growing Degree Days (GDD) for wheat*

During 2007-08 crop took 1865 units accumulated GDD with total 144 days till physiological maturity and during 2008-09 crop took 2168 units accumulated GDD with total 149 days till physiological maturity. This explains the direct impact of temperature on crop growth; every crop needs a certain amount of GDD to enter its next crop stage (Table 1). Vulnerability of winter crops to temperature during reproductive stage was reported under different crop growth conditions (Kalra, 2008). Heat unit concept was applied to correlate phenological development in crops to predict maturity dates (Rao *et al*., 1999). Ram *et al*. (2012) reported higher GDD requirement for wheat crop for normal sowing conditions than the later growing conditions. Late sowing decreased the duration of phenology as compared to normal sowing due to fluctuated un-favourable high temperature during the growing period.

3.3. *Photo Thermal Unit (PTU) for wheat*

During 2007-08 crop took 21710 units of accumulated PTU with total 144 days till physiological maturity and during 2008-09 crop accumulated 23781 units in 149 days till physiological maturity (Table 1). Wheat was among the most temperature sensitive crops

TABLE 2

Accumulated units required for attainment of phenophases and indices for urd

Crop Stages	Days to attain phonological stages	GDD (ºC day)	HTU (ºC day)	PTU (ºC day)	PTI (ºC)
		2007			
Germination	7	137	1067	1902	19.6
Vegetative growth	25	398	1879	5530	15.9
Anthesis	40	730	3663	9960	18.3
First pod	50	914	4515	12378	18.3
Physio-Maturity	90	1596	9077	20880	17.7
		2008			
Germination	8	147	719	2041	18.4
Vegetative growth	28	497	1823	6869	17.8
Anthesis	42	743	2765	10122	17.7
First pod	53	940	3671	12720	17.7
Physio-Maturity	92	1590	8097	20746	17.3

and production could fluctuate with a slight change in temperature.

3.4. *Heliothermal Thermal Unit (HTU) for wheat*

During 2007-08 crop took 13264 accumulated HTU with total 144 days till physiological maturity and during 2008-09 crop took 15503 units with total 149 days till physiological maturity (Table 1). HTU is the product of GDD and actual bright sun shine hours, higher BSS results in more units of HT. Several studies in India have shown that a delay of 20 days in sowing could cause a delay in flowering by 8 days or upto 13 days. (Brar *et al*., 2011)

3.5. *Phenothermal Index (PTI) for wheat*

During 2007-08 and 2008-09 PTI ranged between 9.2 to 13.0 °C and 11.5 to 14.6 °C respectively. In both the stages anthesis and dough stage showed relatively higher PTI, tillering and jointing stages indicating for lower values (Table 1).

3.6. *Thermal use efficiencies for wheat*

Thermal use efficiencies have been shown in Table 3, during 2007-08 the HUE, PTUE and HTUE were 2.28 kg grain/ha degree day^{-1}, 0.20 kg grain/ha degree day^{-1}, 0.32 kg grain/ha degree day^{-1} with grain yield 4250 kg/ha and during 2008 - 09 the HUE, PTUE and HTUE were 1.84 kg grain/ha degree day^{-1},0.17 kg grain/ha degree day^{-1}, 0.26 kg grain/ha degree day^{-1} with grain yield 3978 kg/ha. Rani *et al*. (2012) reported that the heat and radiation use efficiencies decreased with delay in sowing.

TABLE 3

Thermal use efficiencies for wheat and urd

	Wheat			Urd		
	HUE	PTUE	HTUE	HUE	PTUE	HTUE
2007-08	2.28	0.20	0.32	1.18	0.09	0.21
2008-09	1.84	0.17	0.26	0.99	0.08	0.20
Mean	2.06	0.18	0.29	1.08	0.08	0.20
CV%	15.10	11.47	14.63	12.38	8.32	3.45

3.7. *Prevailing weather conditions during urd seasons*

In Tarai region of Uttarakhand urd is grown normally from July-August to October. It largely depends upon monsoon rain and availability of irrigation facilities. Weather conditions remained moderate during urd growing season. The mean air temperature of the urd season was about 27.3 to 30 °C and slightly declined after mid September in both years. The daily maximum temperature fluctuated between 31.2 to 35 °C. However, daily minimum temperature remained in the range of 23.5 to 26 °C upto mid September and thereafter it started declining and later on the winter season start. Average duration of bright sunshine hours in the kharif seasons were 5.9 hr day^{-1}.

3.8. *Urd phenology and thermal indices*

Urd crop were sown on 7 July, 2007 and 20 July in 2008 and about 80-90% seeds geminated within one week after sowing. The crop took 40-45 days for anthesis. Flowering occurred during last week of August. Average crop duration was 89 days and averages of plant heights were between 43-45 cm. The maximum number of leaves per plant was 18 during first week of September. The number of leaves decreased as the crop approached maturity.

3.9. *Growing Degree Days (GDD) for urd*

Stage wise GDD has been presented in Table 2. Accumulated GDD for urd crop during 2007 were 1596 units (90 days to physiological maturity), and during 2008 accumulated GDD were 1590 units (92 days to physiological maturity).

3.10. *Heliothermal Thermal Unit (HTU) for urd*

Accumulated HTU (Table 2) for urd crop during 2007 and 2008 were 9077 and 8097 units respectively. Difference in accumulated pattern between seasons is noticed during anthesis and first pod stages. This is a specific feature of using actual bright sunshine hours in HTU.

3.11. *Photo Thermal Unit (PTU) for urd*

Accumulated PTU for urd crop during 2007 were 20880 units (90 days to physiological maturity), and during 2008, it was 20746 units (92 days to physiological maturity). The grain yield depends on the balance between photosynthesis and respiration therefore air temperature plays important role in potential grain yield realization (Table 2).

3.12. *Phenothermal Index (PTI) for urd*

Phenothermal index for urd crop can be seen in Table 2. Stage wise PTI were calculated during 2007 and 2008 for urd crop. During 2007 and 2008 PTI ranged between 17.7 to 19.6 °C and 17.3 to 18.4 °C respectively. Jalota *et al*. (2009) observed that rain events during flowering to anthesis stage damaged the pollen, which may be reason for reduction in yield.

3.13. *Thermal use efficiency (HUE) for urd*

Thermal use efficiencies were calculated by using accumulated thermal use efficiencies and grain yield (Table 3). PTUE shows lower coefficients of variation since maximum possible day length is a fixed quantity at a location. However, effects of HTU and effect of using actual bright sunshine hours (HTUE) in Heliothermal units giving higher CV values are evident of weather variations in the individual seasons.

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