

Growing Degree Days Requirement and Yield of Wheat Cultivars as Influenced by Irrigation Scheduling and Time of Sowing

Comment [a1]: WRITE IN CAPS LETTER

ABSTRACT

The crop production characteristics are directly related with the temperature and relative humidity of atmosphere during crop growing season. Therefore, the main aim of this study was to highlights thermal requirement (GDD) of wheat varieties for sustainable yield. A field experiments was conducted during Rabi season 2016 and 2017 at Research farm, Rajasthan Agricultural Research Institute, Sri Karan Narendra Agriculture University, Durgapura, Jobner, Rajasthan to find out the response of wheat cultivars to irrigation scheduling under different sowing dates. Thirty six treatment combinations were investigated. Treatments comprises four irrigation levels: I₁ (0.6 ETc), I₂ (0.8 ETc), I₃ (1.0 ETc) and I₄ (1.2 ETc), three cultivars: C₁ (Raj-4120), C₂ (Raj-4079) and C₃ (Raj-4238) and three dates of sowing: D₁ (15th Nov.), D₂ (30th Nov.) and D₃ (15th Dec.) in Split plot design. The pooled analysis of data revealed that irrigation scheduling treatment I₄ (1.2 ETc) recorded significantly higher value of yield and Growing degree days (GDD), By cultivar Raj 4079 observed the higher value of yield and GDD. Further, results showed that the wheat crop sown on 15th November obtained the maximum yield and growing degree days value with phenological stages. The number of days required to attain different phenological stages decreased with late sowing condition. This indicated that irrigation scheduling at 1.2 ETc should adopted in cultivar Raj 4079 at the sowing on 15th November to achieve maximum yield under hot climate of Rajasthan.

Comment [a2]: The

Comment [a3]:

Comment [a4]: were

Comment [Ma5]: Rabi

Key words: Growing degree days, Wheat and Yield

1. INTRODUCTION

Wheat is a thermo-sensitive long-day crop. Temperature is a major determinant of its growth and productivity. Late sowing of wheat exposes pre-anthesis phenological events to high temperature that influence grain development and ultimately the yield (Nagarajane *et al.*, 2008). Phenological development from sowing to maturity is related to accumulation of heat or temperature units above threshold or base temperature (below which no growth occurs). A quantified value of heat or temperature units is required to reach a particular phenophase. Physiological and morphological development in plant is influenced by various meteorological factors such as temperature is an important environmental factor influencing the growth, development and yield of crops. During growth and development of a cereal crop several growth stages are distinguishable in which important physiological processes occur (Sikder, 2008). Plants have a definite temperature requirement before they attain certain phenological stages. Several

Comment [a6]: Spelling

research findings noticed that temperature below (<10 °C) or above (>25 °C) the optimum (12-25 °C) alter phenology, growth and development and finally reduce the yield of wheat cultivars (Hakim *et al.*, 2012). Influence of temperature on phenology and yield of crop plants can be studied under field condition through accumulated heat units system (Bishnoi *et al.*, 1995). Temperature stress intensity is severe under late sowing, causing reduction in the duration of later growth phases resulted in acquisition of less days to mature. Air temperature based agromet indice viz., growing degree days (GDD), has been used to describe changes in phenological behaviour and growth parameters (Kumar *et al.*, 2010). The values of accumulated GDD for each phenophases are relatively constant and independent of sowing date but vary in a crop from cultivar to cultivar (Phadnawis and Saini, 1992). Agronomic application of temperature effect on plant is the concept of heat unit or growing degree days and heat stress in wheat can be mitigated in two ways: heat management or the development of heat-tolerant cultivars. Evaluation of high yielding, stable genotypes having good quality are considered pre-requisite for increasing crop production in any region. So, there is a need to broader genetic base and to replace old cultivars with new and improved ones (Jat *et al.*, 2003). Recommendation of several varieties will also help farmers to select best one and also adequate supply of improved varieties to farmers. Especially in wheat choice of varieties depends on the time of higher, unfavorable air temperature, where difference in crop agronomy lead to difference in sowing dates, longer duration cultivars for earlier sowing and shorter duration cultivars for late sowing are recommended. So this experiment was conducted to study the effect of irrigation scheduling and dates of sowing on the phenology, heat unit requirement and heat use efficiency of wheat cultivars.

2. MATERIALS AND METHOD

Experimental site: - The field experiments was carried out during Rabi season 2016-17 and 2017-18 at Research farm, Rajasthan Agricultural Research Institute, Sri Karan Narendra Agriculture University, Jobner, Rajasthan. The experimental site's geographically situated at 75° 47' East longitudes, 26° 51' North latitude and at altitude of 390 m above mean sea level. The region's climate is classified as semi-arid eastern plain zone of Rajasthan with characterized by aridity of the atmosphere and extremity of temperature both in summer (45.5°C) and winter (4°C) with annual rainfall of 500-700 mm. The weather data for the entire cropping season observed from the RARI, SKNAU, Jobner meteorological observatory. The soil of experimental field was loamy sand in texture, slightly alkaline in reaction. Soil samples from 0-30 and 30-60 cm deep layers

Comment [Ma7]: Agrometeorological indices

Comment [a8]: del

Comment [a9]: were

Comment [a10]: seasons

Comment [Ma11]: Delete

were collected from the experimental field prior to experimentation using core sampler and later, the analysis for various physico-chemical properties was carried out. The details of the initial soil properties of the experimental sites are presented in Table 1.

Table 1. Initial physico-chemical properties of experimental site

S.No.	Parameters	Value		Methods of Analysis Employed			
A.	Mechanical Properties	2016-17	2017-18				
i.	Coarse Sand %	27.5	25.5				
ii.	Fine Sand %	53.8	51.3				
iii.	Silt %	10.7	11.0	Bouyoucos Hydrometer Method			
iv.	Clay %	7.8	8.1				
	Textural class						
B.	Chemical Properties						
i.	pH	8.3	8.1	1:2.5	Soil	water	suspension
		measured with Glass electrode pH					
ii.	EC (ds/m)	0.13	0.18	1:2.5	Soil	water	suspension
		measured with Systronics conductivity meter					
iii.	Organic Carbon (%)	0.27	0.24	Walkley and Black method			
iv.	Available N (kg/ha)	134.2	139.2	Alkaline potassium permanganate method			
v.	Available P (kg/ha)	12.6	12.8	Sodium bicarbonate method			
vi.	Available K (kg/ha)	134.9	136.4	Ammonium acetate method			

Experimentation and crop husbandry: - The experiments was laid out in Split plot design with three replications and thirty six treatment combinations were investigated. Treatments comprises four irrigation levels: I₁ (0.6 ET_c), I₂ (0.8 ET_c), I₃ (1.0 ET_c) and I₄ (1.2 ET_c), three cultivars: C₁ (Raj-4120), C₂ (Raj-4079) and C₃ (Raj-4238) and three dates of sowing: D₁ (15th Nov.), D₂ (30th Nov.) and D₃ (15th Dec.). In the recommended irrigation treatments applied at different irrigation intervals according to ET_c level with the help of water meter. Standard crop production practice and methods were followed for weeding, fertilizer application and crop protection management to grow the crop.

Comment [a12]: wer

Comment [a13]: added

Comment [a14]:

Comment [a15]:

Comment [a16]: del.

Comment [Ma17]: viz.,

Comment [a18]: del

Comment [a19]: The crop was raised by following all agronomic and plant protection measures except irrigation schedule

Measurement and sampling: - Observations on number of days taken to various phenological stages viz., germination, CRI, tillering, jointing, flag leaf and maturity stage were in one metre row length. The readings on various phenophases were recorded once the plants have reached 50% of that particular stage in each replication. Crop was harvested manually in the end week of March and First week of April when 80% of the grains turned to golden colour. Grain and biological yield were recorded at the harvest. Least significant difference at 0.05% level of probability was used to test the significance of differences among treatment means Heat units calculated with the following formulas

Comment [a20]: ?

Comment [a21]: first

Comment [Ma22]: formulae:

Comment [a23]: Thus, the data recorded during the course of investigation were subjected to statistical analysis (Sheoran, 1998).

Growing Degree Days (GDD)

Growing degree days were calculated by simple arithmetic accumulation of daily mean temperature above the base temperature value of 5°C considered for the wheat crop. The different indices for each stage were calculated as suggested by (Nuttonson, 1955).

$$\text{Growing degree days (}^{\circ}\text{C)} = \frac{T_{max} + T_{min}}{2} - Tb$$

where,

T_{max} = Daily maximum temperature ($^{\circ}\text{C}$)

T_{min} = Daily minimum temperature ($^{\circ}\text{C}$)

Tb = Base temperature (5°C)

3. RESULTS AND DISCUSSION

Crop phenology: - Data pertaining to crop phenology and from emergence to maturity duration presented in table 2. Irrigation did not have differential effect on duration from seeding to tillering because of absence of variation in moisture availability and temperature up to tillering stage. However, onset and duration of phenophases beyond maximum tillering increased with increase variation in moisture availability, possibly owing to retention of more physiologically active leaf area for a longer period (Pal *et al.*, 1996). Increasing water availability required more heat units to shift from one phenophase to another. The crop raised with 1.2 ETc irrigation scheduling required more days to attain various phenophases and heat units. The three wheat cultivars showed a significant difference in number of days taken to different phenophases. Cultivar Raj 4079 than other cultivars more days taken to complete different phenophases. This is obvious because of genetic behaviour of each cultivar of a crop had specific requirement of heat units for initiation and completion of its phenological

stages under particular environmental conditions. Similar results were also reported by Dixit *et al.* (2014). Further, results revealed that different phenological stage (Emergence, Crown root initiation, Tillering, Jointing, Flage leaf, Maturity) were significantly influenced by dates of sowing in wheat crop. The crop sown on November 15 took significantly higher number of days (123) to attain maturity as compared to 30 November (117) and 15 December (106) sown crops. The phenological studies revealed that delayed sowing on 15 December required significantly less number of days for initiation and completion of the different phenophases in comparison to the sowing on 15 November and 30 November. Conversely under late sowing, reproductive growth as well as total crop duration was drastically reduced. It is an established fact that the crop phenology is largely dependent on genetic and environmental factor *viz.*, temperature, solar radiation, rainfall *etc.* (Praveen *et al.*, 2013).

Growing degree day (GDD)

The results were revealed that the agro meteorological indice*i.e.* growing degree day (GDD) from emergence to tillering stage not influenced significantly. However, onset and duration of phenophases beyond maximum tillering increased with increase variation in moisture availability, possibly owing to retention of more physiologically active leaf area for a longer period (Pal *et al.*, 1996). Jointing to maturity accounted higher GDD with I₄ (1.2 ET_C) than other irrigation level while lowest GDD observed when crop irrigated with I₁ (0.6 ET_C) and I₂ (0.8 ET_C) irrigation level. At maturity of the crop highest GDD (1797.59°C day) was accounted with I₄ irrigation level than I₃ (1780.97°C day) and I₂ while lowest GDD were recorded in case of I₁ (1688.84°C day) irrigation level (Table 3.). At maturity stage, higher GDD was recorded in case of cultivar Raj 4079 followed by cultivar Raj 4238. In pooled analysis maximum GDD (1730.73 °C day) was recorded for Raj 4079 followed by Raj 4238 (1720.32°C day) (Table 3.).GDD requirement was maximum in November 15 (1772.85 °C day) sowing among the sowing dates and decreased with delay in sowing followed by November 30 (1713.27 °C day) and December 15 (1633.57 °C day) at maturity stage. The requirement of heat unit was higher for timely sown crop than late sown crop due to longer period for all the phenological stages in the timely sown crop. The late sowing decreased the duration of phenophases which caused a decrease in agroclimatic indices during various phenophases forced the crop to attain early maturity. This decline in agroclimatic indices accumulation was due to prevailing low temperature during vegetative phases and high temperature during reproductive phases of development in late-sown crop. Our results were similar to those of (Khichar and Niwas,

Comment [Ma24]: agrometeorological index

2007). Paul and Sarker (2000) also reported that the requirement of heat units decreased for different phenological stages with delay in sowing.

Wheat yield: - Data on grain yield (Table 4) indicated that it was markedly influenced due to different irrigation schedules. The treatment I₄ (Irrigations at 1.2 ETc) recorded significantly higher grain and biological yield of wheat (5136 and 11250 kg ha⁻¹) in pooled analysis, respectively over I₁ and I₂ and at par with I₃ (Irrigations at 1.0 ETc). While significantly lowest grain and biological yield (3442 and 7445 kg ha⁻¹) in pooled analysis was recorded under the treatment I₁ (Irrigations at 0.6 ETc). Higher grain and biological yield under the treatment I₄ and I₃ might be the result of cumulative effect of improvement in growth and yield attributes such as effective tillers, number of grains spike⁻¹ test weight, spike length, number of spikes per unit area, number of spikelets spike⁻¹. It was also found that with sufficient moisture in the soil profile under I₄ irrigation schedule, plant nutrients particularly nitrogen, phosphorus and potassium were more available and might have translocated to produce more dry matter. Secondly, higher yield with higher levels of irrigation might be due to its key role in root development by reducing mechanical resistance of soil, higher transpiration, greater nutrient uptake and more photosynthesis due to metabolic activities in plant (Bhunia *et al.*, 2006). The other reason of yield increase might be that irrigation scheduling at 1.2 ETc and 1.0 ETc throughout growth and reproductive phase created longer reproductive period with larger photosynthetic surface and reproductive storage capacity to attain higher allocation of net photosynthates to yield. The results obtained by (Sharma and Pannu, 2008, Sarwar *et al.*, 2010, Kumar *et al.*, 2015, Mishra and Kushwaha, 2016 and Rojhet *et al.*, 2021) also confirm the findings of present investigation. Since, wheat yield is a complex process and governed by interaction between source (photosynthesis and availability of assimilates) and sink component (storage organs). Thus, as a consequence of marked improvement in both these regulative process as evidenced from higher accumulation of biomass and nutrients as well as yield components under cultivar Raj 4079 led to significant increase in grain and biological yield. Further, the yield of wheat is dependent on two most important components namely spikes per unit area and weight of grains (test weight). Thus, due to a greater number of grains by virtue of increased number of spikes and more test weight under Raj 4079, increased the grain yield over Raj 4238 and Raj 4120, and remained at par with cultivar Raj 4238. Since, biological yield is a sum of grain and straw yield produced by the crop, the increased grain yield under Raj 4079 might have resulted in higher biological yield in this cultivar. The marked variation in various yield components and yield between

cultivars was observed by (Pandey *et al.*, 1999, Nainwal and Singh, 2000, Sardana, 2001 and Singh *et al.*, 2007). Grain, biological yield of wheat increased significantly when sowing of wheat on 15th November. Grain and biological yield decreased significantly as sowing was delayed from 15th November. This might be due to cumulative effect of poor expression of vegetative growth and yield contributing characters *i.e.*, number of spikes, ear length, grains spike⁻¹ and test weight under late sown conditions accompanied with high temperature and hot winds which leads toward forced maturity of the crop and ultimately resulted in lower grain and biological yield. The early sown crop, on the other hand, having favorable cool weather conditions for longer duration recorded better growth and yield attributes resulted in greater productivity (Kulhari *et al.*, 2003).

UNDER PEER REVIEW

Table: 2. Effect of irrigation scheduling, varieties and dates of sowing on phenology of wheat(where is cd in this table)

Treatments	Emergence	CRI	Tillering	Jointing	Flag leaf	Maturity
Irrigation scheduling						
I ₁ (Etc 0.6)	7	22	41	56	67	108
I ₂ (Etc 0.8)	7	22	41	63	74	115
I ₃ (Etc 1.0)	7	22	42	66	78	119
I ₄ (Etc 1.2)	7	22	42	67	79	121
Cultivars						
V ₁ (Raj 4120)	7	21	40	61	73	114
V ₂ (Raj 4079)	7	24	42	64	77	118
V ₃ (Raj 4238)	7	23	41	63	75	117
Date of sowing						
D ₁ (15 th NOV.)	6	24	44	68	80	123
D ₂ (30 th NOV.)	7	23	41	64	75	117
D ₃ (15 th DEC.)	8	21	38	58	68	106

Tables: 3. Effect of irrigation scheduling, cultivars and varying sowing dates on growing degree days (°C days) at different phenological stages of wheat

Treatment	GDD at emergence stage	GDD at CRI stage	GDD at tillering stage	GDD at jointing stage	GDD at flag leaf stage	GDD at maturity stage
Irrigation scheduling						
I ₁ (Etc 0.6)	91.57	313.00	530.40	708.70	835.80	1558.88
I ₂ (Etc 0.8)	91.81	314.17	530.90	799.98	941.96	1688.84
I ₃ (Etc 1.0)	92.19	315.69	533.30	832.22	999.06	1780.97
I ₄ (Etc 1.2)	92.37	316.89	535.90	839.96	1012.12	1797.59
SEm±	0.33	1.34	2.91	3.68	4.99	10.57
CD(P= 0.05)	NS	NS	NS	11.33	15.37	32.58
Cultivars						
V ₁ (Raj 4120)	91.70	307.99	521.70	774.41	910.13	1668.64
V ₂ (Raj 4079)	92.21	319.18	540.80	807.87	969.52	1730.73
V ₃ (Raj 4238)	92.04	317.63	535.50	803.36	962.04	1720.32
SEm±	0.20	0.93	1.91	2.27	2.73	7.72
CD(P= 0.05)	NS	2.68	5.51	6.54	7.86	22.23
Date of sowing						
D ₁ (15 th NOV.)	97.77	331.07	568.80	899.53	1053.88	1772.85
D ₂ (30 th NOV.)	95.36	315.64	531.90	795.54	942.29	1713.27
D ₃ (15 th DEC.)	82.82	298.10	497.20	690.57	845.53	1633.57
SEm±	0.15	0.74	1.27	1.40	1.97	6.41
CD(P= 0.05)	0.43	2.08	3.57	3.92	5.54	17.99

Table: 4. Effect of irrigation scheduling, varieties and dates of sowing on Yield and Heat Use Efficiency of wheat

Treatment	Grain yield	Biological yield
Irrigation scheduling		
I₁ (Etc 0.6)	3442	7445
I₂ (Etc 0.8)	4600	10130
I₃ (Etc 1.0)	4986	10967
I₄ (Etc 1.2)	5136	11250
SEm±	49	102
CD(P= 0.05)	151	315
Cultivars		
V₁ (Raj 4120)	3788	7957
V₂ (Raj 4079)	4974	11051
V₃ (Raj 4238)	4861	10835
SEm±	39	80
CD(P= 0.05)	113	229
Date of sowing		
D₁ (15th NOV.)	5201	11411
D₂ (30th NOV.)	4780	10520
D₃ (15th DEC.)	3641	7912
SEm±	31	58
CD(P= 0.05)	86	164

4. CONCLUSION

Based on the results of two year experimentation, it may be inferred that wheat cultivar 4079 performed better in relevance to consume more heat and produce maximum biological yield with the showing under optimum showing window of wheat crop and at 100% water availability asevapotranspirational requirement.

Comment [Ma25]: Revise this line

Comment [Ma26]: Revise this line

REFERENCES

- Amrawat, T.; Solanki, N.S.; Sharma, S.K.; Jajoria, D. K.; Dotaniya M.L. Phenology growth and yield of wheat in relation to agrometeorological indices under different sowing dates. *African Journal of Agricultural Research* 2013, **49**, 6366-6374.
- Bhunia, S.R.; Chauhan, R.P.S.; Yadav, B.S.; Bhati, A.S. Effect of phosphorus, irrigation and rhizobium on productivity, water use and nutrient uptake in fRevise this enugreek (*Trigonella foenumgraecum* L). *Indian Journal of Agronomy* 2006, **51**, 239-241.
- Bishnoi, O. P.; Singh, S. and Niwas, R.; Effect of temperature on phenological development of wheat (*Triticumaestivum* L.) crop in different row orientations. *Indian J. Agric. Sci.*, 1995, **65**: 211-214.
- Bouyoucos, G.J. A Hydrometer method improved for making particle and size analysis of soil. *Agronomy Journal*, 1962, **54**: 464-466.
- Hakim, M. A.; Hossain, A.; Teixeira da Silva, J. A.; Zvolinsky, V. P. and Khan, M. M. Yield, protein and starch content of 20 wheat (*Triticumaestivum* L.) genotypes exposed to high temperature under late sowing conditions. *J. Sci. Res.*, 2012, **4**, 477-489.
- Jackson, M.L. Soil Chemical Analysis, Prentice Hall of India Pvt. Ltd., New Delhi, 1973, pp. 263-393.
- Jat, B. T., Dhakar, L. L. and Poonia, T. C., Phenological and heatunit accumulation of wheat (*Triticumaestivum* L. emend Fiori and Paol) varieties under varying sowing dates and seed rates. *Agric. Sci. Digest*, 2003, **23**: 84-87.
- Khichar, M. L. and Niwas, R.; Thermal effect on growth and yield of wheat under different sowing environments and planting systems. *Indian J. Agric. Res.*, 2007, **41**: 92-96.
- Kumar, B., Dhar, S., Vyas, A.K. and Paramesh, V., Impact of irrigation schedules and nutrient management on growth, yield and root traits of wheat (*Triticumaestivum*L.) varieties. *Indian Journal of Agronomy*, 2015, **60**: 87-91.
- Kumar, R., Ramesh, K., Singh, R. D. and Prasad, R., Modulation of wild marigold (*Tagetes minuta* L.) Phenophases towards the varying temperature regimes - A field study. *Journal of Agrometeorology*, 2010, **12**: 234-240.
- Mishra, G. and Kushwaha, H.S., Winter wheat yield and soil physical properties responses to different tillage and irrigation. *European Journal of Biological Research*, 2016, **56**: 530-537.

Comment [Ma27]: Relevant references should be there. Obsolete non-relevant references.

Comment [Ma28]: Recheck all the references. References should be according to the guidelines & in similar pattern

- Nagarajan, S., Anand, A. and Chaudhary, H. B., Response of spring wheat (*Triticumaestivum* L.) genotypes under changing environment during grain filling period, *Indian J. Agric. Sci.*, 2008,**78**: 177-179.
- Nuttonson, M. Y., Wheat climatic relationship and use of phenology in ascertaining the thermal and photothermal requirements of wheat. *Am. Inst. Crop Ecol.*, Washington D.C. 1955.
- Olsen, S.R., Cole, C.V., Frank, S.W. and Dean, L.A. Estimation of available phosphorus by extraction with sodium bicarbonate, United States Development of Agriculture Circular number, 1954, 939.
- Pal, S.K., Kaur, S., Thakur, R., Verma, V.N. and Singh, M.K. Effect of irrigation seeding dates and fertilizer on growth and yield of wheat (*Triticumaestivum* L.). *Indian Journal of Agronomy* 1996, **41**: 366-369.
- Paul, N. K. and Sarker, D. K., Accumulated heat units and phenology relationships in wheat as influenced by sowing dates. *Bangladesh J. Bot.*, 2000,**29**: 49-54.
- Phadnawis, B. N. and Saini, A.D., Photothermal effects on tiller survival of wheat. *Ann. Plant Physiol.*, 1992,**6**: 262-267.
- Praveen, K.V., Patel, S.R., Choudhary, J.L., and Bhelawe, S. Heat unit requirement of different rice varieties under Chhattisgarh plain zones of India. *Earth Sci. climatic Change*, 2013,**5**(1): 1-4.
- Richards, L.A. Diagnosis and improvement of saline-alkali soils, *Agricultural Handbook* No. 60, USDA, Washington. 1972.
- Rojh, M.K., Bhunia, S.R., Shivran, H., Bhawariya, H., Bawaliya, S.C., Ramniwas and Mandeewal, R.L. Effect of irrigation levels and intervals on groundnut (*Arachishypogaea* L.) cultivars under drip system. *International Journal of Plant & Soil Science* 2021, **33**(6): 41-45.
- Sarwar, N., Mawqsood, M., Mubeen, K., Shehzad, M., Bhullar, M.S., Qamar, R. and Akbar, N., Effect of different levels of irrigation on yield and yield components of wheat cultivars. *Pakistan Journal of Agricultural Sciences* 2010,**47**: 371-374.
- Sharma, K.D. and Pannu, R.K. Physiological response of wheat (*Triticum aestivum* L.) to limited irrigation. *Journal of Agrometeorology*, 2008, **10**: 113-117.
- Sikder, S. Accumulated heat unit and phenology of wheat cultivars as influenced by late sowing heat stress condition. *Agric. Rural Dev.*, 2008, **7**: 57-64.
- Subbiah, B.V. and Asija, G.L. A rapid procedure for determination of available nitrogen in soil, *Current Science*, 1956,**37**: 29-38.
- Walkley, A.J. and Black, I.A. Estimation of soil organic carbon by chronic acid titration method. *Soil Science*, 1934, **37**: 29-38.