GROWING DEGREE DAYS REQUIREMENT AND YIELD OF WHEAT CULTIVARS AS INFLUENCED BY IRRIGATION SCHEDULING AND TIME OF SOWING

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. The field experiment were 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: I_1 (0.6 ETc), I_2 (0.8 ETc), I_3 (1.0 ETc) and I_4 (1.2 ETc), three cultivars: C_1 (Raj-4120), C_2 (Raj-4079) and C_3 (Raj-4238) and three dates of sowing: D_1 (15^{th} Nov.), D_2 (30^{th} Nov.) and D_3 (15^{th} Dec.) in Split plot design. The pooled analysis of data revealed that irrigation scheduling treatment I_4 (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 15^{th} 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 15^{th} November to achieve maximum yield under hot climate of Rajasthan.

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 (Nagarajan *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 phenophases. 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 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 agrometeorological indices *viz*., growing degree days (GDD), has been used to describe changes in phenological behavior 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 experiments were carried out during *Rabi* seasons 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^{o} 47' East longitudes, 26^{o} 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 (45.5ºC) and winter (4ºC) 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 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	Bouyoucous 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 were laid out in Split plot design with three replications added thirty-six treatment combinations. Treatments comprises four irrigations viz., 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 the recommended irrigation treatments applied at different irrigation intervals according to ETC level with the help of water meter. 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 meter 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. 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).

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

where,

T_{max} = Daily maximum temperature (^{o}C)
T_{min} = Daily minimum temperature (^{o}C)
T_{b} = Base temperature (5^{o}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 phenophases 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 behavior of each cultivar of a crop had specific requirement of heat units for initiation and completion of its phonological 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 agrometeorological index *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 I_4 (1.2 ET_C) than other irrigation level while lowest GDD observed when crop irrigated with I_1 (0.6 ET_C) and I_2 (0.8 ET_C) irrigation level. At maturity of the crop highest GDD (1797.59^{o}C day) was accounted with I_4 irrigation level than I_3 (1780.97^{o}C day) and I_2 while lowest GDD were recorded in case of I_1 (1688.84^oC 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 ^{o}C day) was recorded for Raj 4079 followed by Raj 4238 (1720.32 ^{o}C day) (Table 3.). GDD requirement was maximum in November 15 (1772.85 ^{o}C day) sowing among the sowing dates and decreased with delay in sowing followed by November 30 (1713.27 ^{o}C day) and December 15 (1633.57 ^{o}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 agrometeorological indices during various phenophases forced the crop to attain early maturity. This decline in agrometeorological 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, 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 I_4 (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 I_1 and I_2 and at par with I_3 (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 I_1 (Irrigations at 0.6 ETc). Higher grain and biological yield under the treatment I_4 and I_3 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 I_4 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 a*l., 2010, Kumar *et al*., 2015, Mishra and Kushwaha, 2016 and Rojh *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).

Table: 2. Effect of irrigation scheduling, varieties and dates of sowing on phenology of wheat

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 (^oC 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		
I_1 (Etc 0.6)	3442	7445
I_2 (Etc 0.8)	4600	10130
I_3 (Etc 1.0)	4986	10967
I_4 (Etc 1.2)	5136	11250
SEm±	49	102
CD(P= 0.05)	151	315
Cultivars		
V_1 (Raj 4120)	3788	7957
V_2 (Raj 4079)	4974	11051
V_3 (Raj 4238)	4861	10835
SEm±	39	80
CD(P= 0.05)	113	229
Date of sowing		
D_1 (15^{th} NOV.)	5201	11411
D_2 (30^{th} NOV.)	4780	10520
D_3 (15^{th} 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 irrigation scheduling treatment I_4 (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.

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