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PJBS

ISSN 1028-8880

Pakistan Journal of Biological Sciences

ANSInet
Asian Network for Scientific Information
308 Lasani Town, Sargodha Road, Faisalabad - Pakistan

Pakistan Journal of Biological Sciences 7 (9): 1477-1480, 2004
ISSN 1028-8880

Influence of Different Irrigation Regimes on the Phenology and Accumulated Heat Units in Four Bread Wheat Cultivars

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Abstract: A field investigation was carried out to study the influence of irrigation on phenology and accumulated heat units of four cultivars of bread wheat (*Triticum aestivum* L.) at different phenological stages over two growing seasons. There were three treatments: rainfed, 10 and 20 mm irrigation. The rainfed plants had significantly shorter phenological stages and lower growing day degree than the irrigated plants in all the four cultivars. Cultivars Akbar was found to be early and C 306 was found to be late maturing. Akbar had the lowest and C 306 had the highest growing degree days during all the phenological stages under each irrigation regime. Heliothermal units also showed more or less the same trends. The phenothermal indices and heat use efficiency were found to be higher in the irrigated plants than the rainfed plants.

Key words: Irrigation, phenology, growing degree days, heliothermal unit, phenothermal index, heat use efficiency

INTRODUCTION

Temperature is one of the most important climatic events affecting the growth, phenology, development and yield of wheat[1]. Despite the improved ability to predict onset and modify the impact, it remains as an important factor affecting third world food security. Temperature plays a vital role in almost all biological processes of crop plants. Growth and development of crop plants markedly depend on temperature. Integrated effect of temperature on the physiological processes significantly determines the nature of crop growth and development. The usefulness of different temperature indices like growing degree days (GDD) of heat units has been reported by many workers for predicting crop growth and development[2-4]. Most proposed temperature indices show significantly greater correlation with plant growth and development than does accumulated time. Significant effect of soil moisture on heat units was noticed by several workers[5,6]. Influence of soil moisture stress on the heat unit requirement of crop plants should be assessed in the field as the moisture of farms in a zone varies considerably. The effect of different soil moisture regimes on phenological development and heat use efficiency (HUE) of four bread wheat cultivars grown under field condition was studied in the present investigation through the accumulated heat unit system.

MATERIALS AND METHODS

The experiment was conducted in the research field of Rajshahi University Botany Department with four bread wheat (*Triticum aestivum* L.) genotypes, raised from four regular wheat varieties grown in Bangladesh, viz., Akbar, Opata, Protiva and C 306. The experimental field was prepared after repeated ploughing and harrowing. A basal dose of urea (80 kg ha^{-1}), TSP (60 kg ha^{-1}) and MP (30 kg ha^{-1}) were added to the soil before sowing. The soil of the experimental field was silty loam having a pH 7.5, low in organic carbon (0.44%) and total N (82 ppm). The average field capacity of the soil within a depth of 0.5 m was 34% for the first and 39% for the second year, respectively. The experiment was arranged in a split plot design having three replications with water regimes as main plots and cultivars as sub plots. Three different water regimes were adopted for each growing season, namely, rainfed (I_0), 10 mm irrigation (I_1) and 20 mm irrigation (I_2). The first irrigation was applied at 18 days after sowing and the laters were at 15 days interval. The measured amount of water was uniformly added manually over the irrigated plots with sprinklers. The experiment was conducted in 1998-1999 and 1999-2000 growing seasons. In both the growing seasons, the sowing date was 25 November. The total amount of water received as irrigation was 50 mm for the I_1 plots and 100 mm for the I_2 plots in both growing seasons excluding the natural rainfall. The natural rainfall recorded was 0 mm for the first year and 36 mm for the second year.

The most important stages like crown root initiation, booting, anthesis and grain filling were recorded in days when 50% of a cultivar of each replication reached a definite stage as the representative of that stage. The daily meteorological data from the Regional Meteorological Office, located at about 1 km away from the experimental field, were used. The growing degree days (GDD), heliothermal unit (HTU), phenothermal index (PTI) and heat use efficiency (HUE) were calculated according to the formulae of Rajput[7]:

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I. Growing degree days (GDD) = $\Sigma (T_{max} + T_{min})/2 - T_b$
ii. Heliothermal unit (HTU) = GDD X duration of sunshine hour
iii. Phenothermal index (PTI) = GDD ÷ Growth days
iv. Heat use efficiency (HUE) = Grain yield ha^{-1} ÷ GDD

Here:
T_{max} = Maximum temperature
T_{min} = Minimum temperature
T_b = Base temperature = 10°C

RESULTS AND DISCUSSION

Only the data of 1998-1999 growing season have been reported in the present report because both the data of 1998-1999 and 1999-2000 showed similar trends in the above-mentioned parameters.

The rainfed plants of all the cultivars took shorter time than the irrigated plants in all the four phenological stages. Cultivar C 306 took the longest time (97.8 days) to attain grain filling stage and it was followed by Opata (92.9 days). Akbar took the shortest time to attain grain filling (Table 1). Water stress caused reduction in required days for a particular phenological stage in the present investigation and the number of days taken for attainment of different phenological stages were in the order $I_2 > I_1 > I_0$. Longer duration of the phenological stages might be due to more tillering, maximum leaf emergence, higher plant height and greater yield components. These occurred due to favorable environmental conditions, especially optimum temperature and adequate irrigation throughout the whole growth period. In contrast, the rainfed plants suffered from water stress throughout the growing period and this water insufficiency reduced the number of days for all the phenological characters by supplying the lower amount of assimilates which reflected to different growth stages resulting in quick maturity of plants. Day and Intalap[8] reported that the maturity of wheat plants hastened due to water stress. Gales and Wilson[9] noticed that the plants suffering from water shortage matured earlier

Table 1: Time (days) taken for different phenological stages of four wheat cultivars as influenced by different irrigation regimes

	Crown root initiation				Booting			
Cultivars	I_0	I_1	I_2	Mean	I_0	I_1	I_2	Mean
Akbar	15.8c	16.80b	16.8c	16.5	38.5d	42.80d	44.5d	41.9
Opata	17.0b	17.30b	18.2b	17.5	57.8b	60.70b	61.8b	60.1
Protiva	16.2c	17.00b	17.3c	16.8	45.2c	46.80c	48.3c	46.8
C 306	17.7a	18.00a	18.8a	18.2	60.0a	64.30a	66.2a	63.5
Mean	16.7	17.30	17.8		50.4	53.70	55.2	
*LSD at 5%		0.61				0.41		
	Anthesis				Grain filling			
Cultivars	I_0	I_1	I_2	Mean	I_0	I_1	I_2	Mean
Akbar	53.5d	57.20d	58.8d	56.6	68.8d	71.30d	72.3d	70.8
Opata	74.2b	80.00b	83.7b	79.3	87.7b	94.70b	96.3b	92.9
Protiva	62.0c	65.80c	67.3c	65.1	75.2c	78.80c	81.2c	78.4
C 306	77.2a	84.80a	86.6a	82.9	93.8a	98.80a	100.8a	97.8
Mean	66.7	72.00	74.1		81.4	85.90	87.7	
*LSD at 5%		0.65				0.62		

Table 2: Growing degree days (GDD) of four wheat cultivars as influenced by different irrigation regimes at different phenological stages

	Crown root initiation				Booting			
Cultivars	I_0	I_1	I_2	Mean	I_0	I_1	I_2	Mean
Akbar	160.00c	170.00b	170.0d	167.0	339.00d	385.0d	395.0d	376.6
Opata	172.00b	175.00b	183.0b	176.9	523.00b	551.0b	564.0b	546.4
Protiva	164.00c	172.00b	175.0c	170.4	401.00c	412.0c	423.0c	412.6
C 306	178.00a	181.00a	188.0a	182.8	547.00a	593.0a	612.0a	584.3
Mean	168.80	174.80	179.3		455.40	485.7	498.8	480.0
*LSD at 5%	5.56				4.05			
	Anthesis				Grain filling			
Cultivars	I_0	I_1	I_2	Mean	I_0	I_1	I_2	Mean
Akbar	476.0d	517.00d	531.0d	508.4	647.0d	680.00d	694.0d	674.0
Opata	717.0b	799.00b	855.0b	790.6	914.0b	1019.00b	1050.0b	994.6
Protiva	566.0c	609.00c	625.0c	600.2	730.0c	781.00c	818.0c	776.6
C 306	757.0a	872.00a	902.0a	843.9	1005.0a	1094.00a	1129.0a	1076.3
Mean	629.3	699.60	728.5		824.2	894.00	923.0	
*LSD at 5%		8.66				11.79		

*Difference within variety between treatments, In a column, means followed by a common letter are not significantly different

Table 3: Helio-thermal units (HTU) of four wheat cultivars as influenced by different irrigation regimes at different phenological stages

	Crown root initiation				Booting			
Cultivars	I_0	I_1	I_2	Mean	I_0	I_1	I_2	Mean
Akbar	1369.0b	1439.0c	1429.0c	1412.6	2851.0d	3134.0d	3265.0d	3083.6
Opata	1474.0a	1482.0ab	1527.0a	1494.9	4438.0b	4726.0b	4849.0b	4671.6
Protiva	1401.0b	1445.0bc	1482.0b	1442.9	3320.0c	3430.0c	3520.0c	3423.7
C 306	1484.0a	1510.0a	1560.0a	1518.4	4683.0a	5137.0a	5324.0a	5048.6
Mean	1432.3	1469.3	1500.0		3823.7	4107.0	4239.9	
*LSD at 5%		41.5				40.1		
	Anthesis				Grain filling			
Cultivars	I_0	I_1	I_2	Mean	I_0	I_1	I_2	Mean
Akbar	3993.0d	4383.0d	4517.0d	4298.2	5611.0d	5922.0d	6049.0d	5860.9
Opata	5947.0b	7106.0b	7651.0b	6901.8	8208.0b	9266.0b	9551.0b	9008.7
Protiva	4865.0c	5281.0c	5441.0c	5196.1	6412.0c	6918.0c	7300.0c	6877.1
C 306	6677.0a	7826.0a	8092.0a	7532.2	9128.0a	9994.0a	10316.0a	9813.1
Mean	5371.3	6149.3	6425.6		7340.1	8025.5	8304.3	
*LSD at 5%	120.7				105.2			

Table 4: Phenothermal index (PTI) of four wheat cultivars as influenced by different irrigation regimes at different phenological stages

	Crown root initiation				Booting			
Cultivars	I_0	I_1	I_2	Mean	I_0	I_1	I_2	Mean
Akbar	10.060a	10.12a	10.10a	10.09	8.180b	8.11b	8.06b	8.12
Opata	10.070a	10.07a	10.05ab	10.06	8.540a	8.76a	8.80a	8.70
Protiva	10.110a	10.12a	10.07ab	10.10	8.020b	8.00b	7.89c	7.97
C 306	10.100a	10.09a	10.03b	10.07	8.720a	8.93a	9.01a	8.88
Mean	10.080	10.10	10.06		8.360	8.45	8.44	
*LSD at 5%	0.042				0.046			
	Anthesis				Grain filling			
Cultivars	I_0	I_1	I_2	Mean	I_0	I_1	I_2	Mean
Akbar	10.410b	11.20c	10.97c	10.86	11.140d	11.52d	11.80d	11.49
Opata	13.180a	13.83b	14.82ab	13.94	14.550b	14.96b	15.33b	14.95
Protiva	10.310b	11.01c	10.98c	10.76	12.440c	13.19c	13.86c	13.16
C 306	13.160a	14.67a	15.01a	14.28	15.020a	15.98a	16.35a	15.78
Mean	11.760	12.67	12.94		13.290	13.91	14.33	
*LSD at 5%	0.221				0.177			

Table 5: Heat use efficiency (HUE) of four wheat cultivars as influenced by different irrigation regimes

Cultivars	I_0	I_1	I_2	Mean
Akbar	4.60a	6.65a	7.00a	6.08
Opata	3.25b	4.35c	4.89c	4.16
Protiva	4.03a	5.15b	5.66b	4.94
C 306	4.71a	4.87bc	4.99bc	4.75
Mean	4.07	5.25	5.63	
*LSD at 5%	0.38			

*Difference within variety between treatments

In a column, means followed by a common letter are not significantly different

than the well-watered controls. As cultivar C 306 is late maturing, all the phenological characters showed higher values of required days in the present study (Table 2). Water deficiency decreased the duration of phenology as compared to irrigated condition due to the drought and thereby the requirement of heat units (GDD) decreased for different phenological stages with rainfed condition (Table 2). On average, the highest and the lowest GDD were found in cultivars C 306 and Akbar, respectively for all the four phenological stages. It is likely that maturity days will be more in that cultivar which had the highest GDD and the reported results corroborate the findings of Singh *et al.*[6], Rajput and Sastry[10].

To obtain the HTU of a definite phenological stage, the product of the degree days with the base temperature (10°C) and actual duration of bright sunshine hours was computed (Table 3). Generally the I_2 plants had the highest HTU for all the phenological stages on average and were followed by I_1 and I_0 plants. Rahman *et al.*[11] also reported higher HTUs in the irrigated plants of wheat. Among the cultivars, C 306 had the highest and Akbar had the lowest HTU for almost all the phenological stages. The irrigated plants passed their growth period with bright sunlight and sufficient water that influenced the photosynthesis effectively. In contrast, the rainfed plants passed their growth period with bright sunlight and insufficient water that hampered the different metabolic activities. Water stress compelled the plants to complete its life cycle with a short period of time resulting in decreased HTU that happened in cultivar Akbar in the present investigation.

On average, the PTI during later phenological stages were in the order $I_2>I_1>I_0$ as well in most cases (Table 4). This result was in agreement with Rahman *et al.*[11]. Among the cultivars, C 306 had the highest and Akbar had the lowest PTI during the grain filling stage although the PTI of the cultivars did not differ significantly during the sowing to crown root initiation stage.

The lowest PTI was noticed during booting stage for all the cultivars. The variation in the PTIs for different phenological stages indicated that the accumulated temperature could be utilized for studying the pattern of biomass accumulation at different phenological stages which ultimately influence the crop productivity.

The irrigated plants had higher HUE than the rainfed plants for all the four cultivars (Table 5). Irrigation resulted in higher grain yield via optimum metabolic activities and thereby the irrigated plants had higher HUE. On the other hand, deficiency of water hampered the normal metabolic process and resulted in lower grain yield as well as lower HUE. Higher HUE in the irrigated plants than the rainfed plants was also noticed by Rahman *et al.*[11]. Due to its lowest GDD, Akbar had the highest HUE although the highest grain yield was not obtained by Akbar. On the other hand, Opata had the poorest grain yield as well as higher GDD which resulted in the lowest HUE. Although C 306 had the greatest grain yield, it did not show the highest HUE like the other heat units due to its highest GDD and late maturing nature.

REFERENCES

1. Adam, H.S., O.A.A. Ageeb, D.A. Saunders and G.P. Hettel, 1994. Temperature Analysis and Wheat Yields in the Gezira Scheme. Wheat in Heat-stressed Environments: Irrigated, Dry Area and Rice-wheat Farming Systems. In: Proceedings of the International Conferences (D.A. Saunders), held at Wad Medani, Sudan, 1-4 Feb, 1993 and Dinajpur, Bangladesh, 13-15 Feb, 1993, pp: 143-145.
2. Cross, H.Z. and M.S. Zuber, 1972. Prediction of flowering dates in maize based on different methods of estimating thermal units. Agron. J., 64: 351-355.
3. Fairey, N. A., 1983. Yield, quality and development of forage maize as influenced by dates of planting and harvesting. Can. J. Plant Sci., 63: 157-168.
4. Rajput, R.P., M.R. Deshmukh and V.K. Paradkar, 1987. Accumulated heat units and phenology relationships in wheat (*Triticum aestivum* L.) as influenced by planting dates under late-sown conditions. J. Agron. Crop Sci., 159: 345-348.
5. Mor, R.P. and G.C. Aggarwal, 1980. Evaluation of heat unit concept for emergence of wheat. Indian Soc. Soil Sci., 28: 239-241.
6. Singh, N.T., G.C. Aggarwal and G.S. Brar, 1984. Effect of soil moisture on heat unit requirement of wheat at maturity. Indian J. Agric. Sci., 54: 442-444.
7. Rajput, R.P., 1980. Response of soybean crop to climatic and soil environments. Ph.D. Thesis, IARI, New Delhi, India.
8. Day, A.D. and S. Intalap, 1970. Some effects of soil moisture stress on the growth of wheat (*Triticum aestivum* L. em Thell). Agron. J., 62: 27-29.
9. Gales, K. and N.J. Wilson, 1979. Effect of Water Shortage on Growth and Yield of Winter Wheat. Agricultural Research Council Letcombe Laboratory, Wantage, UK, pp: 44-45.
10. Rajput, R.P. and P.S.N. Sastry, 1985. Comparative Performance of Three Varieties of Rainfed Soybean in a Monsoon Climate. Response to Thermal Environment. Proc. Int. Symp. on CATAC, Held at Waltair, pp: 88.
11. Rahman, M.S., A.M. Sarker and N.K. Paul, 2001. Effect of soil moisture on phenology and accumulated heat units in wheat. Bangladesh J. Sci. Tech., 3: 273-279.