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Water and Heat Unit Requirement of Wheat (*Triticum aestivum* L) Cultivars under Different Seeding Dates and Irrigation Levels

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ABSTRACT

A field experiment was conducted during winter season of 1995-96 and 1996-97 at the University farm, Ranchi on sandy loam soil to estimate the consumptive water use, moisture extraction pattern, crop coefficient, water use efficiency and heat-unit requirement of wheat cultivars under different seeding date and irrigation levels. Timely seeded wheat (21 November) used 3.27mm water per day to produce 3301 kg grain/ha with water use efficiency of 8.35 kg grain/ha-mm. Peak water use rate coincided with flowering stage which was attained during second week of February in timely seeded and during second week of March in very late seeded wheat crop. Timely seeded wheat required more number of days to attain maturity than later seeded wheat. However, a fixed amount of heat unit was needed to proceed from one phenophase to the other irrespective of the seeding time. The crop irrigated at crown-root initiation, maximum tillering, boot and milk stages consumed 384.5mm water to produce 2671 kg grain/ha with water-use efficiency of 6.95 kg grain/ha-mm water. Daily water use and surface soil-moisture extraction increased with increase in irrigation frequency. Crop receiving four irrigations required longer duration, more heat units for expression of various phenophases and higher grain yield than the crop receiving either three or two irrigations. Wheat cultivar HUW 234 consumed 11.4mm less water than K9006 (352.5mm) to produce 2372 kg grain/ha with water use efficiency of 6.95 kg grain/ha-mm water. Cultivar K9006 required longer duration and more heat units to shift from one phenophase to another as compared to cultivar HUW 234.

Key words: *wheat, cultivar, irrigation, seeding date, water requirement, consumptive use, water-use efficiency, heat-unit requirement, yield.*

Water is the key input for efficient utilization of plant nutrients and consequently better growth and yield of wheat (*Triticum aestivum* L. emend, Fiori & Paol) cultivars. Under limited availability of water, scheduling of irrigation at the most critical stages increases

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crop productivity and water-use efficiency (Prihar, 2000). Temperature also plays an important role in increasing the productivity as it determines seeding time and consequently the rate and duration of growth. A change in optimal temperature during its vegetative or reproductive growth adversely affects the onset and duration of phenophases and yield of crop. To increase the productivity of wheat in plateau region of Jharkhand, where availability of irrigation water is meager, knowledge of daily water use is necessary for timely scheduling of irrigation and efficient utilization of applied water. Besides, knowledge of the exact duration of development phases in a particular environment and their association with yield determinants is essential for achieving high yield. Therefore, present study was undertaken to study the effect of seeding time and irrigation levels on water and heat unit requirement for development of various phenophases of wheat.

MATERIALS AND METHODS

The field experiment was conducted during the winter season of 1995-96 and 1996-97 at Birsa Agricultural University Farm, Ranchi (Jharkhand) on sandy loam soil, low in organic carbon (0.39%), available nitrogen (198 kg/ha) and medium in available phosphorus (17.2 kg/ha) and potassium (129.2 kg/ha) with pH 6.2. The soil was having low water retention capacity (95.6 mm/60 cm soil depth). The treatments were set out in split-plot design, keeping 4 seeding dates viz. timely (November 21), moderately late (December 7), late (December 21), very late (January 7) and 3 irrigation levels viz. crown-root initiation and boot (CRI + BT); crown-root initiation, boot and milk (CRI + BT + MK); crown-root initiation, maximum tillering, boot and milk (CRI + MT + BT + MK) in main plots, two wheat cultivars viz. HUW 234 and K 9006 in sub plots with three replications. Wheat was sown 20 cm apart at 5 cm soil depth with a seed rate of 125 kg/ha. The crop was fertilized with 80 kg N, 40 kg P_2O_5 and 20 kg K_2O in form of Urea, SSP and MOP, respectively. Half of the nitrogen and full doses of phosphorus and potash were applied as basal at the time of sowing. The remaining dose of nitrogen was applied after first irrigation at crown-root initiation stage. The crop received 5 ± 1 cm depth of water during each irrigation as per treatment, apart from 86.7 mm and 45.2 mm rainfall during first and second year of experimentation, respectively. Timely seeded crop faced gradually decreasing mean temperature up to boot stage, whereas moderately late seeded and late seeded crop faced decreasing mean temperature up to maximum tillering and very late seeded crop up to crown root initiation and, thereafter, temperature started rising. The onset of development stages was recorded according to the Z'adoks growth scale (Z'adoks *et al.* 1974) which is numerically coded from 0(germination) to 100(ripening) in a decimal fashion and the days taken to crown root initiation, maximum tillering, flag leaf emergence, boot, spike emergence, flowering, milk, soft dough and maturity were recorded corresponding to codes 13, 15, 37, 45, 55, 65, 75, 85 and 92 respectively. The degree day estimates for the onset of phenophases of wheat were computed by summing the daily mean air temperature above the base temperature, 5°C (Morey *et al.* 1984). Periodic soil sample (0-60 cm depth) from sowing to harvesting at 15 days intervals and before and after 24 hours of each irrigation was taken to determine consumptive water use. Crop co-efficient was calculated by dividing consumptive water use for a particular period with corresponding value of pan evaporation.

RESULTS AND DISCUSSION

Seeding time

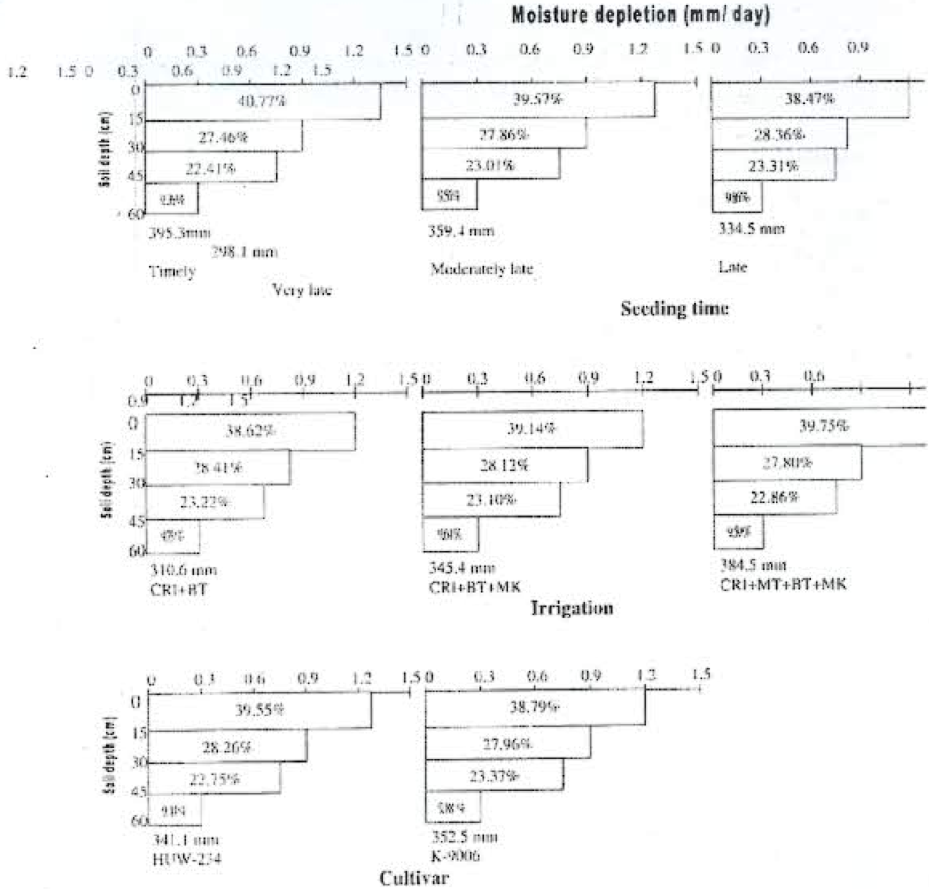
Seeding time influenced the amount and rate of consumptive water use. Timely seeded wheat consumed maximum amount of water (395.3 mm) and produced highest yield (3301 kg/ha) with a water use efficiency of 8.35 kg grain/ha-mm water (Table 1). Seasonal consumptive water use, its rate and water use efficiency decreased in proportion with delay in seeding time. Consequently timely seeded crop consumed 10, 18.2 and 32.6 percent more water than that used by moderately late (359.4 mm), late (334.5 mm) and very late (298.1 mm) crop respectively (Fig. 1). Timely, moderately late and late wheat used major share of their respective seasonal water use in January and February while very late wheat in February and March which coincides with boot to flowering stage of wheat crop. Further timely seeded wheat utilized water at its maximum rate while late and very late wheat utilized water at lower rate during crop growth period (Table 2). Consumptive water use rate increased with crop age, reached its peak during February and declined sharply in the month of March in timely, moderately late and late seeded wheat while it was more or less same during February and March in very late seeded wheat. This may be due to the fact that later sown crop was transpiring actively while former was proceeding towards physiological maturity (Pal *et al*, 1996). Timely seeded wheat extracted maximum amount of water (40.77%) from surface soil (0-15 cm) and it

Table 1

Periodic Consumptive Water use, Grain Yield and Water-use Efficiency of Wheat Cultivars under Different Seeding Dates and Irrigation Levels (Pooled data of 2 years)

Treatments	*Consumptive water use (mm)*							*Grain yield (kg/ha)*	*water-use efficiency (kg/ha-mm)*
	Nov.	*Dec.*	*Jan.*	*Feb.*	*Mar.*	*Apr.*	*Seasonal*		
Seeding Date									
Timely	8.2	60.1	127.7	127.3	72.0	-	395.3	3301	8.35
Moderately late		34.0	120.0	123.0	82.5	-	359.4	2767	7.70
Late		10.3	111.9	120.4	87.4	4.5	334.5	2065	6.17
Very late		-	35.0	114.6	121.5	27.0	298.1	1324	4.44
CD (P = 0.05)		-	-	-	-	-	-	225	-
Irrigation									
CRI+BT		38.4	95.5	111.7	65.1	-	310.6	2071	6.67
CRI+BT+MK		36.2	97.6	118.3	93.2	-	345.4	2349	6.80
CRI+MT+BT+ MK		38.1	102.8	133.9	109.7	-	384.5	2671	6.95
CD (P = 0.05)		-	-	-	-	-		195	-
Cultivars									
HUW 234		36.0	97.2	117.4	90.4	-	341.1	2372	6.95
K 9006		39.1	100.0	125.2	88.2	-	352.5	2355	6.68
CD (P = 0.05)		-	-	-	-	-	-	NS	-

Note: Details of treatments are discussed under materials and methods section.



reduced slightly with delay in sowing as it was 37.87 per cent in very late sown crop, whereas the reverse was true from sub- surface soil i.e. 30-60 cm (Fig 1). Crop coefficient also increased with crop age and was maximum when the crop was in vigorous vegetative growth phase with maximum transpiration and thereafter declined (Agarwal *et al*, 1997). It was maximum during January in timely sown wheat while very late sown wheat attained maximum value during February (Table 2). Higher seasonal and month-wise crop coefficient of timely sown wheat led to higher water requirement compared with that of later sown crops. Grain yield of wheat was significantly affected due to its seeding time. Delay in seeding beyond timely seeding reduced the grain yield by16.2, 37.4 and 59.9 per cent under moderately late, late and very late sown condition, respectively (Table 1). This is expected because most of the growth and yield attributes that determine the biological yield were adversely affected when seeding was delayed beyond 21st November. These findings are in conformity with the reports of Verma *et al*. (1997).

Table 2
Crop Coefficient and Rate of Consumptive Water use of Wheat Cultivars under Different Seeding Date and Irrigation Levels

Treatments	*Crop coefficient*						
	Nov.	*Dec.*	*Jan.*	*Feb.*	*Mar.*	*Apr.*	*Seasonal*
Seeding Date							
Timely	0.23 (0.82)	0.61 (1.94)	1.12 (4.12)	0.91 (4.39)	0.50 (3.60)	- -	0.74 (3.27)
Moderately late		0.43 (1.36)	1.05 (3.87)	0.88 (4.24)	0.40 (3.17)	- -	0.67 (3.24)
Late		0.29 (0.94)	0.98 (3.61)	0.86 (4.15)	0.39 (2.82)	0.22 (2.24)	0.63 (3.22)
Very late		- -	0.38 (1.40)	0.82 (3.95)	0.54 (3.92)	0.24 (2.45)	0.54 (3.11)
Irrigation							
CRI+BT		0.67 (2.13)	0.84 (2.13)	0.80 (3.85)	0.29 (2.10)	- -	0.58 (2.96)
CRI+BT+MK		0.63 (2.01)	0.86 (2.01)	0.85 (4.08)	0.42 (3.01)	- -	0.65 (3.20)
CRI+MT+BT+ MK		0.66 (2.11)	0.90 (2.11)	0.96 (4.62)	0.49 (3.54)	- -	0.71 (3.46)
Cultivars							
HUW 234		0.63 (2.00)	0.86 (3.14)	0.84 (4.05)	0.40 (2.92)	- -	0.64 (3.22)
K 9006		0.68 (2.17)	0.88 (3.23)	0.90 (4.32)	0.39 (2.84)	- -	0.64 (3.20)

Note: Details of treatments are discussed under materials and methods section.

Seeding dates also significantly influenced the onset and duration of various phenophases of wheat cultivars. Delay in seeding delayed the Crown Root Initiation (CRI) stage. However, days taken for onset of various phenophases beyond CRI stage reduced with each delay in seeding after timely seeding. The duration of crop growth was longer in timely seeded crop and consistently decreased with subsequent delay in seeding. Later seeded crop completed its life cycle at an accelerated pace, leading to shortening the onset of maximum tillering, flag leaf emergence, boot, spike emergence, flowering, milk, soft dough and maturity in comparision with that of timely seeded crop. Very late seeded crop took 4 more days for the onset of CRI stage but other stages like maximum tillering, flag leaf emergence, boot, spike emergence, flowering, milk, soft dough and maturity shortened by 5, 9, 10, 12, 15, 21, 25 and 25 days respectively in comparison with timely seeded crop. Sowing time of very late seeded crop was delayed by one and half month as compared to timely seeded crop, but maturity period reduced by 25 days only. Delayed seeding reduced the vegetative growth phase by 10 days and reproductive phase by 15 days due to rise in post-January temperature. This rise in temperature accelerated the development of phenophases, which progressed linearly with increase in temperature (Singh *et al.* 2001). In contrast, heat-unit requirement for the development of various phenophase was relatively constant and independent of seeding date (Table 4). It is so because a fixed amount of heat unit is needed to proceed from one phenophase to another under a location specific environment (Verma *et al.* 1997).

Irrigation

Wheat irrigated at crown root initiation and boot stages utilized 310.6 mm water to attain maturity and produced grain yield of 2071 kg/ha with water use efficiency of 6.67 kg grain/ha-mm (Table 1). One extra irrigation at milk stage increased the water requirement of wheat cultivars by 34.8 mm, with additional grain yield of 278 kg/ha and water use efficiency of 6.80 kg grain/ha-mm than two irrigations. Further, one additional irrigation at maximum tillering stage increased the consumptive water use and grain yield by 39.1 mm and 322 kg/ha respectively, with further increase in water-use efficiency of 6.95 kg/ha-mm than irrigation at crown root initiation, boot and milk stages. Periodic consumptive water use and its rate increased with crop age and reached its peak, during February (boot to flowering stage) indicating that these stages must be matched with adequate irrigation supply. Water use rate at different growth stages depends not only on the transpiration but also on the evaporative demand of the atmosphere (Pal *et al*, 1996). The rate of consumptive water use increased with increase in irrigation frequency beyond crown root initiation stage (Pratibha *et. al.*, 1994). The pattern of soil moisture extraction revealed that maximum utilization of moisture was from surface soil (0-15 cm) and it gradually decreased with increasing depth of soil (Fig. 1). This might be due to maximum concentration of roots in the upper (0-15 cm) layer (Bandyopadhyay, 1997). Wheat cultivars raised with four irrigations extracted more moisture from surface soil (0-15 cm) than two or three irrigations where as reverse was true with sub-surface soil. When irrigation level decreased, more water was extracted from the deeper soil layer (Radder *et al*, 1991). Crop coefficient increased with crop age and was higher during January–February than December and March (Table 2). During January–February crop was at vigorous vegetative growth phase with maximum transpiration without remarkable increase in evaporative demand of the atmosphere but it declined thereafter probably due to decrease in transpiration along with increased evaporative demand. Increase in irrigation frequency also influenced the crop coefficient. Wheat receiving four irrigations had higher seasonal as well as monthly crop coefficient than the crop receiving two or three irrigations. Irrigation levels significantly influenced the grain yield as it increased with increasing irrigation level (Table 1). Crop which received four irrigations (at CRI, maximum tillering, boot and milk) produced 13.7 and 29 per cent more grain yield than the crop grown with three or two irrigations. Likewise, the crop raised with three irrigations had significant edge over two irrigations, which may be due to beneficial effect of soil-moisture regime on growth and yield components (Bhan *et al.*, 1990). Higher availability of moisture might have helped in better nutrient removal by the crop which in turn resulted in assimilation of photosynthates and better development of yield attributes and ultimately gave higher yield.

Irrigation did not have differential effect on duration from seeding to maximum tillering, because of absence of variation in irrigation level up to this stage. However, the onset and duration of phenophases beyond maximum tillering increased with increase in irrigation frequency, possibly owing to retention of more physiologically active leaf area for a longer period (Pal *et al.*, 1996). Increasing frequency of irrigation required more heat units to shift from one phenophase to another. The crop raised with four irrigations required more days to attain various phenophases (Table 3) and heat units (Table 4) to proceed from one phenophase to other beyond maximum tillering. Similarly, the crop receiving three irrigations delayed the maturity by 2 days than the crop receiving two irrigations. Crop receiving two irrigations required 1406 degree days to attain maturity and produced 2071 kg grain yield. Further increase in irrigation frequency at milk stage increased the thermal unit need by 43 more degree days and yield by 278 kg/ha. Addition of one more irrigation at maximum tillering increased the heat sum by 128 degree days to attain maturity and yield by 600 kg/ha. as compared to two irrigations.

Table 3
Days taken for Phenophase Expression in Wheat Cultivars under Different Seeding Date and Irrigation Levels (mean data of 2 years)

Treatment	*Phenophase*								
	*Crown root initiation 13**	*Max. tillering 15**	*Flag leaf emergence 37**	*Boot 45**	*Spike emergence 55**	*Flowering 65**	*Milk 75**	*Soft dough 85**	*Maturity 92**
Timely	22.00	42.55	59.69	67.47	75.14	84.25	101.72	111.64	120.06
Mod. late	21.94	42.30	58.05	65.19	76.16	79.97	95.19	103.58	110.97
Late	22.80	40.97	55.47	62.47	68.56	74.89	89.00	97.11	104.56
Very late	24.30	37.78	50.83	57.47	62.83	68.61	80.83	85.67	95.19
CD (P = 0.05)	0.15	0.30	0.37	0.38	0.47	0.44	0.53	0.46	0.50
Irrigation									
CRI+BT	22.72	40.88	55.50	62.39	68.83	75.83	90.11	97.73	104.75
CRI+BT+MK	22.75	40.86	55.54	65.94	69.02	75.98	90.38	99.52	107.04
CRI+MT+BT+MK	22.77	40.98	57.00	64.51	71.23	78.98	94.58	103.48	111.29
CD (P = 0.05)	NS	NS	0.32	0.29	0.40	0.38	0.47	0.40	0.44
Cultivar									
HUW 234	22.78	40.36	54.86	61.78	68.07	75.23	89.72	98.31	105.93
K 9006	22.76	41.44	57.17	64.52	71.32	78.66	93.65	102.18	109.46
CD (P = 0.05)	NS	0.18	0.17	0.23	0.24	0.27	0.32	0.22	0.32

Note: Details of treatments are discussed under materials and methods section. * Z'adoks growth scale.

Cultivar

Wheat cultivar K 9006 consumed more water throughout the crop growth period and had more seasonal consumptive water use (352.5mm) than HUW 234 (341.1 mm) (Table 1). Cultivar K 9006 extracted more amount of water from sub surface soil (30–60cm) than HUW 234 (Fig. 1).Contrarily consumptive water use, water use efficiency and seasonal consumptive water use rate of cultivar HUW 234 was higher than cultivar K 9006. However, no significant difference was observed in respect of grain yield between cultivars K 9006 and HUW 234. Wheat cultivar HUW 234 extracted

Table 4
Heat unit Requirement of Various Phenophases of Wheat Cultivars under Different Seeding Date and Irrigation Levels (mean data of 2 years)

Treatment	*Phenophase*								
	*Crown root initiation 13**	*Max. tiller-ing 15**	*Flag leaf emer-gence 37**	*Boot 45**	*Spike emer-gence 55**	*Flower-ing 65**	*Milk 75**	*Soft dough 85**	*Maturity 92**
Seeding Date									
Timely	253	449	625	713	804	913	1167	1326	1468
Mod. late	253	448	622	711	800	909	1162	1327	1465
Late	252	447	621	710	799	799	1160	1320	1460
Very late	251	446	621	708	798	798	1158	1317	1458
CD (P = 0.05)	NS	NS	NS	NS	NS	NS	NS	NS	NS
Irrigation									
CRI+BT	252	447	615	701	787	891	1132	1275	1406
CRI+BT+MK	252	447	615	702	790	894	1137	1308	1449
CRI+MT+BT+MK	253	448	634	729	824	941	1217	1382	1534
CD (P = 0.05)	NS	NS	4	3	5	5	6	6	7
Cultivar									
HUW 234	251	452	608	693	777	882	1125	1287	1429
K 9006	254	454	636	728	824	935	1199	1358	1496
CD (P = 0.05)	1	1	2	2	3	4	4	4	5

Note: Details of treatments are discussed under materials and methods section. * Z'adoks growth scale

more moisture than K 9006 from top 0-30 cm soil depth. Monthly crop co-efficient value of both cultivars increased with increase in crop age and reached the peak value during January (HUW 234) and February (K 9006) and declined thereafter till maturity (Table 2). Similar observation was also made by Pratibha *et.al* (1994). Cultivars significantly influenced the onset and duration of various phenophases beyond crown root initiation stage. Wheat cultivar K 9006 required more number of days for onset of various phenophases and finally to attain maturity than cultivar HUW 234. Similarly cultivar K9006 required 67 more heat units to attain maturity than cultivar HUW 234.

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