Journal of Agrometeorology 11 (2): 140-143 (Dec. 2009)

Light interception and radiation use efficiency of wheat varieties as influenced by number of irrigations

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ABSTRACT

An experiment was conducted during *rabi* seasons of 2002-03 and 2003-04 to quantify the light interception and radiation use efficiency for three wheat varieties as affected by variable number of irrigations with the combination of three wheat varieties viz., HUW-234, HD-2285 and PBW-154. The light interception increased successively till 90 days after sowing (DAS) and thereafter a gradual decrease was observed till maturity of the crop. Four irrigations given at CRI, late tillering, late jointing and ear head formation stages showed highest radiation interception followed by three and two irrigations, however, the lowest radiation interception was observed for wheat crop receiving one irrigation only. On an average, 19.08 % and 12.79 % increase in radiation interception was found for wheat crop irrigated four and three times respectively as compared to singly irrigated crop. Highest radiation interception was recorded with HUW 234 followed by HD 2285 at all the growth stages except 15, 30, 45 DAS. More light interception reflected in significantly superior yield and yield attributes in the order of $I_4>I_3>I_2>I_1$. Subsequently, radiation use efficiency (RUE) also followed the similar trend showing highest and lowest RUE with four and one irrigation respectively. Among the different varieties, HUW-234 recorded highest radiation use efficiency followed by HD-2285. The average RUE during the entire growing period for HUW-234 and HD-2285 was found to be 1.68 g MJ^{-1} and 1.63 g MJ^{-1} respectively, which was 4.83 and 1.95 % higher than PBW-154.

Key words: Light interception, radiation use efficiency, wheat, irrigation

Solar radiation is the energy source that sustains organic life on earth. The biologically significant aspects of solar radiation are the intensity of radiation, spectral distribution and radiation distribution in time. The capture of radiation and its use in dry matter production depends on the fraction of the incident photosynthetically active radiation (PAR) that is intercepted and the efficiency with which it is used for dry matter production (Mavi and Tupper, 2004). Quantification of light interception within plant canopy is important due to dependence of photosynthesis rate on the availability of PAR intercepted by the leaves. Additionally, rate of transpiration from plant canopy is also controlled to a great extent by the radiation energy. For wheat crop, the maximum solar radiation and PAR interception was reported at 100 days after sowing (milk ripening stage) by Prasad and Sastry (1994). Monteith (1994) reported that if water and nutrient supply are not a limiting factor, the quantity of biomass produced by mono-crops is restricted primarily by quantity of radiation captured, and seasonal biomass accumulation for any given species. The radiation use efficiency is another important term (Black and Ong, 2000), defined as the quantity of biomass produced per unit of intercepted radiation, which provides a measure of the efficiency with which the captured radiation is used to produce new plant material. Corlett *et. al.* (1992) also demonstrated the intercepted solar radiation, biomass production and radiation use efficiency for different rainy season crops. Numerous studies have shown the existence of close relationship between dry matter production and cumulative intercepted radiation (Stirling *et. al.*, 1990; Mainard and Jeuffroy, 2004). Therefore, it becomes imperative to quantify the light interception to fully utilize the yield potential of a crop. Keeping these points in mind, the present study was undertaken with the objective to evaluate the light interception and radiation use efficiency of three wheat varieties grown with varying number of irrigations for the climatic environment of Eastern Uttar Pradesh.

MATERIALS AND METHODS

A field experiment was conducted during winter season of 2002-03 and 2003-04 at the instructional farm of Narendra Deva University of Agriculture & Technology, Kumarganj, Faizabad (U.P.). This centre is located at 26°47' N latitude, 82°12' E longitude and at an altitude of 113 m from mean sea level). The soil of the experimental field was alluvial silty loam in texture, low in organic carbon (0.45%) and available Nitrogen (109.6 kg ha^{-1}), medium in Phosphorus (12.6 kg ha^{-1}) and Potassium (340.6 kg ha^{-1}). The soil was

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Table 1 : Light interception (%) of wheat as affected by number of irrigations and varieties (pooled data of two years)

Treatments	Days After Sowing (DAS)							
	15	30	45	60	75	90	105	120
Irrigation levels								
I_1	15.62	32.52	42.96	64.57	68.60	65.35	52.21	21.27
I_2	15.40	32.41	42.93	64.83	72.55	72.60	56.36	29.79
I_3	15.58	32.55	43.07	64.89	74.98	76.95	65.84	35.68
I_4	15.35	32.38	42.84	67.32	76.32	81.92	72.42	43.83
SEm±	0.12	0.14	0.32	0.81	1.25	1.40	1.34	1.78
CD (5%)	NS	NS	NS	2.37	3.62	4.17	3.95	5.28
Varieties								
V_1	15.32	32.50	43.46	67.58	75.97	77.12	64.35	34.64
V_2	15.65	32.52	42.91	65.40	72.82	73.10	60.97	32.10
V_3	15.49	32.38	42.48	63.22	70.54	72.39	59.80	31.19
SEm±	0.09	0.10	0.24	0.69	0.74	1.27	1.17	1.67
CD (5%)	NS	NS	NS	2.04	2.16	3.69	3.42	4.78

slightly alkaline in nature (pH 7.8). Treatment consisted of 4 irrigation levels viz., I_1 (one irrigation given at crown root initiation stage), I_2 (two irrigations given at CRI and flowering stages), I_3 (three irrigations given at CRI, late tillering and flowering stages) and I_4 (four irrigations given at CRI + late tillering + late jointing + ear head formation stages) with the combination of three wheat varieties viz., HUW-234, HD-2285 and PBW-154. The experiment was laid out in randomized block design (RBD) and replicated three times. Sowing of the wheat was done during the first week of December in lines with 20cm X10cm spacing.

Radiation measurements were made at 15 days interval in each plot at mid noon when solar intensity was at its peak, using line quantum sensor and digital lux meter. Solar reflection from crop canopy and soil were also recorded by inverting the sensor.

Absorbed PAR (APAR) was calculated using the formula (Asrar *et. al.*, 1989)

APAR = (PARo + RPARs) – (TPAR + RPARc)

Where, APARc = PARo – (RPARs + TPARc)

Where,

PARo = Incident PAR above canopy

RPARs = Reflected PAR from soil

TPARc = Transmitted PAR from canopy

RPARc = Reflected PAR from canopy

Light interception (LI) was calculated using the formula –

$$LI\ (\%) = \frac{LI\ (top\ of\ the\ canopy) - LI\ (bottom\ of\ the\ canopy)}{LI\ (top\ of\ the\ canopy)}$$

Radiation use efficiency (RUE) values were obtained using APAR as follows

$$RUE\ (g\ MJ^{-1}) = \frac{Total\ dry\ matter\ (g\ m^{-2})}{APAR\ (MJ\ m^{-2})}$$

RESULTS AND DISCUSSION

Light interception (%)

Data pertaining to light interception as affected by number of irrigations and varieties has been shown in Table 1. It is evident from the data that light interception values increased successively till 90 DAS. Thereafter, a decreasing trend was recorded for light interception values till the harvesting of the crop. A very sharp increase in light

Table 2 : Radiation use efficiency (g MJ^{-1}) of wheat as affected by number of irrigations and varieties (pooled data of two years)

Treatments	Days after sowing (DAS)							
	15	30	45	60	75	90	105	120
Irrigation levels								
I_1	0.67	0.83	0.97	1.16	2.21	2.52	2.14	2.27
I_2	0.68	0.80	0.92	1.18	2.26	2.57	2.23	2.35
I_3	0.69	0.81	0.93	1.19	2.29	2.59	2.34	2.40
I_4	0.65	0.82	0.94	1.27	2.30	2.61	2.41	2.48
SEm±	0.014	0.012	0.019	0.028	0.021	0.024	0.017	0.013
CD (5%)	NS	NS	NS	0.08	0.06	0.07	0.05	0.04
Varieties								
V_1	0.70	0.84	0.98	1.25	2.32	2.62	2.33	2.41
V_2	0.67	0.81	0.95	1.19	2.26	2.56	2.27	2.37
V_3	0.64	0.79	0.89	1.16	2.22	2.54	2.24	2.35
SEm±	0.011	0.01	0.015	0.022	0.017	0.019	0.011	0.010
CD (5%)	NS	NS	0.04	0.06	0.05	0.05	0.03	0.03

interception from 30 to 60 DAS was seen when vegetative growth was at its peak. The reason for this may be due to increase in the number of leaves and leaf area index that ultimately resulted in the higher light interception. These results are in close proximity with those obtained by Prasad and Sastry (1994). Four irrigations given at CRI, late tillering, late jointing and ear head formation stages showed highest radiation interception followed by three and two irrigations. However, the lowest radiation interception was found for the singly irrigated crop. The overall average interception of light for the I_1, I_2, I_3 and I_4 was found to be 45.39, 48.36, 51.19 and 54.05 %, respectively. If compared with singly irrigated crop, there was 19.08 % and 12.79 % increase in light interception for four and three times irrigated crop. Similarly, highest light interception was recorded with HUW 234 followed by HD 2285 at all the growth stages except 15, 30, 45 DAS. On an average, there were 6.05 and 2.06 % increase in the light interception for the varieties HUW-234 and HD-2285, respectively.

Radiation use efficiency (g MJ^{-1})

Radiation use efficiency varied significantly among different irrigation levels, increased with crop growth and attained its peak value at 90 DAS in all the treatments (Table 2). Thereafter, its value was decreased between 90-105 DAS due to senescence of the crop and then it increased again. The reason for this decline in radiation use efficiency might be due to less PAR interception by the crop resulting from decreased chlorophyll content in the matured leaves. The maximum value of RUE was recorded with the irrigation level I_4 and the minimum RUE value was obtained with I_1 irrigation level due to less dry matter production under the condition of moisture scarcity. Among the different varieties, HUW-234 recorded highest radiation use efficiency followed by HD-2285. The average RUE during the entire growing period for HUW-234 and HD-2285 was found to be 1.68 g MJ^{-1} and 1.63 g MJ^{-1} respectively, which was 4.83 and 1.95 % higher than PBW-154.

Effect on yield and yield contributing factors

Higher radiation interception resulted in the better yield attributes and yield of wheat crop which can be seen in Table 3. Maximum plant height and dry matter accumulation was recorded with four irrigations which was significantly superior over other treatments. Simultaneously better yield attributes resulted in the higher grain and straw yields and it was found in the order of $I_4>I_3>I_2>I_1$. Among the varieties tested, HUW-234 was found to be more efficient in utilization of radiation among the varieties, resulting in superior yield and yield attributes. Amir and Sinclair (1991) concluded that biomass accumulation is a function of intercepted radiation. The positive effect of radiation interception on accumulated dry matter was also reported by Mainard and Jeuffroy (2004).

Table 3 : Yield attributes and yield of wheat as affected by number of irrigations and varieties (pooled data of two years)

Treatments	Plant height (cm)	Dry matter accumulation (g m^{-2})	Grain yield (q ha^{-1})	Straw yield (q ha^{-1})	Harvest index (%)
Irrigation levels					
I_1	83.87	827.22	29.66	47.78	38.15
I_2	91.00	905.18	34.22	52.16	39.45
I_3	98.08	970.85	38.12	56.23	40.12
I_4	100.83	1026.64	40.65	58.83	40.53
SEm±	2.15	20.25	0.91	1.05	0.17
CD (5%)	6.32	59.37	2.67	2.97	0.51
Varieties					
V_1	91.00	972.67	38.54	56.11	40.52
V_2	98.08	922.82	34.58	53.45	39.14
V_3	100.83	903.34	33.86	51.69	39.02
SEm±	2.15	18.65	0.79	0.90	0.15
CD (5%)	6.32	54.72	2.31	2.64	0.44

CONCLUSION

It may be concluded that for obtaining the maximum yield potential of the wheat crop, four irrigations at CRI + late tillering + late jointing + ear head formation stages has been found to be most appropriate, as compared three or two irrigations, since the radiation interception was quite higher in this treatment. Additionally, variety HUW-234 was found to be very efficient in utilization of available solar radiation. Hence, these can be recommended to the farmers of the area.

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Received: July 2009; Accepted: July 2009