Indian J. Plant Physiol., Vol. 17, No. 2, (N.S.) pp. 113-120 (April-June, 2012)

GROWTH AND YIELD OF WHEAT GENOTYPES IN RELATION TO ENVIRONMENTAL CONSTRAINTS UNDER TIMELY SOWN IRRIGATED CONDITION

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Received on 7th March, 2011, Revised and accepted on 15th February, 2012

SUMMARY

Evaluation of morpho-physiological and yield traits of twenty timely sown irrigated wheat genotypes was done during two seasons (2008–2010). Under the prevailing environmental conditions, the genotypes attained flowering and physiological maturity in about 88–105 and 129–137 days after sowing, respectively. Photosynthesis rate (Pn, µmol m^{-2} s^{-1}) was significantly higher in UP 2565 (24.17), while higher rate of transpiration (E, mmol H_2O m^{-2} s^{-1}) was observed in UP 2338 (6.17), PBW 226 (6.68) and PBW 509 (6.78). Photosynthesis rate, photosynthetic radiation use efficiency (mol CO_2 mol^{-1} photon) and apparent carboxylation efficiency (Pn/Ci, µmol m^{-2} s^{-1} $µmol^{-1}$) declined with temperature above 26°C. An optimum PAR of 1270 µmol m^{-2} s^{-1} was observed. A positive association (*r* = 0.84) was observed between total biomass and seasonal radiation use efficiency. Yield performance was significantly higher (5.5–5.7 t ha^{-1}) in DBW 17, HD 2687, HD 2894, PBW 343, PBW 550 and UP 2338, while it was lower (4.6–4.9 t ha^{-1}) in UP 2425, PBW 509, HI 1544 and DBW 16. Grain yield was positively correlated with heat use efficiency and stomatal conductance. Further, the environmental constraints like moderately higher temperatures (above 26°C) affected photosynthesis even under timely sown irrigated conditions in the main wheat producing belt (north western plain zone) of India.**

***Key words*: Growing degree days, heat use efficiency, photosynthesis, temperature, radiation use efficiency, wheat**

INTRODUCTION

Higher productivity of wheat mainly depends on biomass productivity and harvest index. Biomass potential of a genotype is achieved when growth and development phases match with the congenial environmental and management conditions. Wheat (*Triticum aestivum* L.) is a long day crop and requires relatively low temperature for satisfactory growth. Among the climatic factors, temperature and photoperiod play a key role in determining duration of different phenophases, which affect the vegetative and reproductive development and yield (Slafer and Rawson, 1994). Further, photosynthesis and productivity are limited by physiological and environmental constraints (Sharma Natu and Ghildiyal 2005, Parry *et al.* 2011). In India, growing season for wheat is limited by high temperature at maturation and moreover there is also concern for changing climate scenario. It is, therefore, important to study the phenological variability, yield attributes and photosynthetic parameters in relation to ambient conditions (e.g. temperature) so as to understand the physiological and environmental constraints limiting productivity in timely sown irrigated wheat.

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MATERIALS AND METHODS

Field experiments were conducted during two consecutive *rabi* seasons of 2008–2009 and 2009–2010 to evaluate wheat genotypes for phasic development in relation to prevailing climatic conditions of Modipuram (Meerut, U.P.) and to monitor various morpho-physiological parameters in relation to their productivity. Modipuram is located at 29°.4' N latitude and 77°.46' E longitude in North West Plain Zone (NWPZ), India at 237 m asl. The climate is categorised as hot, dry and semi-arid subtropical with moderate summer and severe cold winters. The average annual rainfall is about 800 mm and potential evapo-transpiration of 1600 mm. The soil of the experimental field was typic Ustochrepts, sandy loam, deep and mildly alkaline (pH 8.2) with low- to medium -fertility (OC–0.40%, available P_2O_5–32.5 kg and K_2O–125 kg ha^{-1}). The experiment was conducted in a randomised block design (RBD) with three replications. Seeds of twenty wheat genotypes *viz*, PBW 509, PBW 502, PBW 550, PBW 226, PBW 343, WH 711, WH-1021, WH-542, HD-2894, HI-1544, DBW-17, RAJ-3765, HD-2687, UP-2382, DBW-16, HD-2733, UP-2425, PBW-373 and UP-2565 were sown in rows with 20 cm distance between the rows on November 25th and 17th during 2008–2009 and 2009–2010, respectively. Normal agronomic practices were followed. Phenological observations viz, days to booting, 50% spike emergence, 50% flowering and physiological maturity were recorded in terms of days after sowing (DAS). Plant sampling was done at tillering, ear emergence and flowering to take the observations on leaf area index (LAI) and total biomass. Plant height was recorded at physiological maturity. Net photosynthesis rate and rate of transpirations of flag leaf were recorded using Portable Photosynthesis System (model LI 6400) of LiCor, USA. The photosynthetic water use efficiency was calculated by dividing photosynthesis with rate of transpiration following Morgan and LeCain (1991). Physiological radiation use efficiency (PRUE) was calculated as the ratio of net photosynthesis and photosynthetically active radiation (PAR). Weather data related to maximum temperature, minimum temperature and bright sunshine hour of Agro meteorological observatory of PDFSR, Modipuram were used to derive the various agro meteorological indices. Total heat unit requirement for booting, 50% flowering and physiological maturity was calculated taking the 4°C and 9.5°C base temperature before and after spike emergence, respectively following Slafer and Savin (1991). Heat use efficiency (HUE) and radiation use efficiency (RUE) on PAR basis were calculated following Kingra *et al.* (2007) and Singh *et al.* (2008), respectively.

RESULTS AND DISCUSSION

Phenology, heat unit requirements and yield attributes: Phasic development, that is, days to booting, spike emergence, anthesis and physiological maturity are presented in Table 1. Among different genotypes, HI 1544 was significantly early (66 DAS), while PBW 343, HD 2687, PBW 226, HD 2733 and HD 2382 were late (83 DAS) to reach the booting stage. Spike emergence was early in DBW 16 (78 DAS), while it was late in HD 2733 (95 DAS). In different wheat genotypes, DBW 16 expressed early anthesis (88 DAS) and early maturity (129 DAS), while anthesis (105 DAS) and maturity (137 DAS) were late in PBW 226. On the other hand, PBW 226, HI 1544, WH 1021, PBW-550, RAJ-3765, UP-2425, UP-2565, UP-2382, WH-711, HD-2894, DBW-16 and UP-2338 were early in flowering (88-99 DAS) than other genotypes which flowered in 100–105 days. All these genotypes attained physiological maturity between 129 and 137 DAS. These variations relate to the differential sensitivity of phasic development of wheat genotypes to major environmental factors-temperature and photoperiod (Slafer and Rawson, 1994). The highest LAI was observed at spike emergence in all the genotypes and there after declined. Initially at tillering stage the highest LAI (1.9) was reported in PBW 509 and the lowest (1.0) in PBW 373. However, LAI was the highest in DBW 17 (5.9) and the lowest in PBW 226 (4.6) at spike emergence stage (Fig. 1).

The stature of different genotypes significantly differed from one another and ranged from 83 to 96 cm. UP-2565, PBW-509, WH-1021 and RAJ-3765 were relatively taller (90–96 cm) than rest of the genotypes (83–89 cm). Significant genotypic variations were observed in grain yield and different yield components (spike length, number of spikelets and number of grains/ spike and 1000 grain weight were observed (Table 2).

Table 1. Variation in different phenophases and gaseous exchange in wheat genotypes.

Wheat genotypes	Days after sowing				Photosynthetic rate, Pn ($\mu mol\ m^{-2}\ s^{-1}$)	Transpiration rate, E ($mmol\ m^{-2}\ s^{-1}$)
	Booting	50% spike emergence	50% flowering	Physiological maturity		
UP-2425	73.3	87.0	94.2	133.8	21.76	5.98
PBW-509	71.0	84.3	94.2	134.0	22.45	6.78
HI-1544	66.0	81.7	91.5	132.3	21.77	5.06
DBW-16	67.7	78.7	88.7	129.3	21.35	6.12
PBW-502	78.0	88.8	101.3	135.5	20.95	5.31
PBW-226	83.0	93.3	105.0	135.3	23.32	6.68
HD-2733	83.0	95.5	103.3	137.2	20.13	5.16
UP-2382	83.0	94.8	101.0	135.5	21.44	5.29
PBW-373	82.3	94.3	103.7	134.0	23.25	6.07
WH-711	80.7	89.3	99.3	134.7	21.45	5.89
WH-542	81.3	88.0	95.0	132.0	22.03	4.57
WH-1021	66.0	83.8	91.5	129.7	21.67	6.06
RAJ-3765	76.7	86.8	94.8	134.8	22.09	5.97
UP-2565	73.3	87.2	94.5	133.0	24.17	5.90
DBW-17	79.7	91.5	100.0	132.3	21.32	5.07
HD-2687	83.0	94.2	102.5	136.7	20.84	5.96
HD-2894	81.3	91.2	98.0	135.2	21.74	5.89
PBW-343	83.0	95.2	102.7	135.8	21.20	6.06
PBW-550	76.7	85.7	93.8	133.7	21.20	5.28
UP-2338	79.3	93.7	99.7	137.0	22.94	6.17
CD (P = 0.05)	2.37	1.81	1.35	1.11	1.99	0.38

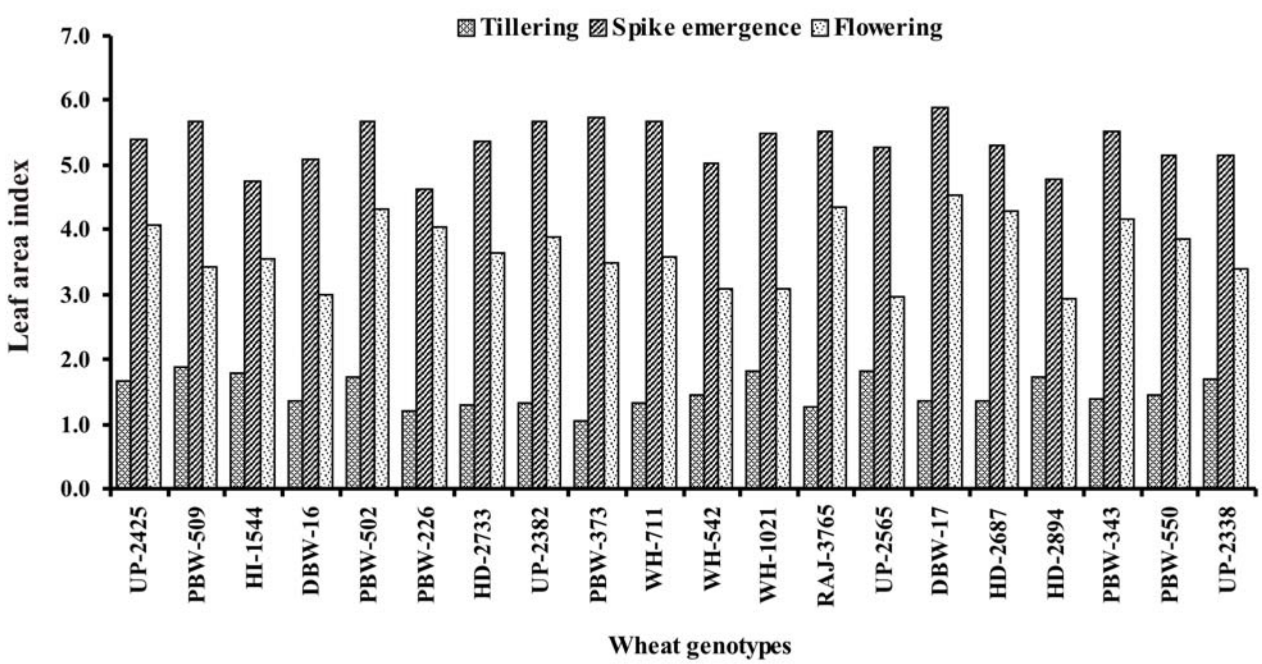

Fig. 1. Variation in leaf area index at different phonological stages in wheat genotypes.

The spike length varied from 8.4 (UP 2565) to 12.2 cm (UP2425) and spiklets per spike were 16.5 (WH 711) to 21.0 (PBW 343). The number of grains per spike were recorded highest (59.1) in WH 1021 and lowest (46.6) in UP 2565. Test weight of 1000 grains was highest (59.3) in UP 2565 and lowest (33.9) in PBW 509. More than 50% of the genotypes *viz,* PBW 509, PBW 550, PBW 226, PBW 343, WH 711, WH 1021, WH 542, HD 2894, HI 1544, DBW 17, RAJ 3765 recorded lower test weight than the mean of the test weight (43.3 g) of the 20 genotypes of wheat. Yield performance was higher (5.5–5.7 t ha^{-1}) in DBW 17, HD 2687, HD 2894, PBW 343, PBW 550 and UP 2338, while it was lower (4.6–4.9 t ha^{-1}) in UP 2425, PBW 509, HI 1544 and DBW 16. In general, the average productivity of early group of genotype was lower (5.2 t ha^{-1}) as compared to long duration genotypes (5.4 t ha^{-1}). There was no significant difference among the total biomass and harvest index of the different genotypes of the wheat. The total biomass ranged from 11.1 t ha^{-1} (UP 2425) to 13.5 t ha^{-1} (HD 2894), while HI ranged from 40.4% (PBW 502) to 45.3% (PBW 550).

Growing degree day (GDD, ^{o}Cd) is a good estimator of wheat growth stages and accumulation of growing degree days for each developmental stage is relatively constant. Data related to agro-meteorological indices are presented in Table 3. Mean of heat requirement to attain the booting was significantly lower (806.2) in low yielding followed by medium yielding (895.8) and higher in high yielding (927.9) wheat genotypes. However, to attain the flowering stage, heat requirement did not vary significantly among the different wheat genotypes. Mean of total heat requirement (^{o}Cd) upto maturity of low yielding genotypes was relatively lower (1775.4) followed by medium yielding cultivars (1815.3) and higher in high yielding cultivars (1838.3). Accumulated GDD predicted the physiological maturity ($R^2 = 0.99$) of wheat genotypes as per following equation: Y=52.508 (0.045*Accumulated GDD), where, Y is days to physiological maturity and

Table 2. Variation in different morphological parameters, yield and yield attributes in wheat genotypes.

Wheat genotypes	Shoot length (cm)	Spike length (cm)	Spikelet $spike^{-1}$	Grains $spike^{-1}$	1000 grains wt. (g)	Grain yield (t/ha)	Biomass (t/ha)	Harvest index (%)
UP-2425	89.4	12.2	16.5	46.6	59.3	4.64	11.1	41.8
PBW-509	96.2	10.1	18.3	49.9	43.8	4.83	11.6	41.6
HI-1544	85.2	10.4	18.6	49.2	41.5	4.84	11.8	41.1
DBW-16	86.2	10.1	17.3	50.2	45.4	4.99	12.0	42.0
PBW-502	89.7	10.0	18.8	50.1	39.9	5.03	12.5	40.4
PBW-226	85.5	10.1	17.9	50.5	38.2	5.04	12.1	42.1
HD-2733	85.7	9.4	18.6	51.0	44.3	5.17	12.4	41.8
UP-2382	83.5	10.3	18.7	54.7	33.9	5.23	12.5	41.9
PBW-373	91.8	10.2	20.4	53.7	42.2	5.25	12.8	41.0
WH-711	87.9	9.7	16.5	47.5	41.0	5.27	12.5	42.4
WH-542	86.6	10.8	20.5	53.5	43.0	5.29	12.8	41.3
WH-1021	93.5	11.6	21.0	58.3	42.8	5.31	12.0	44.4
RAJ-3765	83.6	10.9	20.6	53.5	43.1	5.39	12.2	43.9
UP-2565	90.8	8.4	18.8	52.3	49.2	5.43	12.8	42.5
DBW-17	83.5	10.4	20.0	54.6	44.8	5.58	12.5	44.5
HD-2687	87.3	10.9	20.3	58.7	39.7	5.61	13.4	42.0
HD-2894	89.2	10.2	19.6	57.1	45.6	5.62	13.5	42.0
PBW-343	89.7	10.8	21.0	57.1	43.0	5.63	12.7	44.6
PBW-550	84.9	11.0	19.7	59.1	43.5	5.65	12.4	45.3
UP-2338	89.8	11.5	20.8	58.3	41.7	5.78	12.9	44.8
CD (P = 0.05)	6.28	0.94	1.78	5.54	4.21	0.50	NS	NS

Table 3. Agro-meteorological indices – heat use efficiency (HUE) and radiation use efficiency (RUE) in wheat genotypes.

Wheat genotypes	Growing degree days (°Cd)			HUE (kg ha^{-1} °Cd^{-1})	RUE (g MJ^{-1})
	Up to booting	Up to flowering	Up to maturity		
UP-2425	859.3	1010.3	1808.1	2.57	1.43
PBW-509	812.8	1010.5	1811.4	2.67	1.50
HI-1544	785.0	972.4	1774.4	2.73	1.54
DBW-16	767.6	934.9	1707.8	2.93	1.62
PBW-502	876.8	1125.4	1838.4	2.74	1.58
PBW-226	939.4	1329.6	1842.6	2.74	1.53
HD-2733	968.4	1180.6	1884.9	2.75	1.53
UP-2382	968.4	1120.5	1845.8	2.83	1.58
PBW-373	956.3	1164.7	1812.0	2.90	1.64
WH-711	896.0	1089.3	1827.0	2.89	1.59
WH-542	871.6	1019.3	1768.0	2.99	1.68
WH-1021	756.8	974.6	1714.9	3.10	1.61
RAJ-3765	864.7	1021.2	1830.9	2.94	1.56
UP-2565	859.3	1021.1	1788.6	3.04	1.66
DBW-17	926.1	1104.3	1782.5	3.13	1.64
HD-2687	957.7	1166.4	1871.0	3.00	1.66
HD-2894	916.1	1069.5	1838.8	3.06	1.69
PBW-343	968.4	1147.5	1853.6	3.04	1.60
PBW-550	862.6	1005.0	1805.3	3.13	1.60
UP-2338	936.4	1100.4	1878.9	3.08	1.60
CD (P = 0.05)	19.1	98.1	24.9	0.20	NS

GDD is growth degree days. This result corroborates the findings of Prasad *et al.* (2005). The thermal time duration for grain growth showed a positive relationship (r=0.36) with 1000 seed weight. HUE (kg ha^{-1} °Cd^{-1}) was also positively associated with the grain yield of the different genotypes (r=0.89**).

Photosynthetic traits in relation to environment and yield: Photosynthesis (Pn, µmol CO_2 m^{-2} s^{-1}) and transpiration rate (E, mmole H_2O m^{-2} s^{-1}) showed significant variation in twenty wheat genotypes (Table 1). Mean photosynthesis rate was significantly higher in UP 2565 (24.17) while it was lower in HD 2733 (20.13). Significantly higher transpiration rate was observed in UP 2338 (6.17), PBW 223 (6.68) and PBW 509 (6.78). Analysis of overall photosynthetic light response in the present set of wheat genotypes showed an optimum PAR requirement of 1270 µmol m^{-2} s^{-1} (Fig. 2A). Higher PAR above 1500 µmol m^{-2} s^{-1} was also shown to reduce photosynthesis in wheat crop (Pandurangam *et al.* 2006). Photosynthetic RUE (PRUE) also showed reduction at higher temperatures (Fig 2B). Al-Khatib and Paulsen (1989) also observed thermal injury to photosynthesis and thylakoids by high light intensity. Moreover, higher temperatures reduce photosynthesis through effect on the denaturation of Rubisco activase enzyme (Pushpalatha *et al.* 2007) and increase in photorespiration. The optimum leaf temperature for photosynthesis from the response of the wheat genotypes was about 26°C, (Fig. 3A). The apparent carboxylation efficiency (Pn/Ci, where, Pn=photosynthesis and Ci=internal CO_2 concentration) also showed decline with leaf temperature above 26°C (Fig. 3B). Optimal temperature range between 21°C and 32°C were also observed by Bunce (2000) in eight cool and warm climate herbaceous C_3 species. Therefore, improvement of photosynthetic performance in wheat in relation to changing environment has been suggested (Parry *et al.* 2011).

The rate of photosynthesis and transpiration did not show any significant relationship with grain yield as well

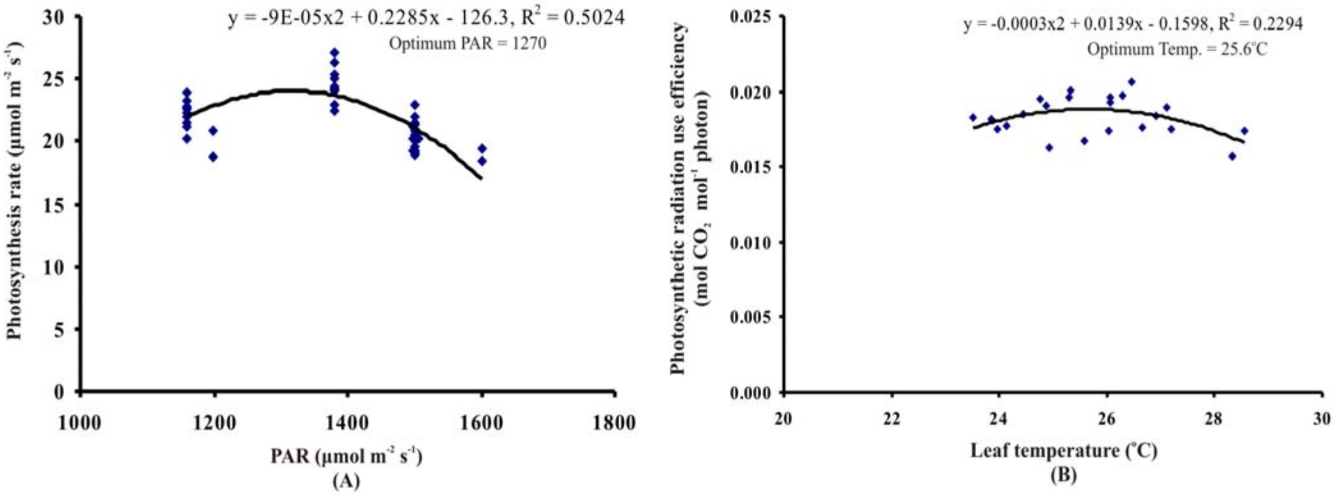

Fig. 2. Influence of PAR on photosynthesis (A) and leaf temperature regimes on photosynthetic radiation use efficiency (B) in wheat genotypes.

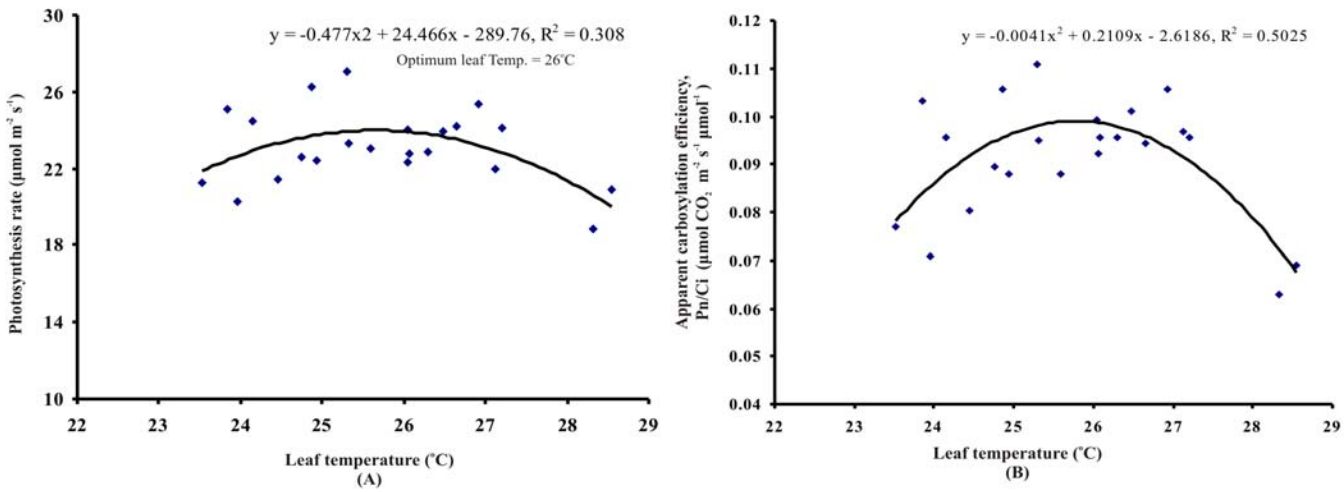

Fig. 3. Influence of leaf temperature regimes on photosynthesis rate (A) and apparent carboxylation efficiency (B) in wheat genotypes.

as total biomass in tested wheat cultivars. However, in the present study, a higher stomatal conductance was associated with grain yield (Fig. 4A). It has been earlier observed that variations in photosynthesis under control of different environmental and biological factors can be related to stomatal conductance (Ball *et al.* 1987). Therefore, a higher stomatal conductance could be an important approach to increasing availability of CO_2 at the site of carboxylation, and therefore, conductance correlates with yield as also reported for wheat (Fischer *et al.* 1998) and rice (Hubbart *et al.* 2007). Another parameter–RUE did not show significant variation among different genotypes and ranged from 1.43 to 1.69 g MJ^{-1}. In another study, Slafer *et al.* (1990) also found no differences in the RUE in irrigated spring wheat. However, the RUE was correlated with biomass (r=0.84**) (Fig. 4B) and the mean RUE of low (1.52 g MJ^{-1}), medium (1.60 g MJ^{-1}) and high (1.63 g MJ^{-1}) yielding cultivars were positively associated with the mean grain yield.

From the present study, differences were observed in growing degree days and HUE among the wheat genotypes and it showed association with yield. Further,

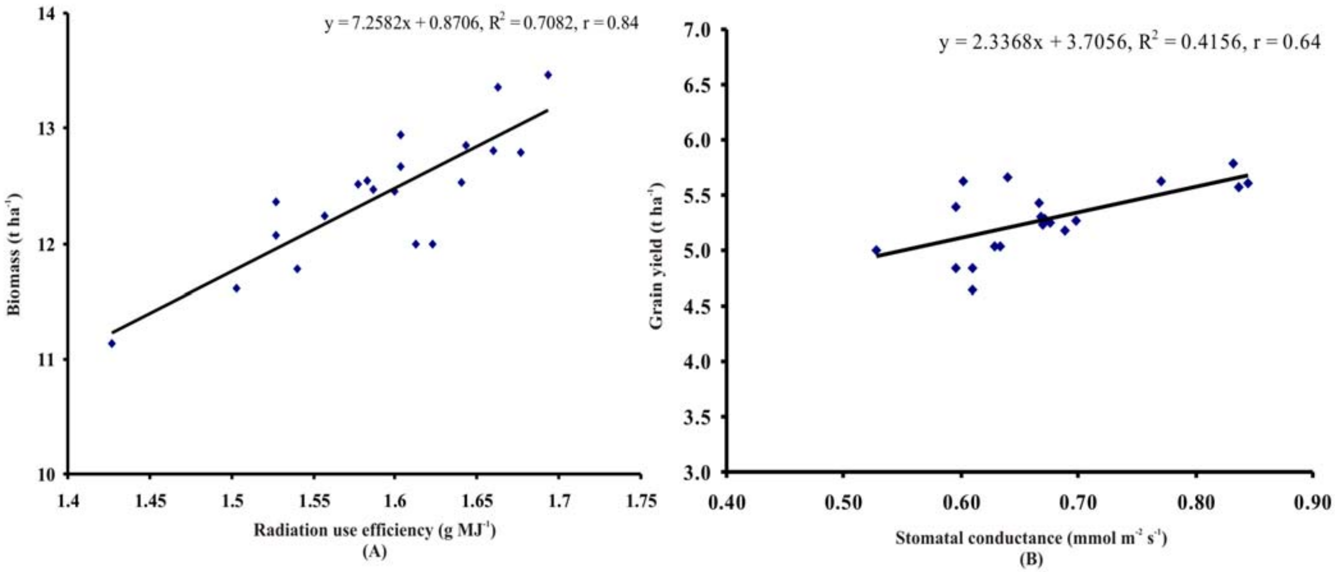

Fig. 4. Relationship of radiation use efficiency with biomass (A) and stomatal conductance with yield (B).

a higher yield response in wheat genotypes was associated with higher stomatal conductance among the genotypes and biomass production was positively and associated with RUE. It also emerged that moderately higher temperatures after anthesis even in timely sown irrigated wheat can constrain photosynthesis.

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