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RADIATION AND WATER USE EFFICIENCY OF WHEAT UNDER VARIOUS ENVIRONMENTAL CONDITIONS IN MIDDLE GUJARAT AGRO-CLIMATIC REGION

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ABSTRACT

The field experiments were carried out on wheat at Anand Agricultural University, Anand Gujarat during five consecutive years of 2009-2013. The experiment was consisted of four dates of sowing (1^{st} Nov., 15^{th} Nov., 30^{th} Nov. and 15^{th} Dec.) and four varieties (V_1: GW-322, V_2: GW-496, V_3: GW-366 (aestivum) and V_4: GW-1139 (Durum) under split plot design with a objective for determination of relationship between dates of sowing, varieties, radiation use efficiency (RUE), water use efficiency (WUE) and grain yield of wheat. Results shown that grain yield had linear relationship with RUE and WUE. Sowing on 15^{th} Nov. (D2) recorded the highest RUE {1.49 (Kg/ha) / MJ/m^2} and WUE {11.21 (Kg/ha) / mm}. Also the variety GW – 322 (V-1) recorded the highest RUE {1.43 (Kg/ha) / MJ/m^2} and WUE {10.91(Kg/ha) / mm}. While the interaction effects of dates of sowing and variety, D_2 V_1 recorded the highest RUE {1.67 (Kg/ha) / MJ/m^2} and WUE {21.86 (Kg/ha) / mm}. The optimum sowing in D_2 provide greater cultivars choice. Under early (D_1) and late sowing (D_3) cv. V_1 found more suitable. Cultivar V_4 was not suitable for early sowing (D_1) but performed better under late sown conditions. These options are serve as an effective and operational tool for best contingent crop planning of wheat under middle Gujarat region.

Keywords: Radiation use efficiency, water use efficiency, temperature, Sowing date, varieties

INTRODUCTION

Wheat is one of the world's most important food grain crop. India is the second largest producer of wheat in the world next only to china. It is considered to be the backbone of the food security in India along with rice. It is the most important source of carbohydrate, vitamins, minerals, copper, manganese, starch, fiber and protein. The gluten protein makes it suitable for preparing bakery products.

Solar radiation and soil moisture are basic meteorological parameters having significance to agriculture. Crop plants require adequate water if they are to grow at an optimum rate. Availability of soil moisture influences many aspects of crop growth and yield (Begg and Turner 1976). Evapotranspiration (ET) is a combination of evaporation and plant transpiration processes into a total moisture flux from the ground to the atmosphere. ET_o is a climatic parameter expressing the evaporation power of the atmosphere. ET_c refers to the evapotranspiration from excellently managed, large, well-watered fields that achieve full production under the given climatic conditions. Water requirements vary with the type of crop and environmental conditions. Better performance of wheat crop depends on availability of water, especially at various growth stages of crop. Water used by crops is normally related to total dry matter production or economic yield. This led to the concept of water use efficiency (WUE) broadly defined as crop yield per unit of water use.

Under adequate supply of water and nutrients, wheat yield has been shown to be closely related to the amount of radiation intercepted during the growing season. Under field conditions, crop growth is dependent on the ability of the canopy to intercept incoming radiation, which is function of leaf area index (LAI) and canopy architecture, and conversion it into new biomass (Gifford et al., 1984). Radiation-use efficiency (RUE) relates biomass production in relation to the photosynthetically active radiation (PAR) intercepted by a plant or crop.

The objective of this field research was to study the light use and water use efficiency of four different cultivars of wheat under four varied environmental condition of middle Gujarat.

MATERIALS AND METHODS

Experimental site

The field experiments were conducted at the Agronomy farm, B.A. College of agriculture, Anand Agricultural University, Anand, (Lat. 22 º 35’, Log. 72 º 55’, 45.1 m from msl) during five consecutive years 2009-2013. The experiment was carried out with four dates of sowing (1^{st} Nov., 15^{th} Nov., 30^{th} Nov. and 15^{th} Dec.) and four varieties (V_1: GW-322, V_2: GW-496, V_3: GW-366 (aestivum) and V_4: GW-1139 (Durum) laid out in split plot design.

Leaf area index:

Plant sample taken from 25 cm^2 leaf area at each phenological phase. The leaves are separated from plant and leaf area was measured. LAI was calculated as the ratio of leaf area to land area (Hunt, 1978).

Radiation interception and radiation use efficiency:

The daily, solar radiation was calculated by CROPWAT 8.0. The incoming solar radiation was converted into incoming photosynthetically active radiation (PAR). The fraction of PAR to solar radiation was converted as the findings of Monteith and Unsworth, 1990 and Campbell and Norman, 1998.The fraction of intercepted radiation (Fi) was calculated from LAI using the exponential equation as suggested by Monteith and Elston (1983):

$$Fi = 1 - exp^{-kLAI}$$

Where, k is the extinction coefficient for total solar radiation. The k value for wheat was considered 0.7 (Lunagaria and Shekh, 2006). The amount of intercepted radiation (I) was determined by multiplying Fi with incident PAR (I PAR) during the season;*I = Fi x I PAR*. Radiation use efficiency for grain yield (RUEGY) was calculated as the ratio of total grain yield to cumulative intercepted PAR (Σ Sa) for each growing season.

Water use efficiency

For calculating reference evapotranspiration Ref ET v 3.1.16 was used where FAO -56 Penman-monteith method was considered for reference evapotranspirationand crop coefficient was obtained from cropwat 8.0 FAO. Crop evapotranspiration (ETc) was calculated from ETc = kc x ETo equation. The FAO-56 Penman-monteith equation;

$$ETo = \frac{0.408\, \Delta\, (Rn - G) + \gamma \frac{900}{T + 273} u_2\, (e_s - e_a)}{\Delta + \gamma\, (1 + 0.34\, u_2)}$$

Where, ETo: grass reference evapotranspiration [mm day^{-1}], Rn: net radiation at the crop surface [MJ m^{-2} day^{-1}], G: soil heat flux density [MJ m^{-2} day^{-1}], T: mean daily air temperature at 2 m height [°C], u_2 wind speed at 2 m height [m s^{-1}], e_s saturation vapor pressure [kPa], e_a actual vapor pressure [kPa], e_s-e_a :saturation vapor pressure deficit [kPa], Δ: slope vapor pressure curve [kPa °C^{-1}], γ: psychrometric constant [kPa °C^{-1}]

Water use efficiency ((kg/ha)/mm) of wheat was calculated as follows (Reddy, 2011 and Hussain et al., 1995,);

$$\text{WUE} = \frac{\text{Grain Yield}}{\text{ET}}$$

All the data of WUE were statistically analyzed as a split plot design, using analysis of variance to calculate mean and interaction effects. Differences among treatment means were compared using least significant difference (LSD) at $P \leq 0.05$ probabilities (Steel *et al*., 1997).

RESULTS AND DISCUSSION

Radiation use efficiency and yield:

The results of RUE of wheat yield under individual as well as pooled were presented in Table 1. Significant interactions was also presented in Table 2. Results showed that, there was significant difference among the different dates of sowing and varieties on radiation use efficiency under individual as well as pooled basis. Among different dates of sowing significantly the higher RUE was observed in D_2 (1.49) sowing which remained at par with D_1 (1.38) sowing. D_3 and D_4 had significantly lower RUE of 1.20 and 1.13 respectively. Significantly higher RUE was observed by V_1 (1.43) followed by V_3 (1.38), V_2 (1.31) and V_4 (1.08). RUE of cultivar V_1-V_3 and V_2-V_4 were found at par.

Water use efficiency and yield:

The individual as well as pooled WUE of grain yield of wheat and significant interactions are presented in Table 3 and 4. Significantly the highest WUE (11.21) was recorded under D_2 sowing while the lowest (8.18) under D_1 sowing. The WUE of D_3 and D_4 was 9.45 and 9.35 respectively and found at par with each other. The WUE of different cultivar, cv V_1 had significantly the highest WUE (10.91), followed by V_3 (10.07), V_2 (9.46) and V_4 (8.35).

Relationship between RUE, WUE, yield and weather:

The phase wise and date wise prevailed weather parameters under respective phenophase were correlated with yield of wheat for ascertaining significant and responsible weather factor for yield and variation in RUE and WUE. The values of correlation coefficients are presented in Table 5. Date wise and phase wise weather variation are depicted in Fig. 1. The results showed that morning RH during TL phase of wheat had positive relationship with wheat yield. The higher rate of RH_1 (>85) in D_2 sowing was benefited for higher yield. While EP and RH_2 during TL phase showed negative relationship with wheat yield. The lower EP rate (< 3.1) and RH_2 (< 41) in D_2 sowing helped in getting higher yield as compared to rest of the dates. Lower BSS (< 8), higher RH_2 (> 43) and MRH (> 66) under D_2 sowing in Booting stage of wheat enhanced the wheat yield. Temperature (Tmax., Tmin, and mean) and vapour pressure (morning, afternoon and mean) during flowering stage of wheat were negatively correlated with wheat yield. The lower values of Tmax (< 28), Tmin (< 12), Tmean (< 20), VP_1 (< 10), VP_2 (≤ 11) and MVP (≤10) prevailed under D_2 sowing favoured in getting higher yield of wheat. Afternoon, during milking stage VP had positive while GDD had negative relationship with wheat yield. The higher VP_2 (> 10) and lower GDD (< 239) during milking stage in D_2 sown wheat favourably helped and increased the wheat yield.

The relationship and interaction between different environmental regimes and grain yield of wheat in relation to their RUE and WUE are depicted in Fig. 2. There was linear relationship with RUE, WUE and grain yield of wheat (Y=19.445*RUE +15.446 R2: 0.805 and Y=2.271 *WUE +4.563 R2: 0.888). Results showed that RUE, WUE and their interaction effects on grain yield of D_2 sowing under cv. V_1, V_2 and V_3 were found most suitable. Optimum sowing (D_2) provide greater cultivars choice. Under early(D_1) and late sowing(D_3)cv. V_1 found most suitable. Cultivar V_4 was not suitable for early sowing (D_1) due to its lower RUE, WUE and yield. However, it was performed better under D_2, D_3 and D_4 late sowings with higher grain yield even under lower WUE and RUE conditions. These options are serve as an effective and operational tool for best contingent crop planning of wheat under middle Gujarat condition.

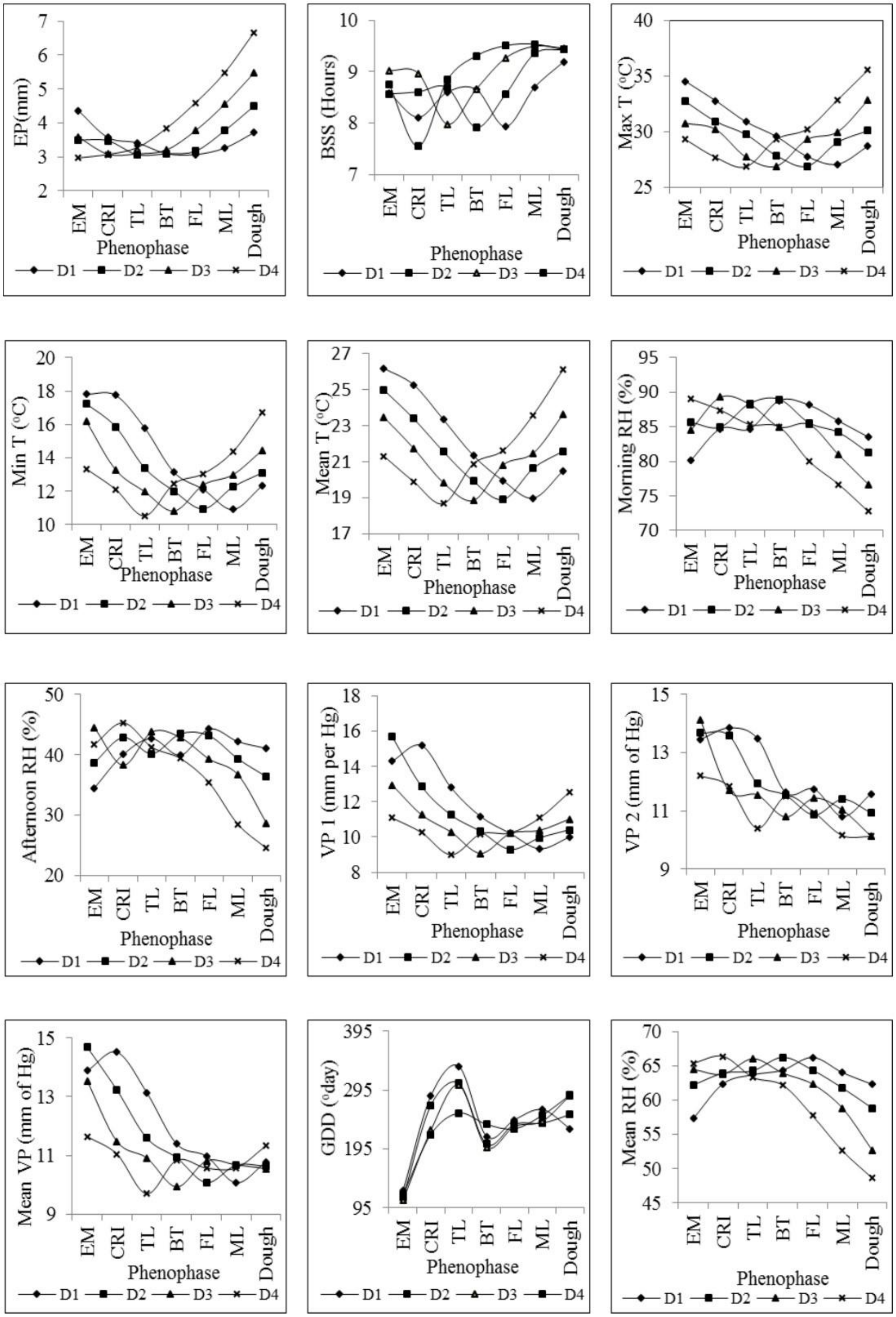

Fig. 1: Phase and date wise mean weather variations

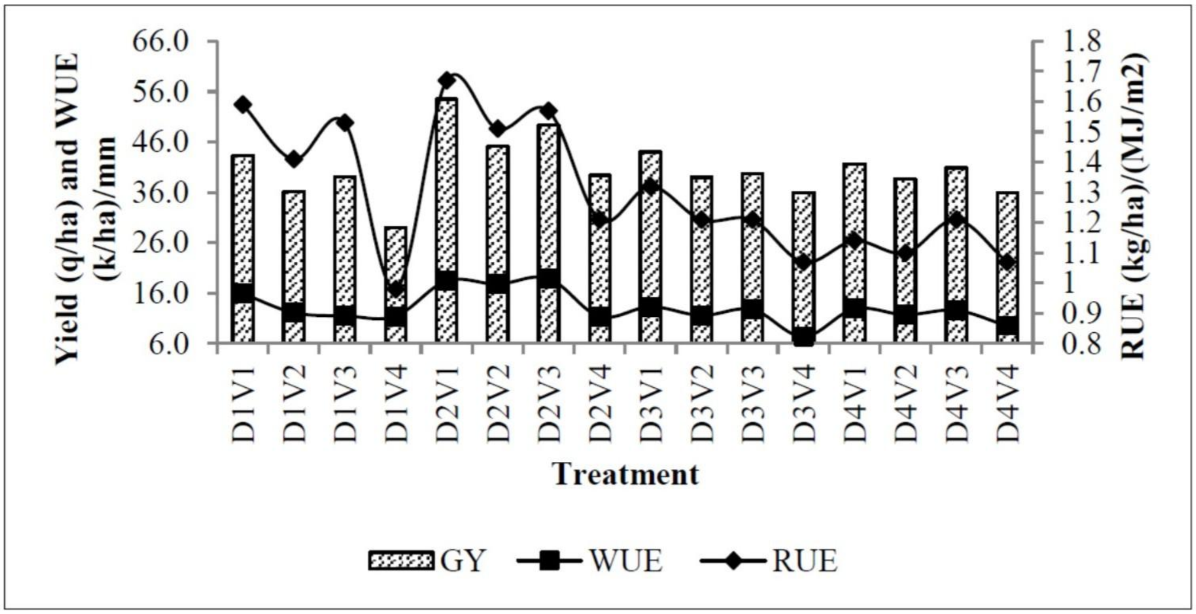

Fig.2 : Relationship between WUE, RUE and grain yield of wheat

Table 1. Radiation use efficiency {(Kg/ha) /(MJ/m^2)} **of wheat**

Treatment	**Radiation use efficiency**					
	2009-10	**2010-11**	**2011-12**	**2012-13**	**2013-14**	**Pooled**
Date of sowing						
D_1	0.92	0.95	1.21	2.14	1.67	1.38
D_2	1.33	1.30	1.34	1.90	1.57	1.49
D_3	0.93	0.98	0.83	1.72	1.54	1.20
D_4	1.03	0.97	0.91	1.36	1.38	1.13
S. Em.±	0.059	0.036	0.035	0.72	0.043	0.075
C. D. at 5 %	0.189	0.114	0.113	0.230	0.139	0.230
CV %	22.46	13.60	13.12	16.14	11.27	15.73
Variety						
V_1	1.24	1.24	1.24	1.86	1.58	1.43
V_2	0.95	0.99	1.11	1.88	1.60	1.31
V_3	1.10	1.08	1.16	1.94	1.63	1.38
V_4	0.92	0.88	0.80	1.46	1.36	1.08
S. Em.±	0.049	0.038	0.032	0.048	0.041	0.037
C. D. at 5 %	0.140	0.109	0.091	0.137	0.118	0.113
CV %	18.58	14.48	11.84	10.69	10.62	12.90
S. I. effect						YxD, YxV, DxV, YxDxV

Table 2: D x V interaction Table of RUE {(Kg/ha) /(MJ/m^2)}

	V_1	V_2	V_3	V_4
D_1	1.59	1.41	1.53	0.98
D_2	1.67	1.51	1.57	1.21
D_3	1.32	1.21	1.21	1.07
D_4	1.14	1.10	1.21	1.07
S Em : 0.054				
CD: 0.156				
CV % : 12.90				

Table 3. Water use efficiency of wheat {(Kg/ha) / mm}.

Treatment	**Water use efficiency**					
	2009-10	**2010-11**	**2011-12**	**2012-13**	**2013-14**	**Pooled**
Date of sowing						
$\mathbf{D_1}$	7.33	7.90	7.03	11.06	10.59	8.78
$\mathbf{D_2}$	10.96	10.69	10.02	12.58	11.80	11.21
$\mathbf{D_3}$	7.81	8.43	7.14	12.57	11.32	9.45
$\mathbf{D_4}$	7.78	8.75	8.41	11.14	10.69	9.35
S. Em.±	0.470	0.307	0.276	0.532	0.285	0.194
C. D. at 5 %	1.501	0.981	0.883	NS	0.910	0.552
CV %	22.19	13.72	13.56	17.98	10.26	16.03
Variety						
$\mathbf{V_1}$	10.20	10.44	9.40	12.51	12.01	10.91
$\mathbf{V_2}$	7.86	8.41	8.30	11.94	10.81	9.46
$\mathbf{V_3}$	8.59	8.80	8.72	12.72	11.52	10.07
$\mathbf{V_4}$	7.23	8.13	6.17	10.18	10.06	8.35
S. Em.±	0.396	0.311	0.252	0.315	0.300	0.214
C. D. at 5 %	1.136	0.892	0.722	0.905	0.862	0.659
CV %	18.69	13.90	12.35	10.65	10.82	13.12
S. I. effect						YxD, YxV, YxDxV

Table 4: D x V interaction Table of WUE {(Kg/ha) / mm}.

	V_1	V_2	V_3	V_4
D_1	18.18	15.18	16.45	12.16
D_2	21.86	18.05	19.77	15.80
D_3	16.83	14.94	15.23	13.81
D_4	14.95	13.87	14.70	12.93
S Em : 0.600				
CD: 1.722				
CV % : 13.42				

Table 5: Correlation coefficient between phasic weather and seed yield of wheat

Phenological phase	Weather parameter	Correlation coefficient (r)
Tillering	EP	-0.76
	RH1	0.74
	RH2	-0.72
Booting	Sunshine hours	-0.75
	RH2	0.75
	MRH	0.70
Flowering	Tmax	-0.55
	Tmin	-0.78
	Tmean	-0.64
	VP1	-0.96
	VP2	-0.75
	MVP	-0.95
Milking	VP2	0.65
	GDD	-0.80

CONCLUSION

- Optimum (D_2: 15th Nov) sowing of wheat had higher radiation and water use efficiency. Under V_1 (GW-322) cultivar.
- There was linear relationship with RUE, WUE and grain yield of wheat.
- Yield variation of V_1 and V_4 clearly suggest that, these cultivars were found most suitable for D_1 to D_3 and D_2 to D_4 sowing window for optimum yield, respectively.

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