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Research Article

WHEAT YIELD OPTIMIZATION USING WEATHER, CULTIVAR, AND OPTIMUM SOWING WINDOW IN MIDDLE GUJARAT REGION

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Abstract: The field experiments were carried out for assessment of wheat-weather relationship at Anand Agricultural University, Anand Gujarat during two consecutive *rabi* seasons of 2012-14. The experiment was consisted of four dates of sowing (1st Nov., 15th Nov., 30th Nov., and 15th 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 an objective for assessment of relationship between wheat yield and weather, dates of sowing and cultivars. There was linear relationship between radiation use efficiency (RUE) and grain yield. This information provide basis for manipulation of different dates and cultivars for higher RUE and grain yield. Results showed that heat use efficiency (HUE) and interaction effects of cultivar on grain yield the D_2 sowing under with V_1, V_2 and V_3 were found most suitable. Optimum sowing (D_2) provides greater cultivars choice. Under early (D_1) and late sowing (D_3) cv. V_1, V_4 found most suitable. Cultivar V_4 was not suitable for early sowing (D_1) due to its lower HUE, and yield. However, it was performed better under D_2, D_3 and D_4 sowing with higher grain yield. These options are served as an effective and operational tool for best contingent crop planning of wheat under Gujarat region.

Keywords: *Radiation use efficiency, Heat use efficiency, Temperature, Sowing date, Varieties*

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Introduction

Wheat is world's most important food grain crop. India is the second largest producer of wheat in the world next to china. It is the backbone of the food security in India. It is the most important source of carbohydrate, vitamins, minerals, copper, manganese, selenium, starch, fiber and protein.

Solar radiation and soil moisture are basic meteorological parameters of 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 [1]. Evapotranspiration (ET) is a combination of evaporation and plant transpiration processes into a total moisture flux from the ground to the atmosphere. ETo is a climatic parameter expressing the evaporation power of the atmosphere. ETc 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 [2]. 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 convert it into new biomass [3]. Radiation-use efficiency (RUE) relates biomass production to the photosynthetically active radiation (PAR) intercepted by a plant or crop. The experiment was conducted with an objective for assessment of relationship between wheat yield and weather, dates of sowing and cultivars [4-6].

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 two consecutive *rabi* seasons of 2012-14. The experiment was carried out with four dates of sowing (1st Nov., 15th Nov., 30th Nov. and 15th 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[7-12].

Radiation interception and radiation use efficiency

The daily, Incident, reflected and transmitted PAR over the crop canopy were measured by line quantum sensor (LI- COR/LI 191 SA). Measurements were carried out during 11.00 – 14.00 hrs in terms of μ mol $m^{-2}s^{-1}$. The daily average value of observations was computed and converted in to M J $m^{-2}day^{-1}$ as per below formula.

$$M\,J\,m^{-2}day^{-1} = 0.00078261\ \mu\,mol\,m^{-2}s^{-1} * BSS$$

Where, BSS= Bright sunshine hours

To quantify the plant stand ability to absorb photo synthetically active solar radiation (PAR) and convert this energy into biomass, the term radiation use efficiency (g MJ^{-1}).

Absorbed PAR: using the three components, the absorbed PAR by plant for photosynthesis was calculated by this formula [13].

$$PAR_a(M\,J\,m^{-2}day^{-1}) = PAR_i - PAR_r - PAR_t$$

Where, a = absorbed, i = incident and t = transmitted

The values of radiation use efficiency (RUE) were calculated for each growing season as follows (Markova *et al.*, 2011);

$$RUE(kg\,ha^{-1}\,MJ^{-1}) = Total\ Biomass/\ PAR_a$$

Estimation of the helio- thermal units (HTU)

The helio-thermal unit for a given day defined as the product of GDD and the actual hours of bright sunshine for that day. The sum of the HTU for the duration of each phenophase were computed by using the following formula:

$$Accumulated\ HTU = \sum_{i=ds}^{dh} (T - Tbi) * Ni$$

Where,

T = Daily mean air temperature in °C obtained as

$$T = \frac{(T\max - T\min)}{2}$$

N_i = Actual hours of bright sunshine

Tbi = Base temperature in °C (5°C)

ds= Date of sowing or the date of commencement of the phenophases.

dh = Date of the harvesting or the date of ending of the respective phenophases

Thermal use efficiencies

Thermal use efficiencies *viz.* heat use efficiency (HUE) was calculated using the equations proposed by Sreenivas *et al.*, (2008) [14]:

HUE = Biomass (kg/ha)/GDD

Results and discussion

Weather prevailed during booting stage and grain Yield

The relationship between minimum temperature ($T_{min.}$) at booting stage and grain yield is depicted in [Fig-1]. Analysis showed that grain yield and booting stage were linearly and negatively correlated with T_{min}. Minimum temperature 9 to 10°C during booting stage significantly increased the grain yield as depicted in [Fig-1]. During 2012-13 year, booting stage $T_{min.}$ was prevailed 9 to 10°C under D_2 and D_3 sowing which significantly increased the grain yield and that was more than 5200 kg/ha. While during 2013-14 year, booting stage $T_{min.}$ Was to the tune of 11°C under D_2 and D_3 sowing which significantly reduced (8%) grain yield as compared to 2012-13. This might be the reason behind the more grain yield was recorded under D_2 and D_3 sowing during 2012-13. On an average $T_{min.}$ increase 3 to 4°C from 10 to 11°C under D_1 and D_4 sowing which significantly reduced10% grain yield than D_2 and D_3 sowing. So, from the above results, it was observed that booting stage $T_{min.}$ in the range of 9 to 10°C is found most favourable for higher production which coincided under D_2 and D_3 sowing.

From the above discussion, it was concluded that D_2 and D_3 sowing was found optimum. Early and delay sowing in wheat significantly reduced 10% grain yield. This finding is very much confirmed with Akhtar *et al.*, (2006) [15], De *et al.*, (1983) [16], Sial *et al.*, (2005) [17], and Arain *et al.*, (1999) [18].

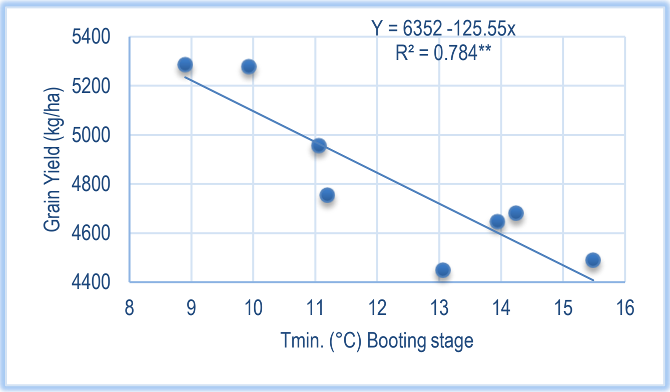

Fig-1 Relationship between $T_{min.}$ and grain yield under booting stage

Vegetative days and grain yield

Vegetative days and grain yield relationship is depicted in [Fig-2]. Results revealed that significant linear relationship was observed between vegetative days and grain yield. Higher vegetative days in the range of 66 to 72 under D_2 and D_3 sowing significantly increased the grain yield under both the individual year. This finding is confirmed with Sial *et al.*, (2005). It might be more conversion of photosynthates in to carbohydrate of reproductive parts and there by grain yield. In general higher vegetative days (70 to 72 days) were recorded under D_2 and D_3 sowing during 2012-13 which significantly increased the grain yield as compared to 2013-14. From the above results, it was concluded that more vegetative days coincide under D_2 and D_3 sowing which significantly increased the grain yield. So, D_2 and D_3 sowing times found most optimum for higher grain yield.

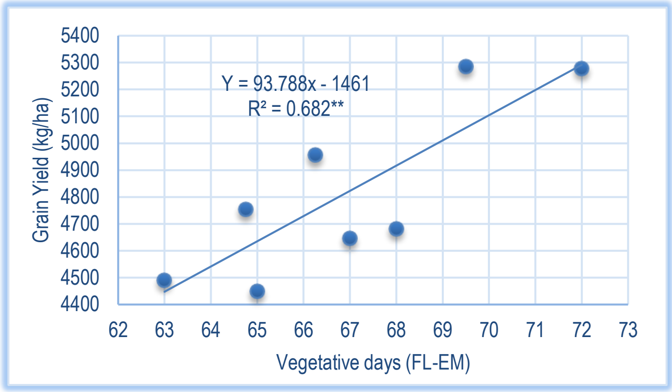

Fig-2 Relationship between vegetative days and grain yield

Radiation use efficiency and yield

Significant positive and linear relationship was observed between radiation use efficiency of grain and straw with grain yield and straw yield respectively as depicted in [Fig-3]. Higher grain RUE (9.07 kg/ha/MJ) and straw RUE (12.89 kg/ha/MJ) significantly increased the grain and straw yield under D_2 and D_3 sowing. It might be due to more PAR utilization under D_2 and D_3 sowing as compared to other dates of sowing.

It was concluded that more PAR utilization significantly increased grain and straw yield under D_2 and D_3 sowings as compared to other dates of sowing. So, it is most advisable to sow wheat during mid to end of November (D_2 and D_3 sowing) for higher production under middle Gujarat region.

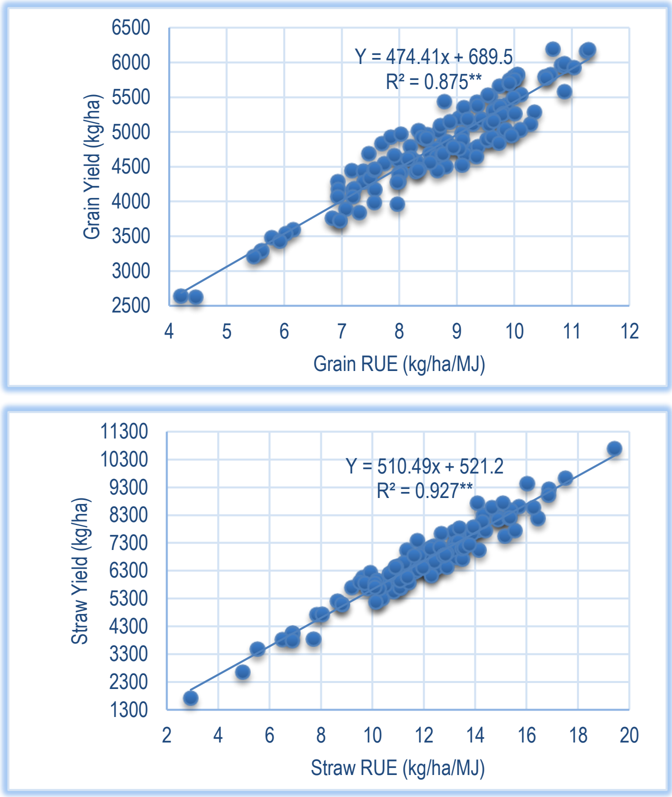

Fig-3 Relationship between radiation use efficiency and yield

Thermal use efficiency and grain yield

Significant positive and linear relationship was observed between heat use efficiency and photo-thermal use efficiency with grain yield as depicted in [Fig-4-6]. Highest heat use efficiency (11.50 kg/ha/°Cday) increased the grain yield under D_2 dates of sowing.

Similarly, highest photo-thermal use efficiency (1.05 kg/ha/°C day) increased the grain yield under D_2 sowing. Lowest heat use efficiency (10.18 kg/ha/°C day) and photo-thermal use efficiency (0.93 kg/ha/°C day) decreased the grain yield under D_1 sowing. Under D_4 sowing (15 Dec.) the highest heat use efficiency (3.1 kg/ha/°C day) was found under V_3 cultivar which increased the grain yield. So, V_3 cultivar was found most suitable for late sowing under middle Gujarat region.

From the above results, it was concluded that highest thermal use efficiency increased the grain yield under D_2 sowing, while lowest thermal use efficiency decreased the grain yield under D_1 sowing. V_3 cultivar was found most suitable for late sowing (15 Dec.) due to higher heat use efficiency with higher grain yield.

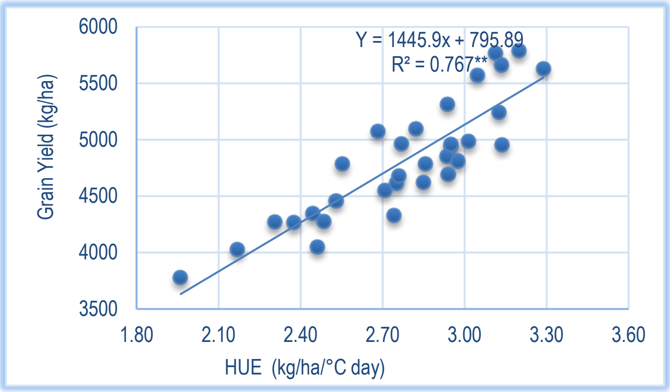

Fig-4 Relationship between thermal use efficiency and grain yield

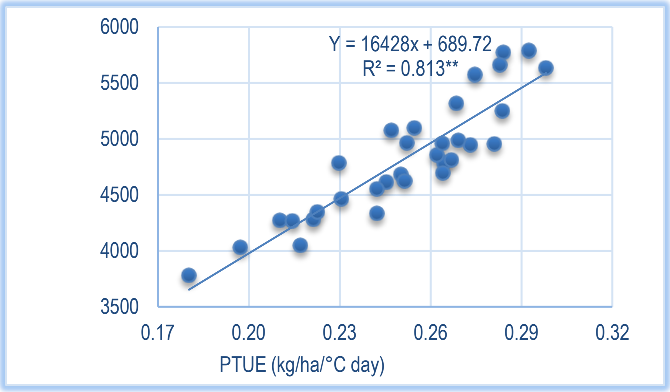

Fig-5 Relationship between thermal use efficiency on grain yield under different dates of sowing

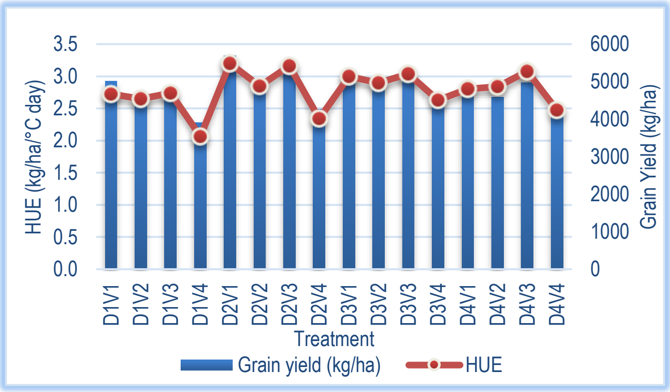

Fig-6 Variation of thermal use efficiency and grain yield under different treatments

Conclusion

Weather prevailed during crop lifecycle profound impact on yield. Booting stage of wheat found most sensitive to temperature. Linear correlation observed between $T_{min.}$ at booting stage and grain yield. Lower $T_{min.}$ 9 to 10°C during booting stage significantly increased the wheat grain yield. Significantly higher grain yield found on 15th -30th November sowing as a result of more numbers of vegetative days in the range of 66 to 72. Higher grain, straw RUE (9.07, 12.89 kg/ha/MJ) significantly increased the grain and straw yield under 15th -30th (D_2 & D_3) November sowing. Maximum heat use efficiency, photo-thermal use efficiency (11.50, 1.05 kg/ha/°C day) increased the grain yield under 15th November (D_2) sowing. Optimum sowing (D_2) sowing provides greater cultivar choice with V_1, V_2 and V_3 as higher heat use efficiency (HUE) and grain yield. Under early (D_1) and late sowing (D_3) cv. V_1, V_4 found most suitable, respectively. Cultivar V_4 was not suitable for early sowing (D_1) due to its lower HUE, and yield. Cultivar GW-366 (V_3) was found most suitable for late sowing (15th Dec.) due to higher (3.1 kg/ha/°C day) heat use efficiency with higher grain yield. Early and delay sowing significantly reduced 10% grain yield of wheat.

Application of research: Research finding will be useful for setting of sowing windows and cultivar selection at different environmental condition.

Research Category: Agricultural Meteorology

Abbreviations: RUE- radiation use efficiency, HUE- heat use efficiency, PTUE- photo-thermal use efficiency, ET- Evapotranspiration, PAR- photosynthetically active radiation, LAI- leaf area index, $T_{min.}$-Minimum Temperature

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Author Contributions: All authors equally contributed

Author statement: All authors read, reviewed, agreed and approved the final manuscript. Note-All authors agreed that- Written informed consent was obtained from all participants prior to publish / enrolment

Study area / Sample Collection: Agronomy farm, B.A. College of agriculture, Anand Agricultural University, Anand

Cultivar / Variety / Breed name: *Triticum aestivum*

Conflict of Interest: None declared

Ethical approval: This article does not contain any studies with human participants or animals performed by any of the authors.
Ethical Committee Approval Number: Nil

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