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Weather Based Agro Indices and Grain Yield of Rice Cultivars Transplanted on Different Dates in Punjab

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Abstract

Rice (*Oryza sativa* L.) is a staple food of more than 50 per cent of the world's population and is very important from food security point of view of India. Sunlight and heat (measured through temperature) are important natural resources which affects rice productivity. Therefore, in order to evaluate the efficacy of rice varieties and date of transplanting to efficiently utilize these natural resources an experiment was conducted at PAU, Ludhiana during *kharif* 2012. Rice varieties PR 115 and PR 118 were transplanted on five dates viz. 15th June, 22st June, 29th June, 6th July and 13th July. The heat units, i.e., Growing-degree days (GDD), were computed using a base temperature of 10^{0}C. The Photothermal units (PTU) were computed by taking the product of GDD and day length. The Heliothermal units (HTU) were computed by taking the product of GDD and corresponding actual sunshine hours for that day. The results revealed that among the cultivars, cv. PR 118 accumulated more heat units than cv. PR 115 due to which the grain yield of cv. PR 118 was higher than cv. PR 115. Among the dates of transplanting, early transplanted rice accumulated more heat units to attain physiological maturity as compared to late transplanted rice. Therefore, the early transplanted rice produced higher grain yield as compared to late transplanted rice.

Keywords: Growing degree days; photothermal units; heliothermal units; yield; varieties.

1. Introduction

Rice (*Oryza sativa* L.) is a staple food of more than 50 per cent of the world's population and supplies 20 per cent of total calories required by world and 31 per cent required by the Indian population (Anonymous, 2011). India will need 112 million tonnes of rice in 2020, which is 23 million tonnes more than the present production. In India rice was cultivated on 41.9 million ha with an average productivity of 2.13 t ha^{-1} and total production of 89.1 million tonnes of rice during the year 2009-10. Rice productivity is highly dependent upon prevailing weather conditions. Some of the weather parameters like sunshine hours, rainfall and heat (measured as temperature) are important natural resources which affect the rice productivity to a great extent. The agronomic practices which optimize the use of these natural resources helps in increasing the rice productivity. The optimum utilization of these resources can also vary among different rice cultivars. To study the extent and comparative utilization of these resources some weather based agro indices have been developed. These indices are also helpful in studying the comparative efficacy of applied agronomic practices in utilizing these natural resources.

The commonly used weather based agro indices are growing degree days (GDD), photothermal units (PTU) and heliothermal units (HTU). GDD is the most common temperature index used to estimate plant development (Qadir et al, 2006). GDD can also be used to assess the suitability of a region for production of a particular crop, estimate the growth stages and heat stress on crop. The phasic development and crop yield are influenced by both temperature and photoperiod. Therefore, it is better to calculate PTU and HTU in addition to GDD.

2. Materials and Methods

2.1. Experimental site

The experiment was conducted at Punjab Agricultural University, Ludhiana, Punjab, India, during *kharif* seasons of 2012. The experimental site is situated in Trans-Gangetic agro-climatic zone, representing the Indo-Gangetic alluvial plain at $30^{o}56'$ N latitude, $75^{o}52'$ longitude and at an altitude of 247 m above mean sea level. The site is characterized by sub-tropical semi-arid type of climate with hot summers and very cold winters. The mean maximum and minimum temperatures shows considerable fluctuation during summer and winter. The temperatures can attain 38^{o} C in summer. The average annual rainfall is 750 mm, approximately 80 per cent of which is received during July to September. The soil was loamy with alkaline reaction. The meteorological data was recorded at Meteorological Observatory of Punjab Agricultural University, Ludhiana, during crop growing season.

2.2. Experimental treatments and procedures

The experiment was conducted in factorial RBD with three replications. The treatments were dates of transplanting [15^{th} June (D_1), 22^{nd} June (D_2), 29^{th} June (D_3), 6^{th} July (D_4) and 13^{th} July (D_5)] and two rice cultivars (PR 115 and PR 118). The agronomic practices recommended by Punjab Agricultural University, Ludhiana, was

followed to raise the crop. The data on crop phenology was taken by visual observations and the crop yield was recorded at maturity. Growing degree days (GDD) were determined as per Nuttonson (1955):

$$GDD = T_{mean} - T_b$$

where, T_{mean} = Mean of maximum and minimum temperature (^oC) during a day

T_b = Base temperature (10.0^oC)

The PTU were computed by taking the product of GDD and day length. The HTU were computed by taking the product of GDD and corresponding actual sunshine hours for that day. The data on grain yield was used to perform Analysis of Variance to determine the effect of treatments. Means were compared using least significant difference (LSD) at 5 per cent probability.

3. Results and Discussion

3.1. Growing Degree Days

The GDD accumulated by rice cultivars transplanted on different dates of transplanteing are shown in Table 1. In case of cv.PR 115 maximum GDD was accumulated when it was transplanted on D_5. GDD accumulated by other dates of transplanting were 9-10% lower than D_5. However, in case of cv. PR 118 maximum GDD was accumulated by D_1 date of transplanting. The GDD accumulated by other dates were lower by 1.2 to 4.2% than that accumulated by D_1. Among phenological stages, both the cultivars accumulated maximum GDD during transplanting to maximum tillering stage. The trend of GDD accumulated by PR 115 under different dates of transplanting is not in line with the trend observed in the grain yield but in case of PR 118 the trend is almost similar as that observed in grain yield. The earlier transplanted dates accumulated more GDD as compared to late transplanted dates, particularly in case of PR 118 and the difference between maximum and minimum value was 121^{o}C day. On the other hand in case of PR 115 the difference between the GDD accumulated was smaller among the dates of transplanting and it was recorded as 91^{o}C day.

Table 1: Weather based agro indices of rice cultivars transplanted on different dates.

Phenological events	**PR 115**					**PR 118**				
	D1	**D2**	**D3**	**D4**	**D5**	**D1**	**D2**	**D3**	**D4**	**D5**
	Growing-degree days (GDD) (oC day)									
Sowing-Transplanting	707	715	720	706	686	707	715	720	706	686
Transplanting–Max.Tillering	777	780	686	706	834	889	942	1013	1023	1030
Maximum Tillering-Booting	226	235	269	317	235	375	404	468	413	484

Booting-Panicle initiation	262	252	181	201	249	155	134	158	118	132
Panicle initiation-Heading	55	39	34	63	40	34	49	35	38	60
Heading-Grain filling	460	375	519	466	542	495	316	305	320	278
Grain filling–Physiol. maturity	138	196	219	176	97	239	230	159	175	103
Total	2625	2592	2628	2635	2683	2894	2790	2858	2793	2773
	Photo-thermal units (PTU) (oC day hour)									
Sowing-Transplanting	9581	9923	10163	10114	9986	9581	9923	10163	10114	9986
Transplanting–Max.Tillering	11747	9923	7500	10732	10572	14451	14255	12127	12874	12038
Maximum Tillering-Booting	3232	4332	3756	3099	2926	6484	5463	6148	5179	4756
Booting-Panicle initiation	3365	2690	2471	3224	3296	1711	1512	2003	1664	1899
Panicle initiation-Heading	527	828	521	488	677	771	483	510	604	405
Heading-Grain filling	7052	5958	6999	4391	4463	4720	5181	4693	3760	3478
Grain filling–Physiol. maturity	1203	2163	2830	2104	1564	2430	2168	2231	1958	1808
Total	36707	35817	34240	34152	33484	40148	38985	37875	36153	34370
	Helio-thermal units (HTU) (oC day hour)									
Sowing-Transplanting	6503	7120	6571	6398	5782	6503	7120	6571	6398	5782
Transplanting–Max.Tillering	6822	5471	4200	4596	4566	7951	7044	5819	5439	4845
Maximum Tillering-Booting	1198	1416	1310	1106	770	2122	1724	1980	2082	2352
Booting-Panicle initiation	1195	987	808	1334	1861	518	548	1030	902	1053

Panicle initiation-Heading	159	269	217	202	281	362	150	282	347	335
Heading-Grain filling	2960	2482	3771	3074	4290	2613	3452	3322	3173	2922
Grain filling–Physiol. maturity	635	1203	1843	1917	1075	2079	1835	1798	1387	1239
Total	19472	18948	18720	18627	18625	22148	21873	20802	19728	18528

3.2 Photothermal Units

The PTU accumulated by rice cultivars transplanted on different dates of transplanted are shown in Table 1. In the case of both cultivars, maximum PTUs were accumulated by D_1 date of transplanting. The accumulation of PTU decreased with the delay in date of transplanting. In case of both the cultivars, the maximum PTU was accumulated during transplanting to maximum tillering stage. The trend of PTU accumulated by both the cultivars under different dates of transplanting was in line with the trend observed in the grain yield. The values of both PTU and grain yield decreased with the delay in transplanting. The difference between maximum and minimum values of PTU in case of PR 115 and PR 118 was 3223 and 5778^{o}C day, respectively.

Table 2: Grain yield (q ha^{-1}) of rice cultivars under different dates of transplanting.

Varieties	**Dates**					
	D1	**D2**	**D3**	**D4**	**D5**	**Mean**
PR 115	60.8	55.9	50.1	45.4	42.2	50.9
PR 118	63.2	60.3	56.7	51.2	45.3	55.3
	62.0	58.1	53.4	48.3	43.8	53.1
LSD (0.05)	Dates of transplanting				5.69	
	Varieties				3.60	
	Interaction				NS	

3.3. Heliothermal Units

The HTU accumulated by rice cultivars transplanted on different dates of transplanted are shown in Table 1. Similar to PTU, the maximum HTUs were accumulated by D_1 date of transplanting in case of both the cultivars, similar results in rice were also reported by Hundal et al (2005). Among the different phenological stages maximum HTU were accumulated during transplanting to maximum tillering stage followed by heading to grain filling stage. Among the similar dates of transplanting the variety PR 118 accumulated more HTU as compared to PR 115. The trend of HTU accumulated by both the cultivars under different dates of transplanting was in line with the trend observed in the grain yield. The values of both HTU and grain yield decreased with the

delay in transplanting. In difference between maximum and minimum values of HTU in case of PR 115 and PR 118 was 847 and 3620^{o}C day, respectively.

3.4 Grain yield

The grain yield (Table 1) of cultivar PR 118 was significantly higher than the cultivar PR 115. The higher grain yield of PR 118 may be due to higher GDD, PTU and HTU by 7.18, 7.53 and 9.20%, respectively, as compared to PR 115. This means that the cultivar PR 118 is more efficient in utilizing heat and sunlight available for growth, development and yield.

Among the dates of transplanting, D_1 resulted in maximum grain yield, but it was statistically at par with the grain yield produced by D_2 and they differed significantly from other dates of transplanting. Optimum transplanting date for paddy around 20th June was also reported by Baloch et al (2006). D_2 was also statistically at par with D_3, D_3 was statistically at par with D_4 and D_4 was statistically at par with D_5. The reason for statistically similar grain yield among the two adjacent dates of transplanting may be due to almost similar values of PTU and HTU among the two adjacent dates of transplanting. These similar values of PTU and HTU among adjacent dates under respective cultivars may have resulted in similar growth and development of the crop leading to the statistically similar grain yield among the adjacent dates of transplanting.

4. Conclusion

The results of the present investigation revealed that among the cultivars, cv. PR 118 accumulated more heat units than cv. PR 115 due to which the grain yield of cv. PR 118 was higher than cv. PR 115. Among the dates of transplanting, early transplanted rice accumulated more heat units to attain physiological maturity as compared to late transplanted rice cultivars and hence yielded higher.

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