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Analyzing heat units for different varieties of aromatic rice under various growing environments in Raipur condition

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Abstract
Field experiment was carried out during *Kharif* season 2016 at Research and Instructional Farm of Indira Gandhi Agricultural University, Raipur (CG), India; to examine yield and heat unit requirements of three scented rice varieties as influenced by three different growing environments in factorial Randomized Block Design (RBD). Highest grain yield was recorded with Dubraj selection-1, as compared to Tarun selection-1 and Badshah bhog selection-1 on an average basis/overall basis under 27th June (D_1) growing environment. With respect to heat units the cumulative growing degree days was found highest for Dubraj selection-1(2447) and Tarun selection-1 (2447) followed by Badshah bhog selection-1(2427) under 27th June growing environments (D_1). Maximum growing degree days were observed in early sown crop D_1 growing environments (27th June) as compared to late sown crop under D_2 and D_3 growing environment (12th July and 27th July). Similar results were found in the case of accumulated photo thermal units and helio thermal units also. Radiation use efficiency and HUE in D_1 (27th June) growing environment might be due to better conversion of light in to dry matter, better yield component and harvest index in D_1 (27th June) growing environment as compared to 12th July (D_2) and 27th July (D_3) growing environments.

Keywords: Growing degree days, Photo thermal unit, heat use efficiency, Helio thermal unit, growing environments

Introduction
Rice (*Oryza sativa* L.) is the world's single most important food crop and a primary food source for more than a third of the world's population. More than 90% of the world's rice is grown and consumed in Asia. Central India is well known for its native wealth of rice genetic resources and among these the large number of indigenous short grained, scented varieties are cultivated in different parts of the M.P. and C.G. states.

Almost every state of India has its own varieties of aromatic rice, this area are identified from hundreds of years of experience of farmers. This is despite the fact that some of the non-Basmati scented rice is much superior to Basmati types. The production and productivity of any crop are mainly dependent upon its genetic makeup and environment. In Indira Gandhi Krishi vishwavidyalaya some suitable scented rice varieties have been refined and released for cultivation in the state. To examine the potential of scented rice, this experiment was planned and laid so as to understand phenological nature and basic traits.

Materials and Methods
The experiment was set at Research and Instructional Farm of Indira Gandhi Krishi Vishwavidyalaya, Raipur situated in Eastern Central part of Chhattisgarh at latitude of 21°.16' N, longitude 81°.36' E and altitude 289.5 m above mean sea level. The present experiment was conducted during the *kharif* season of 2016. Three rice varieties *viz*. Badshah bhog selection-1, Dubraj selection-1 and Tarun selection-1 were used and cultivated in a factorial Randomized Block Design (RBD) with three growing environments. The GDD, PTU, HTU, PAR and HUE were computed by using following formula:

Accumulated Growing Degree Days (GDD)
GDD = Σ [(Tx + Tn)/2 – Base temperature]
Where,
Tx = Daily maximum temperature
Tn = Daily minimum temperature
The base temperature which is considered 10°C for *Kharif* crops

Accumulated Photothermal Unit (PTU)
PTU is calculated by multiplying GDD with maximum possible sunshine hours (N)

PTU= GDD X N
Where,
N =maximum possible sunshine hours.

Accumulated Helio Thermal Unit (HTU)
HTU is calculated by multiplying GDD with actual sunshine hours (n).

HTU = GDD X n
Where,
n = actual sunshine hour.

Heat Use Efficiency (HUE)
Heat use efficiency (HUE) for total dry matter was obtained as under

$$HUE\ (g/m^2/^0\ day) = \frac{Biomass\ (g/m^2)}{GDD\ (^0days)}$$

Radiation Use Efficiency (RUE)
RUE (gMJ^{-1}) = Biomass (g/m^2) / IPAR ($M\ J/m^2/day$)
Where,
IPAR is cumulative intercepted photo synthetically active radiation.

Results and Discussion
Grain yield (kg/ha)
Grain yield as influenced by different growing environments are given in table 1. Growing environments and varieties showed significant variation on grain yield. On the mean basis the highest grain yield of 19.97 qha^{-1} was recorded in variety Dubraj selection-1(V_2) followed by Tarun selection-1 (V_3) of 18.27 qha^{-1} and Badshahbhog selection- 1 (V_1) 16.20 qha^{-1}. On an average the first growing environment shows maximum yield of 19.18 qha^{-1} followed by second growing environment and then third growing environments. It is clear from figure that Dubraj selection-1 (V_2) is the highest yielding variety 19.97 qha^{-1} in the region followed by Tarun selection-1. However, these varieties were found to be statistically at par and grain yield of Dubraj selection-1 is significantly higher than Badshahbhog selection-1.

Table 1: Grain yield in scented rice varieties as affected by different growing environments

	D_1 (27th June)	**D_2(12th July)**	**D_3 (27th July)**	**MEAN**
(V_1)Badshahbhog selection- 1	16.37	16.81	15.42	**16.20**
(V_2) Dubraj selection- 1	19.91	21.09	18.89	**19.97**
(V_3) Tarun selection- 1	21.25	17.09	16.48	**18.27**
MEAN	19.18	18.33	16.93	**18.15**
	Growing environments	Varieties	Intraction	
SEm	0.77	0.77	1.34	
CD	NS	2.32*	NS	

Phenology and heat units
The heat units acquired by different scented varieties during growth stages are shown in table 2. The higher GDD was accumulated in the first growing environment during all the growth stages starting from planting to maturity. Among the different varieties the higher GDD was accumulated in Dubraj selection-1 and Tarun selection-1 (2447) whereas, the least GDD accumulated in Badshah bhog selection-1(2427). From the table, it was also observed that the highest Photo thermal Unit during maturity was recorded in 27th June (D_1) compared to D_2 and D_3. Among the varieties the higher PTU was observed in variety Dubraj selection-1 and Tarun selection-1, while the least PTU is observed in variety Badshah bhog selection-1. Similarly The maximum helio thermal units was recorded under 27th June growing environments in all the three scented rice varieties viz. Dubraj selection-1, Tarun selection-1 and Badshah bhog selection-1 (11658, 11658 and 11476 respectively).
Heat use efficiency was higher in D_2 (12th July) growing environment (4.85g/m2/0day) at 75 DAT. Among varieties significantly higher HUE was found in variety Tarun selection-1 (4.77 $g/m^2/^0day$) followed by Dubraj selection-1 (4.75 $g/m^2/^0day$). The Heat Use Efficiency found increasing along with advancing age and reached maximum at 75 DAT and after that decreased from 90 DAT. Radiation use efficiency was recorded highest in Tarun selection-1 (13.48 gMJ-1) followed by Dubraj selection-1 (13.47 gMJ-1) and Badshah bhog selection-1(12.59 gMJ-1) at 75 DAT.

Table 3: Phenology of different scented rice varieties in Raipur condition

Growing environments	**Seedling**	**Tillering**	**PI**	**Booting**	**PE**	**50% Flowering**	**Milking**	**Dough**	**Maturity**
V I Badshahbhog selection- 1									
(D_1) 27th June	18	33	87	99	107	110	118	128	143
(D_2) 12th July	18	32	79	90	98	101	108	119	132
(D_3) 27thJuly	18	33	71	80	85	94	100	109	121
V II Dubraj selection -1									
(D_1) 27th June	18	33	91	103	111	115	123	132	145
(D_2 12th July	18	34	81	92	101	104	111	122	133
(D_3) 27thJuly	18	33	74	83	87	97	103	112	124
V III Tarun selection- 1									
(D_1) 27th June	18	34	92	104	111	116	124	132	145
(D_2) 12th July	18	34	82	93	102	105	111	122	133

Table 4: Accumulated Growing Degree days (GDD)

V I Badshah bhog selection-1									
D_1 – 27th June	327	599	1555	1764	1906	1958	2079	2229	2427
D_2 – 12th July	324	557	1403	1596	1729	1774	1878	2043	2192
D_3 – 27th July	307	572	1256	1414	1491	1624	1715	1832	1967
V II Dubraj selection-1									
D_1 – 27th June	327	599	1629	1837	1974	2035	2154	2290	2447
D_2 – 12th July	324	593	1438	1631	1774	1818	1924	2078	2203
D_3 – 27th July	307	572	1310	1461	1521	1671	1762	1871	2003
V III Tarun selection-1									
D_1 – 27th June	327	618	1646	1854	1974	2050	2168	2290	2447
D_2 – 12th July	324	593	1454	1648	1789	1834	1924	2078	2203
D_3 – 27th July	307	572	1328	1461	1535	1685	1762	1871	1991

Table 5: Accumulated Photo Thermal Units (PTU)

V I Badshahbhog selection-1									
D_1 - 27 June	4316	7821	19686	22133	23789	24394	25779	27456	29668
D_2 - 12 July	4185	7168	17495	19751	21309	21812	22975	24821	26477
D_3 - 27 July	3926	7220	15439	17281	18170	19660	20677	21986	23476
V II Dubraj selection-1									
D_1 - 27 June	4316	7821	20546	22986	24583	25283	26611	28141	29891
D_2 - 12 July	4185	7636	17898	20154	21812	22305	23491	25219	26599
D_3 - 27 July	3926	7220	16066	17832	18502	20186	21204	22421	23870
V III Tarun selection-1									
D_1 - 27 June	4316	8060	20745	23179	24583	25448	26773	28141	29891
D_2 - 12 July	4185	7636	18091	20362	21979	22478	23491	25219	26599
D_3 - 27 July	3926	7220	16274	17832	18666	20344	21204	22421	23737

Table 6: Accumulated Helio Thermal Units (HTU)

Growing environments	Seedling	Tillerin-g	PI	Booting	P E	50% flowering	Milking	Dough	Maturity
V I Badshah bhog selection -1									
D_1 – 27thJune	1097	2100	5435	6355	6901	7349	8560	9877	11476
D_2 – 12th July	1041	1548	4970	5659	6753	7212	8198	9547	10772
D_3 – 27th July	904	1837	4697	5574	6346	7628	8342	9331	10425
V II Dubraj selection-1									
D_1 – 27thJune	1097	2100	5909	6675	7488	8120	9256	10388	11658
D_2 – 12th July	1041	1642	5056	5842	7212	7641	8578	9877	10868
D_3 – 27thJuly	904	1837	4901	6037	6642	7987	8719	9627	10747
V III Tarun selection-1									
D_1 – 27thJune	1097	2218	5961	6675	7488	8270	9402	10388	11658
D_2 – 12th July	1041	1642	5114	5988	7358	7784	8578	9877	10868
D_3 – 27th July	904	1837	4943	6037	6786	8103	8719	9627	10639

Table 7: Heat Use Efficiency ($g/m^2/{}^0day$) at different stages

Growing environments	**15 DAT**	**30 DAT**	**45 DAT**	**60 DAT**	**75 DAT**	**90 DAT**	**At harvest**
D_1 – 27th June	0.19	0.75	2.10	3.27	4.84	4.27	3.70
D_2 – 12th July	0.21	0.94	2.75	3.51	4.85	4.11	3.60
D_3 – 27th July	0.36	1.40	2.07	3.15	4.04	3.62	3.17
SEm ±	0.040	0.073	0.109	0.089	0.142	0.131	0.115
CD (p=0.05)	0.119*	0.218 **	0.326**	0.267 *	0.427**	0.393**	0.345*
Varieties							
VI Badshah bhog selection -1	0.241	0.953	2.236	3.153	4.368	3.806	3.323
V II Dubraj selection -1	0.268	1.173	2.412	3.416	4.675	4.098	3.575
V III Tarun selection -1	0.245	0.968	2.269	3.370	4.677	4.102	3.584
SEm ±	0.040	0.073	0.109	0.089	0.142	0.131	0.115
CD (p=0.05)	(NS)	(NS)	(NS)	(NS)	(NS)	(NS)	(NS)

Table 8: Radiation Use Efficiency (g/MJ^{-1}) at different stages

Treatments							
Growing environments	**15 DAT**	**30 DAT**	**45 DAT**	**60 DAT**	**75 DAT**	**90 DAT**	**At harvest**
D_1 – 27th June	0.55	2.21	6.1	9.63	14.16	12.22	10.7
D_2 – 12th July	0.65	2.77	8.17	10.37	13.88	11.91	9.54
D_3 – 27th July	0.97	4.04	5.98	8.82	11.5	9.32	7.69
SEm ±	0.116	0.212	0.319	0.261	0.412	0.362	0.311
CD (p=0.05)	0.347*	0.634**	0.956**	0.782 **	1.235 **	1.085 **	0.932 **
Varieties							
V_1 Badshah bhog selection-1	0.699	2.791	6.55	9.142	12.585	10.599	8.837

V_2 Dubraj selection -1	0.773	3.412	7.057	9.904	13.473	11.419	9.528
V_3 Tarun selection-1	0.700	2.812	6.641	9.773	13.483	11.435	9.563
SEm ±	0.116	0.212	0.319	0.261	0.412	0.362	0.311
CD (p=0.05)	(NS)	(NS)	(NS)	(NS)	(NS)	(NS)	(NS)

Yield attributes

The data on yield attributes are shown in table 9. It was observed from the table that the growth characters like plant height, test weight, number of effective tillers per m^2, grain yield, harvest index were recorded maximum under growing environments on 27th June (D_1), while crop growth rate, sterility percentage are maximum in growing environments on 27th July (D_3). Relative growth rates, filled grain per panicle, length of panicle, are highest under 12th July (D_2) growing environments. Among the different varieties, plant height, test weight, grain yield, harvest index were recorded maximum in Dubraj selection-1 as compared to other varieties. The number of effective tillers per m^2 and number of filled grain per panicle were recorded maximum in Tarun selection-1 while length of panicle and sterility percentage is maximum in Badshah bhog selection-1.

Table 9: Yield attributes of different rice varieties as influenced by different growing environments

Treatment	Plant height (cm)	Numbers effective tillers/m2	length of panicle (cm)	Number of filled grains/ panicle	Sterility (%)	Test weight (kg/ha)	grain yield (q/ha)	Straw yield (q/ha)	Harvest index
Growing environments									
D_1 – 27th June	163.5	246.41	23.4	192.1	7.73	15.23	19.18	29.21	39.55
D_2 – 12th July	154.7	232.26	23.6	207.4	9.55	14.8	18.33	28.03	39.51
D_3 – 27th July	136	224.37	23.4	198.4	11.07	15.18	16.93	27.89	37.76
SEm ±	2.67	6.128	0.37	9.1	1.27	0.372	0.77	0.76	1.549
CD (p=0.05)	8.0**	(NS)	(NS)	(NS)	(NS)	(NS)	NS	NS	NS
Varieties									
(V_1)Badshahbhog sel.-1	148.6	232.63	27.2	202.2	10.53	14.69	16.2	29.96	35.08
(V_2) Dubraj selection -1	155.1	234.93	21.6	184.1	10.13	17.14	19.97	27.24	42.31
(V_3)Tarun selection -1	150.4	235.48	21.7	211.7	7.69	13.38	18.27	27.92	39.42
SEm ±	2.67	6.12	0.37	9.1	1.27	0.37	0.77	0.76	1.549
CD (p=0.05)	NS	(NS)	1.11**	(NS)	(NS)	1.12**	2.32*	NS	4.64*

Conclusion

Based on the above findings, it was concluded that higher grain yield and straw yield along with the heat units *viz*. accumulated growing degree days, photo thermal unit, helio thermal unit, radiation use efficiency and heat use efficiency were recorded maximum in crop sown in first growing environment on 27th June as compared to crop sown on 12th July and 27th July growing environments.

On the other hand, it can be concluded that first growing environment is found favorable than 2nd and 3rd growing environments for higher grain yield. With respect to varieties Dubraj selection-1 recorded maximum grain yield and straw yield along with heat units *viz*. growing degree day, photo thermal and helio thermal units whereas, radiation use efficiency and heat use efficiency were maximum in Tarun selection-1.

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