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Crop weather relation in *kharif* rice for Chhattisgarh plains

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Abstract
Studies on crop weather relationship in rice were carried out *kharif* 2016 at Indira Gandhi Krishi Vishwavidyalaya, Raipur Chhattisgarh. Three rice varieties *viz*. Swarna, Mahamaya and MTU-1010 were grown under irrigated conditions with three dates of sowing *viz*. and D_1(01June2016), D_2 (15June2016) and D_3 (30 June2016). The cumulative growing degree days at maturity stage were highest (2724) for Swarna fertilized @ 100:60:40 kg $NPK^{-1}$and Swarna fertilized @ 60:40:40kg NPK^{-1}under 01st June sowing. Maximum growing degree days were observed in early sown crop 1st June as compared to late sown crop 15th June and 30th June. At maturity stage, the maximum helio thermal unit of 13247, 13247, 11122 and 10366 was recorded for varieties Swarna fertilized @ 100:60:40 kg NPK^{-1}, Swarna 60:40:40, Mahamaya and MTU-1010 respectively sown on 01st June was recorded. The maximum photo thermal unit of 34283, 34283, 31556 and 28914 was recorded for four varieties viz. Swarna fertilized @ 100:60:40 kg $NPK^{-1}$and Swarna fertilized @ 60:40:40kg NPK^{-1}, Mahamaya and MTU-1010 sown on 01st June respectively. The highest radiation use efficiency was recorded at maturity stage with MTU-1010 (1.52gMJ^{-1}) where as the heat use efficiency was higher in D_2 (15stJune) sowing (0.58g/$m^{2/0}$day). The highest HUE was found in variety Swarna fertilized @ 60:40:40kg NPK^{-1} (0.58g/$m^{2/0}$day).

Keywords: GDD, HTU, PTU, RUE, HUE rice crop, Chhattisgarh state, sowing dates

Introduction
Rice (*Oryza sativa* L.) is one of the most important food crops of the world, representing the staple food for more than half of the world population (Confalonieri and Bocchi, 2005). Rice belong to family Poaceae originated from South East Asia, where more than 90 percent of world's rice is produced and consumed (Li and Xu, 2007) [4]. Two countries, China and India, growing more than half of the world total rice production. Out of 24 species of rice only two species *Oryza glaberima* and *Oryza sativa* are cultivated. India is the second largest producer of rice after China having an area of 43.83 million hectare with the production of 104.80 million tonnes (Anonymous, 2014-15). To generate required crop management data, a field experiment was conducted at college of agriculture IGKV, Raipur (21°16'N Latitude, 81° 36'E Longitude and an altitude of 289.5 m above mean sea level) Chhattisgarh, India, during *kharif* season of the year 2016. The treatment consisted of three cultivars viz. V_1 (Swarna), V_2 (Mahamaya) & V_3 (MTU-1010) with three dates of sowing D_1 (01 June2016), D_2 (15 June2016) & D_3 (30 June2016). Rice crop needs a hot and humid climate. It is best suited to regions which have high humidity, prolonged and bright sunshine and an assured supply of water. The average temperature required throughout the life period of the crop ranges from 21º to 37 ºC. At the time of tillering, the crop requires a high temperature for growth. The temperature requirement for blooming is in the range of 26.5 ºC to 29.5 ºC while at the time of ripening the temperature should be in between 20-25 ^{0}C.

Materials and methods
Chhattisgarh state, Raipur district situated in Eastern India is located 21°16'N Latitude, 81° 36'E Longitude and an altitude of 289.5 m above mean sea level, during *kharif* season of the year 2016. Daily weather data of the study area used in study were collected from the Department of Agricultural Meteorology, Indira Gandhi Krishi Vishwavidyalaya Raipur (Chhatisgarh).

1. Growing Degree Days
Growing degree days (GDD) concept assumes that there is a direct and linear relationship between growth and developments of plants and temperature and the growth is dependent on the total amount of heat units to which it is subjected during its life time. The growing degree days was computed by using following formula:

GDD = Σ [(Tx + Tn)/2 – Base temperature]
Where,
Tx = Daily maximum temperature
Tn = Daily minimum temperature
The base temperature is defined as, "The temperature below which no plant physiological activity takes place" which is considered 10 ºC for *Kharif* crops following Alocilja and Ritchie (1991) [1].

2. Photo Thermal Unit (PTU)
PTU is calculated by multiplying GDD with maximum possible sunshine hours (N).
PTU= GDD X N
Where,
N =maximum possible sunshine hours.

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

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

4. Heat Use Efficiency (HUE)
Heat use efficiency (HUE) for total dry matter was obtained with help of following formula.
HUE (g/m^2 / 0 day) = Biomass ($g\ m^{-2}$) / GDD (^{0}days)

5. Radiation Use Efficiency (RUE)
RUE (gMJ^{-1}) = Biomass ($g\ m^{-2}$) / IPAR ($M\ J\ m^{-2}\ day^{-1}$)
Where,
IPAR is cumulative intercepted photo synthetically active radiation.
The photo synthetic active radiation can be calculated by using the following formula
PAR = Rs X 0.5
Where,
Rs = incoming solar radiation (MJm^{-2})
The incoming solar radiation can be calculated by the formula
Rs = Rs0 (a + b * n/N)
Where,
Rs0 = Extra-terrestrial radiation (MJm^{-2})
n = Bright sunshine hours
N = Possible sunshine hours
a = 0.18, b = 0.5

Results and Discussion
The accumulated GDD (Table 1) required for reaching different phenophases, it was observed that similar pattern like that of phenophase durations was noticed at all phenophases. The accumulated GDD for different varieties varied considerably from sowing to maturity. The cumulative GDD at maturity stage were highest (2724.9) for Swarna fertilized @ 100:60:40 kg NPK $ha^{-1}$and Swarna fertilized @ 60:40:40 kg NPK ha^{-1} followed by Mahamaya (2487.4) and MTU-1010 (2261.6) under D_1 (01st June) sowing as compared to late sown crop D_2 (15th June) and D_3 (30th June.) sowing. In general the accumulated growing degree day values decreased with delayed sowing due to early maturity of crops because of high value of temperature at maturity. These results are in general agreement with the findings of Sreenivas *et al.* (2010) [5] and Chopra and Chopra (2004) [3].
The observed value of accumulated Helio Thermal Units (HTU) at maturity stages of different varieties of rice under various growing environments is given in the Table 2. The cumulative HTU at maturity stage were highest (13247) for Swarna fertilized @ 100:60:40 kg NPK $ha^{-1}$and Swarna fertilized @ 60:40:40 kg NPK ha^{-1} followed by Mahamaya (11122) and MTU-1010 (10366) under D_1 (01st June) sowing as compared to late sown crop D_2 (15th June) and D_3 (30th June.) sowing.
The accumulated Photo Thermal Unit (PTU) computed for different rice varieties under different dates of sowing from sowing to maturity phase are shown in Table 3. Highest accumulated PTU was observed under D_1 sowing in all the varieties followed by D_2 sowing and D_3 sowing. Among variety Swarna fertilized @ 100:60:40 kg NPK ha^{-1} and 60:40:40 kg NPK ha^{-1} observed the highest PTU at maturity stage with D_1 sowing (34283) followed by D_2 sowing (31246) and D_3 sowing (29113). In variety Mahamaya the maximum accumulated photo thermal units was found with D_1 sowing (31556) followed by D_2 sowing (28904) and D_3 sowing (26860). In case of variety similarly the highest PTU value was observed by MTU-1010 under D_1 sowing (28914) followed by D_2 sowing (26442) and D_3 sowing (24851).
Highest value of RUE were recorded at maturity phase are shown in Table 4. MTU-1010 ($1.52gMJ^{-1}$) followed by Swarna fertilized @ 60:40:40 kg NPK ha^{-1} ($1.48gMJ^{-1}$), Swarna fertilized @ 100:60:40 kg NPK ha^{-1} ($1.40gMJ^{-1}$) and Mahamaya ($1.48gMJ^{-1}$). Similarly dates of sowing found highest RUE recorded under D_2 (15thJune) sowing ($1.54gMJ^{-1}$). Similarly HUE was higher phase are shown in Table 5 in D_2 (15stJune) sowing ($0.58g/m^2/^0$day). Among varieties higher HUE was found in variety Swarna fertilized @ 60:40:40 kg NPK ha^{-1} ($0.58g/m^2/^0$day) followed by Swarna fertilized @ 100:60:40 kg NPK ha^{-1}MTU-1010 both ($0.55g/m^2/^0$day) and Mahamaya ($0.50g/m^2/^0$day).

Table 1: Accumulated growing degree days (GDD) at different growth stages of rice varieties under different growing environments

Sowing dates	seedling	Tillering	Panicle initiation	booting	Panicle emergence	50% flowering	milking	dough	maturity
V_1 SWARNA fertilized @ 100:60:40 kg NPK ha^{-1}									
D_1 - 01 June	696	1307	1990	2060	2171	2245	2380	2556	2725
D_2 - 15 June	588	1149	1724	1780	2009	2099	2202	2341	2520
D_3 - 30 June	540	1038	1619	1722	1829	1881	2050	2170	2367
V_2 SWARNA fertilized @ 60:40:40 kg NPK ha^{-1}									
D_1 - 01 June	696	1307	1990	2060	2172	2245	2380	2556	2725
D_2 - 15 June	588	1149	1724	1780	2009	2099	2202	2341	2520
D_3 - 30 June	540	1038	1619	1722	1829	1881	2050	2170	2367
V_3 Mahamaya									
D_1 - 01 June	696	1084	1485	1600	1811	1901	2097	2208	2487
D_2 - 15 June	588	987	1322	1437	1618	1724	1924	2185	2311
D_3 - 30 June	540	861	1243	1349	1515	1586	1778	2005	2170
V_4 MTU-1010									
D_1 - 01 June	696	1014	1431	1549	1731	1791	1901	2078	2262
D_2 - 15 June	588	861	1265	1322	1511	1583	1724	1907	2099
D_3 - 30 June	540	713	1172	1279	1385	1441	1570	1795	1990

Table 2: Accumulated HTU at different growth stages of rice varieties under different growing environments

Sowing dates	seedling	Tillering	Panicle initiation	booting	Panicle emergence	50% flowering	milking	dough	maturity
V_1 SWARNA fertilized @ 100:60:40 kg NPK ha^{-1}									
D_1 - 01 June	5006	6881	8913	9121	9840	10313	10760	11581	13247
D_2 - 15 June	3426	4974	6902	7083	8396	8722	9085	10336	12003
D_3 - 30 June	2269	3743	6193	6881	7145	7404	8461	9672	11578
V_2 Swarna fertilized @ 60:40:40 kg NPK ha^{-1}									
D_1 - 01 June	5006	6881	8913	9121	9840	10313	10760	11581	13247
D_2 - 15 June	3426	4974	6902	7083	8396	8722	9085	10336	12003
D_3 - 30 June	2269	3743	6193	6881	7145	7404	8461	9672	11578
V_3 Mahamaya									
D_1 - 01 June	5006	5735	7105	7500	8676	8780	9403	10096	11122
D_2 - 15 June	3426	4815	5462	5847	6742	6902	8059	9042	10016
D_3 - 30 June	2269	3468	4802	5319	5522	5971	7001	8019	9672
V_4 Mtu-1010									
D_1 - 01 June	5006	5692	7011	7175	8016	8602	8780	9284	10366
D_2 - 15 June	3426	4046	5138	5462	6565	6714	6902	7946	8722
D_3 - 30 June	2269	3190	4353	5170	5348	5438	5852	7041	7873

Table 3: Accumulated photo thermal units (PTU) at different growth stages of rice varieties under different growing environments

Sowing dates	seedling	Tillering	Panicle initiation	booting	Panicle emergence	50% flowering	milking	dough	maturity
V_1 Swarna fertilized @ 100:60:40 kg NPK ha^{-1}									
D_1 - 01 June	9224	17169	25683	26544	27855	28715	30302	32361	34283
D_2 - 15 June	7772	14965	22058	22708	25391	26442	27648	29235	31246
D_3 - 30 June	7076	13391	20478	21667	22912	23522	25512	26860	29113
V_2 Swarna fertilized @ 60:40:40 kg NPK ha^{-1}									
D_1 - 01 June	9224	17169	25683	26544	27855	28715	30302	32361	34283
D_2 - 15 June	7772	14965	22058	22708	25391	26442	27648	29235	31246
D_3 - 30 June	7076	13391	20478	21667	22912	23522	25512	26860	29113
V_3 Mahamaya									
D_1 - 01 June	9224	14319	19441	2886	23476	24583	26991	28292	31556
D_2 - 15 June	7772	12889	17114	18523	20753	22058	24403	27454	28904
D_3 - 30 June	7076	11242	15926	17246	19195	20068	22284	25016	26860
V_4 Mtu-1010									
D_1 - 01 June	9224	13418	18754	20259	22502	23236	24583	26771	28914
D_2 - 15 June	7772	11277	16410	17114	19435	20317	22058	24201	26442
D_3 - 30 June	7076	9361	15039	16369	17668	18334	19855	22507	24851

Table 4: Heat use efficiency ($g/m^2/^o$day) of rice varieties as influenced by different growing environments at maturity stage

Varieties	D1	D2	D3	Mean
Swarna fertilized @ 100:60:40 kg NPK ha^{-1}	0.65	0.44	0.55	0.55
Swarna fertilized @ 60:40:40 kg NPK ha^{-1}	0.62	0.54	0.57	0.58
Mahamaya	0.39	0.62	0.49	0.50
MTU1010	0.42	0.70	0.52	0.55
Mean	0.52	0.58	0.53	0.54

Table 6: Radiation use efficiency ($g/m^2/Mj$) of rice varieties as influenced by different growing environments at maturity stage

Varieties	D1	D2	D3	Mean
Swarna fertilized @ 100:60:40 kg NPK ha^{-1}	1.73	1.12	1.35	1.40
Swarna fertilized @ 60:40:40 kg NPK ha^{-1}	1.63	1.38	1.42	1.48
Mahamaya	1.08	1.67	1.29	1.35
MTU1010	1.15	1.97	1.44	1.52
Mean	1.40	1.54	1.38	1.44

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