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Agro-meteorological indices and heat units of rice varieties under different dates of planting in east and south eastern coastal plain zone of Odisha

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Abstract
The experiment revealed that the rice transplanted earliest on 21 July took longer duration to achieve a particular phenological stage from sowing to maturity as compared to other dates of planting. The grain yield (4225 kg/ha), straw yield (4904 kg/ha) and harvest index (46.06%) , leaf area index (4.22) were recorded maximum in 5 August planting which were significantly at par with 21 July planting. Growing degree days and Photothermal units, were higher in 21 July planting but the Heliothermal units recorded highest in 5 August planting. The result of growth characters revealed that the total dry matter production, number of effective tillers/m², crop growth rate, leaf area index, grain yield, straw yield and harvest index were recorded maximum in variety Swarna which was significantly at par with the variety Hasanta. Swarna with grain yield of 4507.5 kg/ha was at par with Hasanta (4402.5 kg/ha) due to their long duration growth period and better RUE. The highest growing degree days ranged from 2357.8 to 2756.4 degree days in Hasanta variety. The Heliothermal units ranged from 11814.7 to 13214 degree day's hours and Photothermal units ranged from 26960.8 to 33210.1degree days hours in Hasanta variety followed by Swarna. The Heliothermal units ranged from 11814.7 to 13214 degree day's hours and Photothermal units ranged from 26960.8 to 33210.1 degree days hours in Hasanta variety followed by Swarna.

Keywords: Agro-meteorological indices, growing degree days, heliothermal units, photo thermal units

Introduction
Though, India has the largest area under rice cultivation yet the yield is much lower than the world average (FAOSTAT). The reason is due to lack of potential varieties, management practices and the climatic factors. The yield can be increased by using improved cultural practices like altering the transplanting dates, selection of promising varieties, efficient use of water and fertilisers etc. Weather parameters like sunshine hours, rainfall, evaporation, wind speed and temperature are important natural resources that affect the rice productivity to a great extent. However, temperature had the greatest effect on the rice crop. The high temperatures affect the plant growth and reduce the rice yield significantly (Satake, T. and Yoshida, S., 1978) [10]. Lower temperature from panicle initiation to flowering leads to formation of more number of grains per plants, mainly due to prolonged duration of the period. For many grain crops, active leaves present at flowering are associated with the production of photosynthates for grain formation. Production of dry matter per unit leaf area is highly affected by the temperature. Heat unit concept states that higher the daily temperature, shorter the crop duration and lower the temperature, longer is the crop duration. Growing Degree Days are used to assess the suitability of a region and estimating the heat stress accumulation on crop, predicting the physiological maturity and harvesting dates. Looking into the importance of temperature and solar radiation, the present experiment has been conducted to study the effect of sowing dates on phenology and yield of rice varieties under different planting dates.

Materials and Methods
The field experiment was conducted during the kharif season of 2019 at the Research and Instructional farm of OUAT, College of Agriculture, Bhubaneswar, Odisha situated at 20.15 ^{0}N latitude and 85.52 ^{0}E longitude and at an altitude of 25.9 m above the mean sea level. It comes under the East and South-East coastal plain zones of Odisha.

The climate is hot and humid with the normal maximum and minimum temperature being 32.4 °C and 25 °C respectively. The experiment was laid out in a split plot design with four planting dates *viz*. 21 July, 5 August, 20 August and 4 September in main plots and four rice varieties *viz*. Mandakini, Bina-11, Swarna and Hasanta in sub-plots with three replications. Leaf area was measured using Liver 320 Leaf area meter. Leaf area index was calculated by the formulae i.e. total leaf area to total ground area.

$$LAI = \frac{\text{Total leaf area } (cm^2)}{\text{Ground area } (cm^2)}$$

Harvest index
The harvest index was calculated using the formula –

$$HI\ (\%) = \frac{\text{Grain yield}}{\text{Grain yield + Straw yield}} \times 100$$

Heat units
The Growing Degree Days (GDD) was calculated by the formulae

$$GDD = \frac{\sum[T_{max} + T_{min}]}{2} - Tbase$$

Where
T_{max} = Daily maximum temperature
T_{min} = Daily minimum temperature
T_{Base} = Base temperature

N.B: The base temperature is defined as, "The temperature below which no plant physiological activity takes place." It is 10 °C for kharif rice.
Photothermal unit **(**PTU) was calculated by multiplying GDD with day length.
Heliothermal unit was calculated by multiplying GDD with bright sunshine hours.

Statistical analysis
All the data were tabulated and analysed statistically as per the procedure suggested by Panse and Sukhatme (1967) [11] and Chandel (1984) [12]. The F test was used for judging the significance of the treatments mean at 5% level. Whenever F test showed significant difference the difference between treatments means were further tested by using critical difference (CD) value. To compare different mean value of treatments, critical difference (CD) values were calculated as follows.

$$SEm\pm = \frac{\sqrt{Ems}}{n}$$

Where, SEm± = Standard error of mean
EMS = Error mean square
n = Number of observations on which the mean values is based.
CD (5%) = SE m × √2 × t (at 5% for error difference).

Result and Discussion

Crop weather
In this course of investigation of rice varieties under different dates of planting, the average maximum temperature prevailed was 30.9 °C with a maximum temperature of 37 °C and average minimum temperature of 22.5 °C with a maximum temperature of 27.8 °C from 25 June 2019 to 14 January 2019. During this period, the average temperature persisted was 26.7 °C and average bright sunshine hours was found to be 4.88 hours.

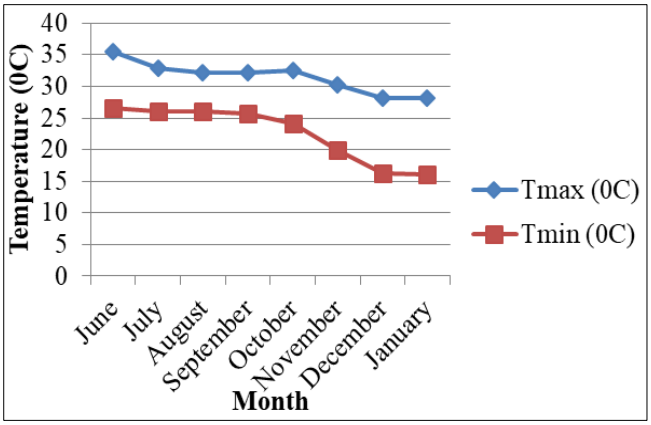

Fig 1: Monthly maximum and minimum temperature (June 2019 to January 2020)

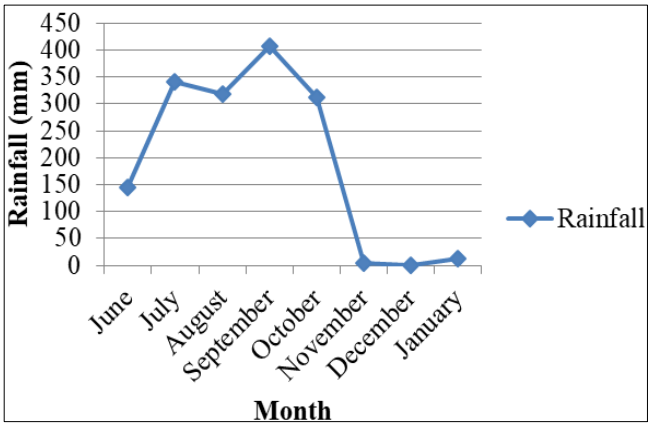

Fig 2: Monthly rainfall (June 2019 to January 2020)

Phenological stages
Rice crop planted on 21 July took more calendar days to mature while in 5 August and 20 August, it took less days (table-1). Satish *et al* (2017) [13] revealed that early transplanted crop took more number of days to mature. Among the varieties, Hasanta being a long duration variety, took maximum number of days (144-150 days) to mature i.e. 2-4 days more than Swarna (also a long duration variety; 142-148 days). Mandakini being a short duration variety, matured at 109 days in 21 July while it took 104 days when transplanted on 4 September. Two rice cultivars showed a significant difference in number of days to attain different phenological stages may be due to differential genetic makeup of varieties, Bhat *et al* (2015) [1] . This result also agreed with the findings of Bashir *et al* (2010) [14] who revealed that with delayed planting, the crop growth period shortened.

Table 1: Effect of different dates of planting and varieties on phenology of rice (days from seeding)

Varieties	Transplanting	Tillering	Panicle initiation	Panicle emergence	50% Flowering	Physiological Maturity
21 JULY						
Mandakini	21	26	52	82	86	109
Bina-11	21	27	71	101	107	130
Swarna	21	28	88	117	124	148
Hasanta	21	28	89	118	125	150
5 August						
Mandakini	21	27	50	80	84	107
Bina-11	21	27	70	99	105	129
Swarna	21	28	85	114	121	146
Hasanta	21	28	88	117	124	149
20 August						
Mandakini	21	27	50	79	84	107
Bina-11	21	28	68	99	105	128
Swarna	21	28	84	112	119	144
Hasanta	21	28	88	116	123	148
4 September						
Mandakini	21	27	47	77	82	104
Bina-11	21	28	64	94	100	124
Swarna	21	28	82	110	117	142
Hasanta	21	28	84	112	119	144

Yield and Harvest Index

The rice crop planted on 5 August recorded the highest grain yield of 4225 kg/ha as the number of tillers/m^2 was higher due to favourable and optimum environmental condition persisted for better growth and development, Mukesh *et al.* (2013) [6]. But, delayed planting could not accumulate sufficient time to complete the vegetative phases, Singh *et al.* (2018) [8]. Similarly, the highest yield was observed in Swarna followed by Hasanta, being long duration varieties, they accumulated more dry matters during their developmental stages. The highest harvest index (46.06%) was observed when the crop was planted on 5 August in the variety Swarna followed by Hasanta.

Table 2: Yield attributes of different rice varieties under different dates of planting

Dates of transplanting	Plant height (cm) at physiological maturity	Number of tillers/m^2 at physiological maturity	Leaf area index at physiological maturity	Ear bearing tillers per m^2	Total grains per panicle	Fertility %	Test weight (g)
21 July	114.1	291.8	0.76	282.5	113.1	80	23.2
5 August	114.9	294.0	0.78	288.4	114.2	80.5	23.3
20 August	110.6	278.2	0.67	270.4	105.9	78.8	21.3
4 September	110.1	228.1	0.64	218.9	104.4	78.1	21.1
SEm±	0.6	3.56	0.018	3.7	0.3	0.07	0.04
CD (p=0.05)	1.9	10.8	0.054	11.1	1.3	0.24	0.12
Varieties							
Mandakini	125.6	207.7	0.32	197.9	103.6	78.5	22.9
Bina-11	102.2	240.9	0.50	231.5	106.9	79.1	22
Swarna	101.5	323.1	1.0	316.9	114.8	79.9	21.5
Hasanta	120.5	320.6	0.71	313.7	112.2	79.8	23.1
SEm±	0.7	3.57	0.02	3.7	0.3	0.05	0.04
CD (p=0.05)	2.1	10.42	0.06	10.7	0.9	0.13	0.13

Table-3: Yield and Harvest Index (HI) of different rice varieties under different dates of planting

Dates of transplanting	Grain yield (kg/ha)	Straw yield (kg/ha)	Harvest Index (%)
21 July	4155	4844	45.94
5 August	4225	4904	46.06
20 August	3800	4704	44.62
4 September	3217	4619	41.25
SEm±	48.06	37.57	0.34
CD (p=0.05)	148.24	112.92	1.03
Varieties			
Mandakini	2880	4283	40.45
Bina-11	3607.5	4769	43.27
Swarna	4507.5	5036	47.24
Hasanta	4402.5	4985	46.92
SEm±	46.23	39.77	0.34
CD (p=0.05)	134.94	116.08	0.99

Heat Units

Accumulated Growing Degree Days (AGDD)

The highest growing degree days were accumulated in 21 July planting and it gradually decreased with the subsequent planting. Such variation in growing degree day's requirement for attainment of different phenophases in rice crop was mostly due

To the different duration to attain the physiological stages. This finding confirms the earlier findings of Anju *et al*., 2018 and Medhi *et al*., 2019 [5]. Rice variety Hasanta accumulated highest GDD value to attain the physiological maturity stage followed by Swarna due to the different duration took by the varieties to attain the physiological maturity stage. Similar varietal differences in accumulated growing degree days were also reported by Sreenivas *et al*., 2010 [9].

Accumulated Heliothermal units (AHTU)

The variation in temperature and the actual sunshine hours prevailed throughout the crop growth period from August to October and declined thereafter resulted in varied HTU. Similar results were found by Praveen *et al*., 2014 [7]. Among the varieties, Hasanta accumulated maximum HTU followed by Swarna because of the long duration variety than Mandakini and Bina-11.

Accumulated Photothermal units (APTU)

On an average, the day length from June 2019 to January 2020 gradually decreased. Such variations in day length over the months influenced the variations in PTU under different transplanting dates, thus resulting in lower grain yield (Satish *et al*., 2017) [13]. The varietal differences recorded in PTU accumulation was due to attainment of different phenophases at different duration (Kaur and Dhaliwal, 2014) [4].

Table 4: Growing Degree Days (GDD) requirement of different rice varieties at various phenophases under different dates of planting

Date	21 July				5 August				20 August				4 September			
Phenological stages	Varieties				Varieties				Varieties				Varieties			
	Mandakini	Bina-11	Swarna	Hasanta	Mandakini	Bina-11	Swarna	Hasanta	Mandakini	Bina-11	Swarna	Hasanta	Mandakini	Bina-11	Swarna	Hasanta
Transplanting	432.9	432.9	432.9	432.9	429.6	429.6	429.6	429.6	419.8	419.8	419.8	419.8	423.3	423.3	423.3	423.3
Tillering	533.1	549.6	567.9	567.95	544.1	544.1	564.6	564.6	534.3	551.6	551.6	551.6	538.8	558.2	558.2	558.2
Panicle initiation	1025.8	1386.8	1709.5	1726.65	985.8	1373.9	1647.9	1702.2	975.9	1310.9	1604.9	1671.9	912	1229.1	1547	1581.2
Panicle emergence	1600.2	1952.2	2241.7	2257.2	1550.9	1903.8	2163	2208	1512.1	1864.2	2059.4	2114.9	1458.6	1730.6	1959.2	1985.8
50% flowering	1678.6	2061.9	2363.9	2381.8	1629	2005.9	2269.3	2312.5	1604.9	1955.4	2157.2	2213.2	1547	1818.1	2049.9	2077.7
Physiological maturity	2097.4	2465	2728.5	2756.4	2040.5	2386	2617.5	2659.6	1984.2	2281.8	2492.2	2536.5	1874.2	2148.7	2340.3	2357.8

Table 5: Heliothermal Units (HTU) requirement of different rice varieties at various phenophases under different dates of planting

Date	21 July				5 August				20 August				4 September			
Phenological stages	Varieties				Varieties				Varieties				Varieties			
	Mandakini	Bina-11	Swarna	Hasanta	Mandakini	Bina-11	Swarna	Hasanta	Mandakini	Bina-11	Swarna	Hasanta	Mandakini	Bina-11	Swarna	Hasanta
Transplanting	1982.1	1982.1	1982.1	1982.1	2083.5	2083.5	2083.5	2083.5	1340	1340	1340	1340	1238.7	1238.7	1238.7	1238.7
Tillering	2629.7	2636.3	2636.3	2636.3	2634.1	2634.1	2634.1	2634.1	1505.6	1526.4	1526.4	1526.4	1607	1607.0	1607	1607
Panicle initiation	4056.4	4891.5	6528.8	6545.9	3825.2	5765.9	6957.3	7233.3	3224.3	4864.5	6981.8	7046.7	3324.5	5353.1	7284.8	7353.7
Panicle emergence	6141.4	7799.3	9633.7	9698.6	6341.7	8888.4	9996.4	10074.2	6089.3	8089.8	9481.6	9861.6	6840.7	8365	9673.2	9845.4
50% flowering	6511.2	8517.8	10381.7	10465.6	6915.9	9208.9	10627.2	11007.8	6981.8	8591.6	10076.6	10349.3	7284.8	9035.8	10357.2	10571.3
Physiological maturity	8741.2	10819.5	12659.1	12763.4	9483.4	11595.9	12894.1	13214	8843.4	10697.2	11919.1	12160.6	9340.5	10931.4	2340.3	11814.7

Table 6: Photothermal Units (PTU) requirement of different rice varieties at various phenophases under different dates of planting

Date	21 July				5 August				20 August				4 September			
Phenological stages	Varieties				Varieties				Varieties				Varieties			
	Mandakini	Bina-11	Swarna	Hasanta	Mandakini	Bina-11	Swarna	Hasanta	Mandakini	Bina-11	Swarna	Hasanta	Mandakini	Bina-11	Swarna	Hasanta
Transplanting	5662.2	5662.2	5662.2	5662.2	5547.4	5547.4	5547.4	5547.4	5256.2	5256.2	5256.2	5256.2	5236.7	5236.7	5236.7	5236.7
Tillering	6968.4	7183.4	7421.9	7421.9	6980.4	6980.4	7236	7236	6672.5	6886.5	6886.5	6886.5	6649.6	6885.3	6885.3	6885.3
Panicle initiation	13160.8	17602.6	21409.3	21601.9	12449.6	17105.7	20228	20849.3	12074.2	15890.6	19245.7	20003.5	11004.3	14640.2	18227.4	18609.8
Panicle emergence	20178	24183.1	27476.1	27650.8	19111.5	23144	26060.3	26562.9	18192.5	22162.1	24333	24944	17239.5	20272.3	22772.2	23053.1
50% flowering	21060.8	25434.8	28853.5	29053.1	20011	24298.7	27243.3	27722.8	19245.7	23178.6	25409.2	26018.8	18227.4	21239.8	23728.7	24020.9
Physiological maturity	25839.8	29983.3	32903.5	33210.1	24690.1	28536.2	31028.57	31471.4	23498.3	26742.4	28954.8	29419.5	21856.9	24766.5	26777.2	26960.8

Conclusion

Based on the above findings, it was concluded that **t**he crop transplanted in the month of July (21 July) took maximum number of days to attain the phenol phases than the delayed transplanted dates. The leaf area index, ear bearing tillers, along with the grain yield, straw yield and harvest index were found to be maximum in 5 August planting which were significantly at par with 21 July planting. The highest GDD and PTU accumulation were observed in 21 July planting and it decreased gradually with delayed planting whereas the highest HTU accumulation was recorded in 5 August planting. It was recorded that 21 July and 5 August planting were almost similar in all the yield attributes. Therefore, for any cause if a farmer skipped planting on 21 July, 5 August planting can be recommended for the farmer to get a satisfactory yield. Among the varieties, Swarna and Hasanta were almost equal significant with each other being Swarna with slightly higher yield.

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