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Agro-meteorological indices and phenology of rice (*Oryza sativa* L.) under different dates of planting and nitrogen levels

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Abstract
A field experiment was conducted during *Kharif* season of 2016 at Research Farm of Odisha University of Agriculture and Technology, Bhubaneswar, India to study the phenology and various agro-meteorological indices *viz.,* accumulated growing degree days (GDD), heliothermal units (HTU), photo thermal units (PTU), and heat use efficiency (HUE) of rice variety 'Hasanta' grown under different dates of transplanting and nitrogen levels. The rice variety 'Hasanta' was transplanted on four dates *viz.,* 10th July, 20th July, 30th July and 10th August with three levels of nitrogen 75%, 100% and 125% of recommended dose of fertilizer, respectively. The crop transplanted on 10th July took maximum calendar days to attain different phenological stages till physiological maturity (143.74 days) which reduced significantly with subsequent delay in transplanting date with highest growing degree days (2677.2) for maturity, heliothermal units (13531 degree day hours) and photo thermal units (417923 degree day hours), heat use efficiency was found to be highest 0.88(g/m^2/ °C day), when transplanted on 10th July followed by 20th July and 30th July. Heat units required to attain different phenological stages decreased in all the varieties with delay in transplanting date. Planting on 10thJuly with application (125% nitrogen) produced maximum grain yield of 4443 kg/ha which was at par with planting on 10th, 20th, and 30thJuly with applying either 125% nitrogen or 100% nitrogen.

Keywords: Agro-meteorological indices, phenology, Rice, *Oryza sativa* L., planting, nitrogen levels

Introduction
Rice is the most important staple food crop for more than half of the world's population, providing 21% of the total calorie intake (Singh *et al.*, 2017) [11]. In India, it occupies an area of 43.8 million ha and a production of 105 million tonnes, with average productivity of 2.21 t/ha. Demand for rice growing is increasing every year, and it is estimated that by 2025 AD, its requirement would be 140 mt. To sustain the present food self-sufficiency and to meet the future food requirement, India has to increase rice productivity by 3% per annum (Kumar *et al.*, 2015) [6].
Rice production is affected by various meteorological variables like rainfall, temperature and solar radiation etc (Ji *et al.*, 2007) [4]. During crop growth period, the occurrence of various phenological events can be estimated by computing accumulated growing degree days (Gouri *et al.*, 2005) [3]. Various developmental stages as well as harvest date of crop can be estimated from the knowledge of accumulated GDD. Heat use efficiency (HUE), i.e., efficiency of heat utilization in terms of dry matter accumulation, depends on genetic factors, crop type and sowing time and has great practical application (Rao *et al.*, 1999) [9]. Crop phenology is an essential component of weather based dynamic crop growth and yield simulation models and can be used to estimate the most appropriate date and time of specific development process. Hence, it becomes imperative to have the knowledge of exact duration of various phenological stages of crop in a particular growing environment and their impact on its yield. In the present study, an attempt is made to predict the growth and yield of rice with agro-climatic indices *viz*. growing degree days, heliothermal units, photothermal units, heat use efficiency. Planting time is the major factor that determines the productivity of a crop.
Optimum planting time for a crop is location specific. It increases the rain water use efficiency as compared to the delayed planting. It ensures that vegetative growth occurs during a period of satisfactory temperatures and high levels of solar radiation. Secondly, the optimum sowing

time for each cultivar ensures the cold sensitive stage occurs when the minimum night temperatures are historically the warmest. Sowing on time guarantees that grain filling occurs when milder autumn temperatures are more likely, hence good grain quality is achieved (Farrell *et al.*, 2003) [2].

Nitrogen is the key element in the production of rice and gives by far the largest response. Nitrogen management is another important factor that influences the growth, development, yield and yield components of transplanted rice significantly. Balanced fertilization ensures the plant to grow properly with their aerial and underground parts and help to increase the dry matter of the plant. Application of less or more fertilizer than the optimum are not economic i.e., both of this situation give lower yield. Nitrogen application in right time in right dose has to be ensured as yield and quality of rice crop which requires as much as possible at an early and mid tillering stages to maximize panicle numbers and during reproductive stages to produce more number of spikelets per panicle and percentage filled spikelets (Lampayan *et al*., 2010) [7]. Hence, present experiment on was conducted to study the growth, yield and crop phenology of rice variety 'Hasant' with agro-climatic indices i.e., growing degree days, heliothermal units, photothermal units, heat use efficiency under different planting dates and nitrogen levels.

Materials and methods

The field experiment was conducted out during kharif season of 2016 at Research Farm of College of Agriculture, Orissa University of Agriculture and Technology, Bhubaneswar, situated at an elevation of 25.9 m above mean sea level at 20°15'N latitude and 85° 52'E longitude. It is in the East & South East Coastal Plain of Odisha, which falls under Tropical wet dry or Tropical Savanna. The weekly mean maximum temperature during the crop growth period ranged from 27.1 to 35.7 °C, with a weekly average of 32.3 °C, whereas, the monthly mean minimum temperature varied from 14 to 25.9 °C with a weekly average of 22.9 °C.

The mean morning relative humidity during the crop growth varied from 82 to 96%, while the mean afternoon relative humidity varied from 44 to 84%.The mean bright sunshine hour received during the crop growth period varied from 4.4 to 8 hours, with a weekly average of 6.2 hours. The total rainfall received during the crop growth period was 766.8 mm with total of 47 rainy days. The field experiment was conducted during kharif season of 2016, laid out in a split plot deign with four dates of Planting (10^{th}, 20^{th}, 30^{th} July and 10^{th} August) in main plots and three levels of nitrogen (75%, 100%, 125%) of RDF in sub plots. The recommended dose of fertilizer is (RDF) 80:40:40 kg NPK ha^{-1} was applied in the form of Urea, Single super phosphate (SSP) and Muriate of Potash (MOP). One-third dose of nitrogen, entire dose of phosphorus and half of the potash were applied basally, remaining nitrogen was applied in equal splits during active tillering (30 days after planting) and panicle initiation stage (65 days after planting), respectively and the remaining half of potash was applied during panicle initiation stage. Urea and MOP were broadcasted along the field and SSP was incorporated in the root zone of plants. Test variety 'Hasanta' is one of the highly adaptable rice cultivar of Odisha. It is a semi-dwarf, late duration variety (140-150 days). It is most suitable for rain fed low lands ecosystem and is moderately resistant to leaf blast, BLB and tolerant to sheath rot.

Phenological observations

The crop was inspected at frequent intervals (2 or 3 days) to observe the phenological events closely on date of occurrence of different phenophases like seedling, tillering, panicle initiation (PI), panicle emergence (PE) and physiological maturity were recorded.

Growing degree days (GDD)

Cumulative growing degree days were determined by summing the daily mean temperature above base temperature, expressed in degree day. This was determined by using the following formula as per (Nuttonson, 1995) [8].

$$GDD = \frac{(Tmax + Tmin)}{2} T_{base}$$

Where,

T_{base} = Minimum threshold/base temperature (˚C), T_{max} = Daily maximum temperature (°C), T_{min} = Daily minimum temperature (°C)

Heliothermal units (HTU), degree day hrs

The heliothermal units for a day represent the product of GDD and the hours of bright sunshine for that day. The sum of HTU for particular phenophases of interest was determined according to the equation:

$$HTU = \sum \{GDD \times BSS\ (n)\}$$

Where,

GDD = growing degree days, BSS (n) = bright sun shine hours (hrs)

Photothermal units (PTU), degree day hrs

Photothermal units are the cumulative value of growing degree days, multiplied by the day length. This can be mathematically represented using the following formula:

$$PTU = \sum (GDD * N)$$

Where,

GDD = Growing degree days, N = Maximum possible sunshine hours or day length (hrs)

Heat use efficiency (HUE)

Heat use efficiency indicates the amount of dry matter produced per unit of growing degree days or thermal time. This was computed by using the following formula

[HUE (g/m2/ oC day) = Biomass (g/m2) / GDD (oC day)

Results and discussion

Phenology

Among the different dates of transplanting, rice transplanted on 10^{th} July took more number of days to attain physiological maturity followed by 20^{th} July, 30^{th} July and 10^{th} August (table 1). Sharma *et al*., (2011) [10] reported that early transplanting took more number of days for maturity. Applying 125% nitrogen of recommended dose of fertilizer enhanced maturity duration in (143. 74days) which was significantly different from other levels of nitrogen. The crop could express its potentiality when planted on suitable date with required amount of fertilizer.

Table 1: Effect of dates of transplanting and levels of nitrogen on phenophases of rice variety 'Hasanta'.

Treatments	Days after transplanting (DAT)				
	Tillering	**P.I**	**P.E**	**50% Flowering**	**Physiological maturity**
Dates of transplanting					
10th July	51.09	73.46	104.84	112.85	142.90
20th July	51.05	73.12	103.84	108.51	141.57
30th July	50.08	72.12	102.50	107.85	140.57
10th August	49.08	69.78	100.17	108.18	140.23
C.D(0.05)	0.35	0.06	0.07	0.08	0.04
Levels of Nitrogen					
75%	49.33	68.61	100.17	105.18	138.23
100%	50.58	72.87	103.17	109.93	141.99
125%	51.59	74.87	105.18	112.94	143.74
C.D(0.05)	0.24	0.05	0.04	0.07	0.04

P.I.= Panicle initiation, P.E.= Panicle emergence

Growing Degree Days

Growing degree days accumulated at different phenophases were calculated during growth of rice is presented in table 2. The highest number of growing degree accumulated in rice planted on 10th July followed by 20th July, 30th July and 10th August. Applying 125% nitrogen to rice crop accumulated highest GDD in all phenophases followed by 100% nitrogen because crop took more number of days to mature under higher level of nitrogen and early planting. Abhilash *et al.*, (2017) [1] reported that accumulated GDD were higher under early transplanting.

Table 2: Growing degree days (GDD) requirement of rice variety 'Hasanta' at various phenophases under different dates of planting and levels of nitrogen.

Dates of transplanting	**10th July**			**20th July**			**30th July**			**10th August**		
Phenological Stages	N_1	N_2	N_3	N_1	N_2	N_3	N_1	N_2	N_3	N_1	N_2	N_3
Transplanting	481.9	481.9	481.9	474.7	474.7	474.7	477.6	477.6	477.6	485.1	485.1	485.1
Tillering	922.8	990.3	1007.2	955.1	990.2	1007.7	913.8	934.3	836.8	922.0	940.3	957.5
Panicle initiation	1343.3	1381.1	1447.72	1336.2	1401.1	1418.7	1287.7	1343.7	1400.7	1272.8	1366.4	1384.5
Panicle emergence	1925.4	1979.7	2014.6	1889.4	1962.6	2016.8	1862.2	1912.9	1929.1	1827.0	1858.0	1890.3
50% Flowering	2068.6	2125.7	2160.9	2035.0	2086.3	2136.3	1912.4	2030.2	2046.4	1925.4	2013.0	2046.9
Maturity	2590.0	2664.2	2677.2	2519.1	2579.3	2603.3	2443.6	2497.2	2523.2	2417.8	2477.4	2502.4

Table 3: Helio thermal units (HTU) degree day hours' requirement of rice variety 'Hasanta' at various phenophases under different dates of planting and levels of nitrogen.

Dates of transplanting	**10th July**			**20th July**			**30th July**			**10th August**		
Phenological Stages	N_1	N_2	N_3	N_1	N_2	N_3	N_1	N_2	N_3	N_1	N_2	N_3
Transplanting	2488.26	2488.26	2488.26	2350.77	2350.77	2350.77	2858.12	2858.12	2858.12	2200.05	2200.05	2200.05
Tillering	5161.17	5161.17	5161.17	4301.00	4406.35	4455.35	4339.68	4503.68	3915.63	4466.01	4480.65	4480.65
Panicle initiation	6531.19	6696.67	7310.61	6274.61	6292.11	6325.55	5879.11	6107.51	6391.46	5812.19	6154.42	6230.23
Panicle emergence	9172.83	9359.34	9422.31	8637.03	8932.61	9147.42	8725.95	9146.03	9289.22	8921.67	9066.99	9240.4
50% Flowering	9750.85	10162.2	10185.86	9285.74	9694.39	10133.26	9587.47	10046.79	10169.91	9341.58	10045.16	10247.25
Maturity	13092.33	13430.84	13530.94	12559.94	12965.09	13251.37	12682.25	13145.34	13371.7	12878.62	13268.57	13480.05

Table 4: Photo thermal units (PTU) degree day hours' requirement of rice variety 'Hasanta' at various phenophases under different dates of transplanting and levels of nitrogen.

Dates of transplanting	**10th July**			**20th July**			**30th July**			**10th August**		
Phenological Stages	N_1	N_2	N_3	N_1	N_2	N_3	N_1	N_2	N_3	N_1	N_2	N_3
Transplanting	6350.25	6350.25	6350.25	6240.77	6240.77	6240.77	6250.50	6250.50	6250.50	6296.79	6296.79	6296.79
Tillering	12762.76	12928.65	13146.32	12445.54	12257.38	13115.55	11826.38	12084.88	10855.41	11835.65	12053.05	12257.39
Panicle initiation	17462.61	18191.47	18719.76	18143.36	18011.76	18220.85	16437.37	17122.25	17819.36	16075.75	17202.36	17419.50
Panicle emergence	24582.83	30214.74	32433.94	23907.09	25003.62	25640.21	23322.78	23909.12	24103.59	22625.94	22981.82	23352.63
50% Flowering	26294.43	31940.71	34353.21	25625.88	26225.00	26809.65	24103.59	25271.12	25457.1	23755.58	24748.21	25131.17
Maturity	32345.23	33341.29	41792.68	31165.05	31836.28	32148.48	29937.58	30527.16	29338.15	29246.39	29885.25	30148.71

Heliothermal Units (HTU)

Heliothermal units (HTU) required to attain different phenophsaes of rice were calculated. Transplanting on 10th July with 125% nitrogen accumulated highest HTU and decreased with delay in transplanting under different levels of nitrogen. It followed the similar trend as GDD. Similar observations were recorded by Kaur and Dhaliwal (2014) [5].

Heat Use Efficiency (HUE)

Heat use efficiency (HUE) was also computed at various growth intervals of rice crop (table 5). Heat use efficiency is the conversion of heat energy into dry matter and depends on crop type, genetic factors and sowing time (Rao *et al.*, 1999) [9]. Total heat energy available to any crop is never completely converted to dry matter even under most favourable agro-climatic conditions. Among the dates of transplanting, date 10th July transplanted crop exhibited maximum HUE in all the phenophases followed by 20th July and 30th July. HUE decreased with delay in transplanting and was least on 10th August.

Among different transplanting dates, highest HUE at the time of harvest was recorded in 10th July planting 0.88 (g/m²/ºC day) followed by 20th July and 30th July. Among different nitrogen levels highest HUE at the time of harvest was recorded in 125%N (0.86g/m²/ ºC) day was at par with 100% N (0.84g/m²/ ºC day). Application of 75% N recorded the least HUE.

Table 5: Heat use efficiency (HUE) (g/m²/ºC day) of rice variety 'Hasanta' at various phenophases under different dates of planting and levels of nitrogen.

Treatments	Phenophases					
	Transplanting	**Tillering**	**P.I.**	**P.E.**	**50% Flowering**	**Physiological maturity**
Dates of transplanting						
10th July	0.38	0.56	0.79	0.87	1.21	0.88
20th July	0.36	0.54	0.74	0.85	1.15	0.85
30th July	0.33	0.52	0.73	0.83	1.06	0.82
10th August	0.31	0.48	0.69	0.78	0.94	0.75
C.D(0.05)	0.03	0.02	0.03	0.03	0.05	0.03
Levels of Nitrogen						
75%	0.31	0.49	0.69	0.76	0.96	0.77
100%	0.35	0.54	0.75	0.86	1.14	0.84
125%	0.38	0.55	0.77	0.88	1.17	0.86
C.D(0.05)	0.02	0.01	0.02	0.02	0.03	0.02

P.I.= Panicle initiation, P.E.= Panicle emergence

Grain yield

The grain yield of rice is a function of total number of panicles, number of grains per panicle and the test weight, which was significantly influenced by dates of planting and nitrogen levels (table 6). Among the four different dates of planting early transplanted rice on 10thJuly registered maximum grain yield of 4131 kg/ha which was at par with planting on 20thJuly and 30thJuly, but significantly different and almost 11.1% on 10thAugust. Application of 125% nitrogen produced maximum grain yield of 4302 kg/ha which was at par from 100% Nitrogen and significantly different and almost 20.1% from 75% Nitrogen. Among the treatment combinations, planting on 10thJuly with an application of 125% Nitrogen produced maximum grain yield of 4443 kg/ha which was at par with planting on 10th, 20th, and 30thJuly with applying either 125% Nitrogen or 100% Nitrogen. Sharma *et al.*, (2011) [10] observed significant reduction in yield and yield attributing characteristics with delay in transplanting.

Table 6: Grain yield (kg/ha) of rice variety 'Hasanta' under different dates of sowing and nitrogen levels.

Dates of transplanting	Levels of Nitrogen			
	N_1	**N_2**	**N_3**	**mean**
D_1	3661.4	4287.2	4443.2	4130.6
D_2	3646.5	4297.2	4422.3	4122.0
D_3	3590.9	4279.3	4416.4	4095.5
D_4	3427.0	3809.4	3924.7	3720.4
Mean	3581.5	4168.3	4301.6	4017.1
	D	N	D X N	N X D
SEm±	62.2	51.1	57.4	54.6
CD (p=0.05)	180.1	149.6	179.9	159.2

Conclusion

It may be concluded that, the different agro meteorological indices *viz*. GDD, HTU, PTU, and HUE were higher in rice crop transplanted early on 10th July. Maximum grain yield can be obtained by planting by 30thJuly with application of 100% nitrogen of recommended dose of fertilizer. The present study indicates that the application of agro meteorological indices provides a scientific basis for determining the effect of temperature, radiation or photoperiod on phenological behaviour of a standing crop. These can also be used very effectively for forecasting the occurrence of different phenophases of the crop.

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