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Study the impact of weather based agro meteorological indices on growth and development of *boro* rice at different phenological phases vis-à-vis the final yield

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Abstract
To investigate how the different agro-climatic factors impacted on growth and development of *boro* rice at different phenological stages in addition to assessing the variability of final yield due to variation of spacing, varieties and age of seedling, a field experiment was conducted during *boro* seasons of 2017-18 and 2018-19 hereafter known as 2018 and 2019 respectively at the District Seed Farm (D bl °C k farm) of Bidhan Chandra Krishi Viswavidyalaya, at Kalyani in Nadia district. The experiment was laid out in factorial randomized bl °C k design (FRBD) with three varieties, three spacing and two ages of seedlings with two replications. The present study observed that the barometric characters of boro rice are highly influenced by the varieties, spacing and age of seedling. Triguna variety is found to have higher grain and straw yield, whereas the lowest grain and straw yield were found in Heera variety. The wider spacing of 20 cm x 15 cm produced higher grain and straw yield and while the closer spacing of 15 cm x 15 cm reproduced the lowest grain and straw yield. The 32 days age of seedling is found to achieve higher grain and straw yield as compared to 25 days age of seedling. The amount of energy utilized in various phenological phases by the crops was assessed on the basis of accumulated GDD, HTU, and PTU. The result indicates that the Triguna variety consumed more GDD, HTU and PTU at 25 days age of seedling compared to 32 days age of seedling. The highest grain yield by 6020 and 6294 (Kg ha^{-1}) was observed for Triguna variety and maximum grain yield of 5254 and 5647 (Kg ha^{-1}) for wider spacing of 20 cm x 15 cm while significant highest yield of 5454 and 5647 (Kg ha^{-1}) for 32 days age of seedlings was achieved in case of two consecutive growing seasons namely 2018 and 2019, respectively. It was also revealed that the maximum significant straw yields by 8194 and 8432 (Kg ha^{-1}) for Triguna variety, by 7153 and 7285 (Kg ha^{-1}) for wider spacing and by 7247 and 7356 (Kg ha^{-1}) for 32 days age of seedlings was also produced at physiological maturity stage in year 2018 and 2019 respectively. It is concluded that duration of different phenological stages slightly by 2-3 days which may alter different productivity in different cropping seasons as energy utilize in terms of GDD, HTU and PTU changes significantly at different phenol-logical stages.

Keywords: Boro rice, phenology, grain yield, age of seedlings

Introduction
Rice is the most important cereal food crop of India. It is the staple food of more than 60% of the world's population especially for most of the people of South-East Asia. It °Ccupies about 23.3% of gross cropped area of the country. It plays vital role in the national food grain supply during 2017-2018; rice contributed 43.79% of total food grain production of the country. It plays vital role in national food grain production and contributes 46% of the total cereal production of the country; while it °C cupies about 23.3% of gross cropped area. Rice having immense industrial and food value with production of 110.15 Million tones and productivity 2.4 tones per hectare. India ranks 2^{nd} position after China in term of gross rice production and contributes nearly 20% of total global production. In India out of total area under cultivation of rice, 59.6% are irrigated. It is reported that irrigation based *boro* rice cultivation is 26% with a averaged productiovity is 1417 kg $hectare^{-1}$ which comparatively higher than the productivity rice in other cropping season like *Kharif* and *Rabi*.

During the entire crop growth period, the °C currence of various phenological events can be estimated by computing accumulated growing degree days (GDD) (Gouri et. al., 2005) [6]. Accumulated growing degree days (AGDD) provides an estimate of harvest date as well as development stages of crop (Ketring and Wheless, 1989) [8]. Various developmental stages as well as harvest date of crop can be estimated from the knowledge of accumulated GDD. Thermal time can be used as a tool for characterizing thermal responses in different crops as it is an independent variable to describe plant development.

Heat use efficiency (HUE), i.e., efficiency of heat utilization in terms of dry matter. 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. 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. Computation of weather based agro indices (GDD, PTU and HTU) on different phenological stages can provide an added information for on-farm crop management to achieve optimum productivity in addition to have total accumulated thermal energy requirement of the crop during the entire growing periods. With this background information, the present paper highlights the duration of major phenological states and sub-stages and quantifies the values of different thermal indices and discusses their role for the growth and development to achieve the final rice yield in the two-consecutives boro seasons of 2018 and 2019.

Materials and Methods

A field experiment was conducted during the *boro* i.e. summer season 2017-18 and 2018-19 to see the crop-weather relationship at different phenological phases on *Boro* rice over new alluvial zone of West Bengal". The specific l °Cation of the experiment was in the humid sub-tropics of West Bengal at the District Seed Farm (D bl °Ck farm), Kalyani, Nadia at Bidhan Chandra Krishi Viswavidyalaya (BCKV). The experiment was laid in fairly uniform topography and well-drained soil, which had homogenous fertility and textural makeup. The details of the experiment and the methodology used for present study are discussed in the following sections.
The experiment was laid out in factorial randomized bl °Ck design (FRBD) with three varieties, three spacing and two ages of seedlings with two replications.

Description of major phenological phases of rice

The major distinct phenological phases and the start and end dates and their duration of *Boro* rice will be observed during the entire growing period. The three major phenological phases along with their sub-phases is defined as a) vegetative phase**:** i) transplanting-tiller initiation ii) tillering - panicle initiation**,** b) reproductive phase: i) panicle - flower initiation ii) flowering – milk, and c) ripening phase: i) milk - dough ii) dough - physiological maturity.

Description of observed weather conditions during two experimental years

The variation of weather conditions in terms of temperature, relative humidity, rainfall, evaporation and bright sunshine for consecutive two years of field experiment namely 2017-18 and 2018-19 has been shown in Fig 1 and Fig2 respectively.

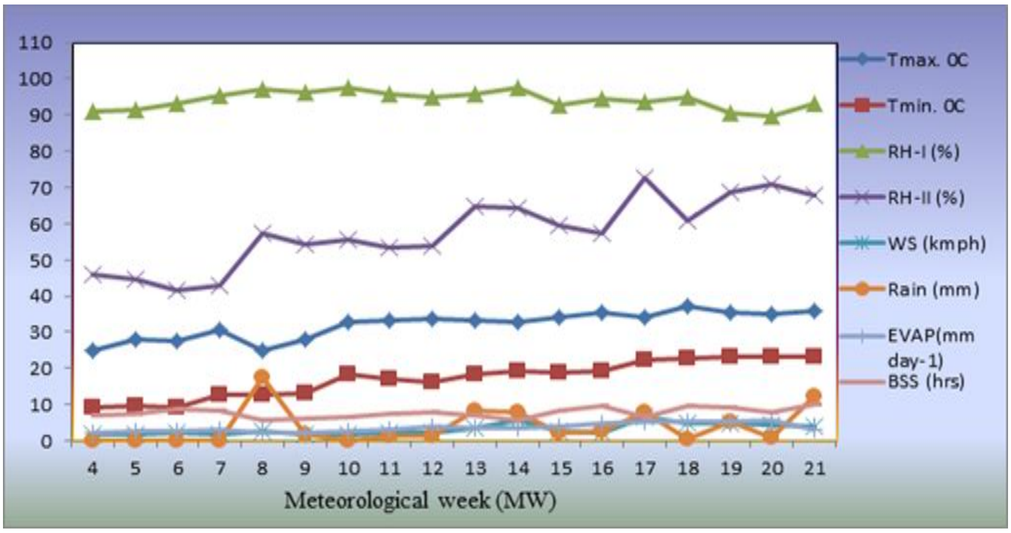

Fig 1: Weather condition during the boro rice-growing season 2017-18

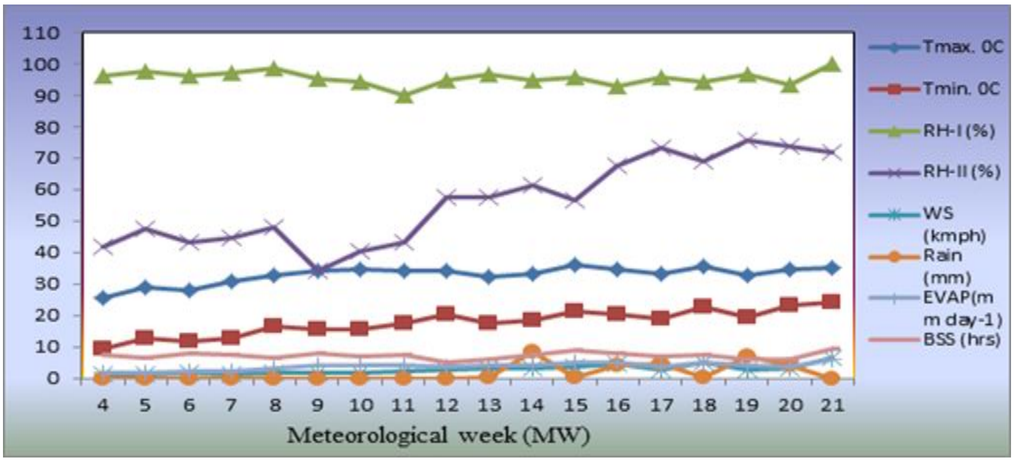

Fig 2: Weather condition during the boro rice-growing season 2018-19

During the experiment period, the maximum temperature ranged from 26 °C to 34 °C and 24 °C to 35 °C (2017-18, 2018-19) and the average minimum temperature ranged from 8 °C to 22 °C and 9 °C to 23 °C (2017-18 and 2018-19).

Meteorological Observation

Growing Degree Days

A degree-day or a heat unit is the departure from the mean daily temperature above the threshold temperature of the crop. Growing degree days (GDD) concept assumes that there is a direct and linear relationship between growth of plants and temperatures. The threshold or base temperature is the temperature below which no growth takes place. This varies with crop, generally higher values for tropical crops and lower values for temperate crops, and for rice the base temperature is taken as 10 °C (Thomas, 1957). For calculating growing degree-days, weather data will be collected from Agro-Meteorological Observatory of BCKV, Kalyani l °Cated at C Bl °Ck farm, Kalyani. Growing degree days were computed from date of sowing to harvesting of the crop to give accumulated growing degree days. This was expressed as °C day. The GDD were calculated by the following equation (Vittum *et al*., 1965) [19]:

$$GDD = [(T_{max} + T_{min})/2] - T_b$$

Where, T_{max} = Maximum temperature, T_{min} = Minimum temperature and T_b = Base temperature (°C)

Heliothermal Units

Heliothermal unit (HTU) was calculated by multiplying GDD with bright sunshine hours, which was measured daily with the help of sunshine recorder. This was expressed as °C day hour. This was calculated using the formula as given by Rajput, (1980) [16]:

$$HTU = (GDD) \times (\text{Bright sunshine hours})$$

Photothermal Units

Nuttonson (1955) made an attempt to improve GDD concept applying day length factor and used Photothermal unit (PTU) concept in climatic analogue studies. This was calculated by multiplying GDD with maximum possible bright sunshine hours. This is expressed as °C days hour. This was calculated using the formula:

$$PTU = GDD \times \text{Day length}$$

Results and Discussion

The many meteorological factors are influencing the growth and development of *boro* rice which was assessed by computing several meteorological indices like GDD, HTU and PTU which was based on air temperature, bright sun shine hours and day-length. These indices may provide guideline when a crop is likely mature. The heat unit system developed at place is not exactly applicable to another place. The concept was provide good estimate to aim at approximate time of maturity of the crop on the basis of data of seasons, crop duration, summation of bright sunshine hours and day length for the heat unit and photothermal units for boro rice.

4.1 Phenological phase–wise assessment of thermal indices

Different thermal indices namely growing degree days (GDD), HTU and PTU accumulated at different phenol phases were calculated during the two consecutive crop-growing seasons for Boro rice. It is observed that the computed values of GDD, HTU and PTU were significantly varied according to variety chosen, considered duration of age of seedling and two cropping seasons (Table 1). It is observed that highest accumulated GDD (AGDD) was observed (1714-1801 °C day) for Triguna variety for entire growing period comprising of 9 pheno-phases, followed by Shatabdi variety with a range between 1441-1550 °C day while Heera variety consumed lower accumulated GDD ranging between 1268-1363 °C day. How the accumulated GDD vary significantly across 9 sub-phenological phases for different varieties, age of seedling and crop growing years have been summarized in Table 1. It is noticed that the range of the value of AGDD for phenological phase P1 (Transplanting - Tiller initiation) is 215-293 °C day, for P2 (tiller initiation - maximum tillering) is 288-532 °C day, followed by P3 (maximum tiller – panicle initiation) is 414-674 °C day, P4 (panicle initiation – complete panicle) is 538-864 °C day, P5 (complete panicle- flower initiation) is 643-1045 °C day, P6 (flower initiation - 100% flowering is 734-1217 °C day, P7 (100% flowering-milk) is 843-1364 °C day, P8 (milk-dough is 1011-1596 °C day and the last sub-phase P9 (dough – physiological maturity) is 1194-1801 °C day. The variation the AGDD for different varieties (Triguna, Shatabdi and Heera), ages of seedling (25 and 32 day) and cropping seasons (2017-18, 2018-19) are varying significantly from pheno-phase to phenol-phase with minimum values in the PI to maximum in P9 pheno-phase. On the basis of AGDD values requirement of different varieties for entire life cycle, the cultivars could be arranged as Triguna > Shatabdi > Heera. The higher values of AGDD in 25 days age of seeding leads to late harvest and less plant height, less number of tiller, less dry matter and less leaf area index imply less grain yield as compare to 32 days age of seedling. It is interesting to note that the 32 age of seedling produced higher grain yield due to favourable weather condition i.e. higher maximum and minimum temperature as well as available resources during the reproductive and ripening phases hence increase the productivity of boro rice for three selected varieties and for two considered consecutive crop growing seasons over the new alluvial zone of West Bengal. Several studies conducted in different parts of India (Banerjee *et al*. 2018, Tauseef *et al*. 2015 and Maity and Khan 2008) [3, 17, 11] reported the similar results while their analyses were on the basis of accumulated GDD requirements at different phenological phases.

In case of observed HTU, it is noticed that the Triguna variety shows the highest accumulated HTU (AHTU) raining between 12478-13998 °C day hours for entire crop growing period irrespective to age of seedling and cropping season followed by Shatabdi indicated moderate AHTU ranging between 10843-11536 °C day hours and the minimum AHTU ranging between 8833-9937 °C day hours was observed in Heera variety. The variation of accumulated HTU varies significantly across 9 sub-phenological phases and the results have been displayed in (Table1). It is noticed that the range of the value of AHTU for phenological phase i.e., P1 (transplanting – tiller initiation) is 1413-2081 °C day hours, P2 (tiller initiation to maximum tillering) is required 2136-3795 °C day hours, followed by P3 (maximum tiller – panicle initiation) is 2918-4919 °C day hours, P4 (panicle initiation – complete panicle is consumed 3762-5735 °C day hours, P5 (complete panicle- flower initiation) is 4627-7127 °C day hours, P6 (flower initiation - 100% flowering) is 5348-8441 °C day hours, P7 is (100% flowering-milk is 6056-9998 °C day hours, P8 is milk-dough is 7192-11842 °C day hour and finally the P9 (dough – physiological maturity) is required 8833-13998 °C day hour. It is also noticed that there is wide variation of AHTU for different sub-pheno-phase across selected three varieties (Triguna, Shatabdi and Heera) and two considered ages of seedling (25 and 32 day) for cropping seasons (2017-18, 2018-19). The based on accumulated HTU for entire life cycle, the cultivars could be arranged as Triguna > Shatabdi > Heera. The higher values of AHTU in 25 days age of seeding leads to late harvest and less plant height, less number of tiller, less dry matter and leaf area index compared to 32 days age of seedling. Younger seedling (25 days) produced the higher grain yield due to prevails of favorable weather conditions i.e., optimum thermal condition in terms of maximum and minimum temperature and ample amount of bright sunshine hours and other available resources during the reproductive and ripening phases. Similar results like younger seedlings compared to older seedlings produce more grain yield was obtained by the other researchers (Tauseef *et al*. 2015 and Hundal *et al*. 2005) [17, 7] for their experimental research in other parts of India.

Similarly, it is observed that highest accumulated PTU (APTU) ranging between 20817-21645 °C day hours for entire 9 pheno-phases were noticed in the Triguna variety irrespective to age of seedling and cropping season followed by Shatabdi ranging between 17112-18745 °C day hours and Heera ranging between 14248-16142 °C day hours. How the accumulated PTU vary significantly across 9 sub-phenological phases have been worked out and the results were summarized in Table1. It is noticed that the range of the value of APTU for phenological phase P1 (transplanting – tiller initiation) is 2110-3221 °C day hours, P2 (tiller initiation to maximum tillering required) is 3275-5942 °C day hours, followed by P3 (maximum tiller – panicle initiation) is 4747-7728 °C day hours, P4 (panicle initiation–complete panicle) is 6214-10117 °C day hours, P5 (complete panicle- flower initiation) is 7474-12211 °C day hours), P6 (flower initiation - 100% flowering is 8574-14315 °C day hours, P7 (100% flowering-milk is 9900-16445 °Cday hours, P8 (milk-dough is11965-19278 °Cday hours and P9 (dough – physiological maturity is 14248-21645 °C day hours. The based on accumulated PTU for entire crop growing period, the cultivars could be arranged as Triguna > Shatabdi > Heera. The higher values of APTU in 25 days age of seeding leads to late harvest and less amount of plant height, number of tiller, dry matter and leaf area index resulting less amount of grain yield as compare to 32 days age of seedling. The higher grain yield in case of 32 age seedlings was obtained due to favourable weather condition maximum and minimum temperature as well as day length during the reproductive and ripening phases, hence increase the productivity of boro rice, at three varieties in both the crop growing seasons in new alluvial zone of West Bengal. Similar relationship was also reported by other researchers (Tauseef *et al*. 2015) [17].

Table 1: Variation of thermal indices on different phenological phases for different varieties and age of seedling the season of 2017-18 and 20 18-19

Year	Phenological phases	Age of seedlings 32									Age of seedlings 25								
		Shatabdi			Heera			Triguna			Shatabdi			Heera			Triguna		
		GDD	HTU	PTU	GDD	HTU	PTU	GDD	HTU	PTU	GDD	HTU	PTU	GDD	HTU	PTU	GDD	HTU	PTU
2017-18	P1	239	1720	2692	215	1575	2420	265	1897	2990	263	1915	3022	269	1841	2743	293	2022	3221
	P2	460	3313	5252	336	2439	3839	484	3526	5555	484	3582	5641	367	2610	4140	532	3795	5942
	P3	559	4135	6423	484	3526	5546	638	4625	7369	667	4742	7542	510	3623	5771	674	4919	7728
	P4	701	5040	8118	606	4362	6989	804	5488	9359	805	5431	8937	654	4715	7436	864	5735	10117
	P5	893	6021	10439	718	5075	8324	974	6536	11425	945	6423	11196	798	5417	9165	1045	7127	12211
	P6	1004	6806	11801	835	5529	9793	1147	8071	13563	1085	7145	12097	912	5934	10442	1217	8441	14315
	P7	1185	8443	14044	956	6298	11219	1289	9247	15338	1224	8644	14624	1012	7110	12107	1364	9998	16445
	P8	1341	9670	15997	1103	7589	13034	1530	11101	18400	1412	10123	16454	1156	8147	13989	1596	11439	19170
	P9	1499	10843	17795	1287	9152	15321	1774	12478	21126	1550	11504	18745	1362	9937	16142	1801	13187	21623
2018-19	P1	234	1748	2532	187	1413	2110	250	1953	2835	264	1993	2785	218	1635	2456	271	2081	3056
	P2	390	2755	4322	288	2136	3275	429	2879	4878	433	2973	5121	312	2198	3348	490	3376	5496
	P3	510	3476	5495	414	2918	4747	568	3996	6482	548	3834	6685	429	2979	4827	618	4424	7186
	P4	630	4524	7185	538	3762	6214	703	4882	8106	711	4948	8475	585	4023	6584	758	5495	9005
	P5	821	5854	9248	643	4627	7474	871	6260	10260	889	6141	10589	703	4982	7907	985	6981	11412
	P6	954	6480	10909	734	5348	8574	1040	7456	12349	1015	7102	12010	817	5860	9455	1102	8187	13205
	P7	1090	7929	12965	843	6056	9900	1180	8786	14106	1113	8238	13545	914	6527	10823	1327	9897	16123
	P8	1237	9355	14843	1011	7192	11965	1503	11497	18221	1305	9580	15682	1087	7876	13036	1538	11842	19278
	P9	1441	10976	17112	1194	8833	14248	1714	13445	20817	1491	11536	17981	1268	9479	15194	1779	13998	21645

P1-Transplanting- first tiller initiation, P2-First tiller initiation- maximum tillering, P3-Tillering – panicle initiation, P4-Panicle initiation – complete panicle, P5- Panicle – flower initiation, P6- Flower initiation – 100% flowering, P7- 100% Flowering – Milk, P8-Milk-dough, P9-Dough – Physiological maturity

Table 2: Variation of the length of duration of different phenological phases across varieties and age of seedlings and cropping season

Growing season	Phenological phases	Age of seedling 32			Age of seedling 25		
		Shatabdi	Heera	Triguna	Shatabdi	Heera	Triguna
2017-18	P1	27	24	28	30	27	30
	P2	15	9	15	15	8	17
	P3	7	10	10	10	9	8
	P4	10	8	10	8	9	13
	P5	12	7	11	11	9	13
	P6	7	7	9	7	8	8
	P7	8	7	8	7	7	10
	P8	8	10	13	10	9	10
	P9	8	7	13	7	9	12
	P10	102	89	117	105	95	121
2018-19	P1	26	23	30	29	25	31
	P2	15	9	16	16	8	17
	P3	7	12	9	9	11	9
	P4	9	8	9	10	9	11
	P5	12	7	12	11	8	12
	P6	7	6	9	7	10	9
	P7	10	7	10	7	7	10
	P8	7	9	12	9	9	12
	P9	9	10	10	7	8	10
	P10	102	91	117	105	95	121

P1-Transplanting- first tiller initiation, P2-First tiller initiation- maximum tillering, P3-Tillering – panicle initiation, P4-Panicle initiation – complete panicle, P5- Panicle – flower initiation, P6- Flower initiation – 100% flowering, P7- 100% Flowering – Milk, P8-Milk-dough, P9-Dough – Physiological maturity

Description of the variation the length of different phenological phase

In general boro rice has three major phenological phases under which some sub-phenological phase exists. For example, the vegetative phase comprises of three sub-pheno-phases namely P1 (Transplanting – Tiller initiation), P2 (Tiller initiation – maximum tiller) and P3 (Maximum tiller – panicle initiation). Similarly the reproductive phases has two sub-phenophases namely P4 (Panicle initiation – complete panicle), P5 (Complete panicle- flower initiation) P6 (Flower initiation – 100% flowering) and ripening phase has three phenophases namely P7 (100% flowering – Milk), P8 (Milk-Dough), and P9 (Dough – Physiological maturity). How the length of the duration of different phenol-phases were varied in different major phenological stages and subsequent sub-phases were observed in the field for the three varieties for two consecutive growing seasons and the results are summarized in Table 2. Days taken to attain each phenological phase were influenced by age of seedling and varieties. The Triguna variety required highest duration across all the phonological stages. It is observed that all three varieties required more DAT to attain it maturity in case of 25 days of seedlings compared to 32 days of seedlings. As for example for Triguna required highest duration of 121 days for 25 age of seedling and 117 days in case of 32 days old seedlings required, while Shatabdi required 105 days and 102 days and Here required 95 days and 89 days for 25 ages of seedling and 32 age of seedlings respectively. This duration is slightly changes (2-3 days) in case of two growing seasons of 2017-18 and 2018-19. It is observed from Table 2 that the phenophase P1 (transplanting to tiller initiation) took more days (24- 30 days) irrespective to three varieties and the second phenophases i.e., tiller initiation to maximum tillering is required 8-15 days, followed by P3 (maximum tiller – panicle initiation is 7-12 days, P4 (panicle initiation – complete panicle is 8-11 days, P5 (complete panicle- flower initiation) exhibits 7-13 days, P6 (flower initiation – 100% flowering is required 7-10 days, P7 (100% flowering – Milk) tooks 7-10 days, P8 (Milk-Dough) is 8-13 days, and P9 (Dough – Physiological maturity) is 7-13 days. The length of duration of each phenological phase showed slight (few days) variation from crop season to next season due to the exposure of new weather conditions. The variation the duration of phenol-phases for different varieties (Triguna, Shatabdi and Heera), ages of seedling (25 and 32 day) and cropping seasons (2017-18, 2018-19) indicate the use of different amount of radiation and consumption of thermal energy which is playing the major role to achieve different amount of production components and finally the different grain yields in two consecutive years. This phenological phase wise duration of boro rice may carefully be observed and farmers have to be educated about these sensitive phases to proper management of their field crop to avoid the crop damage under any extreme weather condition. The variation of the length of phenol-phases in different varieties may changes the final grain yield of boro rice has already be mentioned by Kobayashi *et al* (2010) where they stated that change of the duration of phenol-phase leads to result to early or delayed fulfillment of thermal requirement for a particular phenol-phases under the different micro - environmental conditions.

Grain yield (kg ha^{-1})

How the grain yield vary significantly across season, variety, spacing and age of seedling was summarized in Table 3. The maximum grain yield (Kg ha^{-1}) was noticed at physiological maturity stage in the Triguna variety by 6020 and 6294 kg hectare in the year 2018 and 2019 respectively. Similarly maximum grain yields (5254 and 5647 kg hectare) was achieved through the wider spacing of 20 cm x 15 cm in the year 2018 and 2019 respectively. However, older seedlings (32 days) the highest grain yields of 5454 and 5647 kg hectare was observed at physiological maturity stage in year 2018 and 2019 respectively.

Table 3: Variation of grain and straw yields of *boro* rice across variety, spacing and age of seedlings

Treatment		Grain and Straw Yield (kg hectare^{-1})			
		2018	2018	2019	2019
Variety		**Grain**	**Straw**	**Grain**	**Straw**
V1 (Shatabdi) (S)		5093	6985	5124	7128
V2 (Heera) (S)		3908	5785	3988	5942
V3 (Triguna) (M)		6020	8194	6294	8432
Sem(±)		8	7	9	8
CD at 5%		24	20	27	23
Spacing					
S1 (20 cm x 15 cm)		5254	7153	5428	7285
S2 (20 cm x 20 cm)		4998	7006	5133	7187
S3 (15 cm x 15 cm)		4769	6805	4845	7029
S.Em(±)		8	7	9	8
CD at 5%		24	20	27	23
Age of seedling					
A1 (32 Days)		5454	7247	5647	7356
A2 (25 Days)		4560	6729	4624	6978
S.Em(±)		7	6	8	7
CD at 5%		20	17	24	21
Interaction					
A X V	S.Em(±)	14	11	15	12
	CD at 5%	42	33	45	36
A X S	S.Em(±)	14	11	15	12
	CD at 5%	42	33	45	36
VX S	S.Em(±)	14	11	15	12
	CD at 5%	42	33	45	36
S X V X A	S.Em(±)	20	16	21	17
	CD at 5%	59	48	63	51

Straw yield (kg ha^{-1})

Similar to grain yield, how the straw yield vary significantly across season, variety, spacing and age of seedling was also summarized in Table 3. Maximum straw yield was noticed at physiological maturity stage in the Triguna variety by 8194 and 8432 (Kg ha^{-1}) in years of 2018 and 2019 respectively. Again wider spacing of 20 cm x 15 cm produced significantly more straw yields 7153 and 7285 (Kg ha^{-1}) at physiological maturity stage in year 2018 and 2019 respectively. As expected the 32 ages of seedling produces more straw yields of 7247 and 7356 (Kg ha^{-1}) at the physiological maturity stage was obtained in year 2018 and 2019 respectively (Table 2).

Conclusions

The growth and development of Boro rice heavily depend on the availability and variation natural resources in terms of moisture contains, thermal regimes prevails through different meteorological parameters in three major and 9 sub-phenological stages of the rice crops. Hence assessment of weather based thermal indices is necessary to properly monitor the crop at field level. The major finding of the present study indicates a slightly change the duration of pheno-phases by 2-3 days in two consecutive crop growing years (2017-18 and 2018-19) imply the different amount of utilization of energy. The amount of energy utilized in various phenological phases by the crops based on the accumulated GDD, HTU, and PTU indicates the Triguna variety consumed more at 25 days age of seedling compared to 32 days age of seedling. The Triguna variety to accumulate more grain yield compared to Shatabdi and Heera varieties.

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