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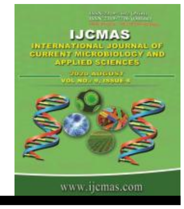

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Assessing the Effect of Agrometeorological Indices on Rainfed Rice Crop at Bhubaneswar (Odisha), India

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ABSTRACT

Keywords

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Field experiment was conducted in *kharif* season at research farm of ICAR-IIWM, Khurdha, Odisha to assess the effect of meteorological indices on rice cv. Lalat under two (2018-19 & 2019-20) growing seasons. The duration of phenological stages and accumulation of agro-climatic indices (GDD, PTU and HTU) were greatly influenced with different growing season and delay in transplanting. The study revealed that the higher GDD, PTU and HTU were accounted on different growth stages at second growing season. Among the seasons and transplanting dates, the meteorological indices accretion was perceived in 2nd growing season as compared to 1st growing season crop. Second season crop had transplanted earlier and get highest heat use efficiency.

Introduction

Weather variability and climate change greatly influence the agricultural productivity at all hemisphere. Production and productivity of every crop has its own definite requirements for particular weather condition for its proper growth, development and gaining optimum yield (Razzaq *et al.*, 1986; Zinn *et al.*, 2010). Temperature is one of the most important weather parameters for regulating and controlling the crop growth and development and plays the role in disease and pest infection. The concept of heat units based on the concept that real time required to achieve the phenological stage is linearly related to temperature in the range between base temperature & optimal temperature. Heat units are considered as the fundamental units used to examine the phenology of crops over climatic variations (Leith, 1974; Sreenivas *et al.*, 2010). Efficiency, utilization of heat in terms of dry matter accretion, depends on crop type, genetic factors & sowing time and it has great practical application on crop production and productivity (Rao *et. al.*, 1999). Delay in transplanting significantly reduced yield and yield attributes (Singh *et al.*, 2004). Growth and yield performance varied with different growing season due to day-to-day changing weather conditions. Temperature based agro-meteorological indices such as growing degree days (GDD) and Heat Use Efficiency (HUE) are quite useful in predicting growth and yield of different crops. Influences on weather situations as well as temperature on phenology and yield of crop plant can be studied under two growing seasons through the accumulated heat unit system (Shankar *et. al.*, 1996). The aim of the present study was to predict pant stages and yield of rice crop using agrometeorological indices in tropical region of Khurdha district of Odisa.

Materials and Methods

Study area

The farm experiment was carried out during kharif season (2018 and 2019) at ICAR-IIWM, Deras, Mendhasal, Khurdha District of Odisha state. Which lies between Latitude 20°17' N and, Longitude 85°41' E; 23 m above sea level. The average annual rainfall of study area is 1428 mm. The rainfall receives mainly through south-west monsoon, which is started from end of June to lasts till October. The weather remains little dry from November to June. Summer season is hot humid and sometimes feel mercury crosses 45.5^{0}C in the May-June while winter is cool and dry. In this reason the warmest average temperature is 31.3^{0}C and lowest average temperature is 21.8^{0}C.

Observations

The rice crop (cv. Lalat) was transplanted on July 2018 and 2019,respectively on 20 cm spaced ridges keeping plant-to-plant distance of 10 cm, with a seed rate of 50 kg ha^{-1} and N:P:K fertilizer dose of 60:30:30. Dates of major phenological stages viz., emergence, transplanting stage, tillering stage, panicle initiation stage, flowering, milking, dough and maturity stages were recorded from the experimental plots. Weather data were recorded from the Agro-meteorological Observatory, situated near the experimental farm and weather variables namely Tmax, Tmin, SSH, wind speed (km/hrs), Rainfall, Air Pressure, RH (%), Soil temperature are recorded daily during growing season 2018 and 2019.

Agro-meteorological Indices

The different agro-meteorological indices, viz. growing degree days (GDD), helio-thermal units (HTU), photo thermal units (PTU), pheno-thermal index (PTI), radiation use efficiency (RUE) and heat use efficiency (HUE) were computed by adopting procedure laid out by Singh *et al.*, 2015.

Growing degree days (GDD)

The sum of the degree days for the completion of each phenophases were obtained by using the following formula:

$$GDD=\Sigma\ [(Tx + Tn)/2 - T_{base}]$$

Where,

Tmax= Daily maximum temperature (^{o}C)
Tmin= Daily minimum temperature (^{o}C)
Tbase= Minimum threshold/Base temperature (^{o}C)

The growing degree days were computed by considering the base temperature of 10 ^{0}C.

Photo thermal Unit (PTU)

The day and night period is one of the basic factors controlling the period of vegetative growth for photosensitive cultivars. In case of long day plants, the length of night is critical for determining, whether plants will enter into reproductive phase or not. Photo-thermal units are the cumulative value of growing degree days, multiplied by bright sunshine hours. This can be mathematically represented by the following formula:

PTU (day °C hour) = GDD X N

Where, N = maximum possible sunshine hour.

Heliothermal Unit (HTU)

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

HTU (day °C hour) = GDD X n
Where, n = actual bright sunshine hours (n).

Phenothermal index (PTI)

Phenothermal index the ratio of degree days to the number of days between two phonological stages was calculated was determined according to the equation:

PTI(°C) =GDD/Number of days between two phenological stages.

Radiation use efficiency (RUE)

The radiation use efficiency is a ratio of biological yield and the radiation intercepted. It can be represented by using the following formula:

RUE (gMJ^{-1}) = Biomass (g /m^2) / PAR (MJ/m^2/day)

Where, PAR is cumulative intercepted photo synthetically active radiation.

Line Quantum sensor was used to measure the amount of intercepted radiant energy (PAR in the range of 380-700 nm) above the crop surface and ground surface keeping the sensor 5 cm above the surface. The observations were record at different growth stages. The intercepted PAR (IPAR) was measured following relationship:

$I_i = I_0 - I_{re} - I_t + I_{rg}$
I_i (%) by the canopy= $(I_i/I_0)*100$

where,

Ii = Intercepted photosynthetic active radiation (PAR) by the canopy
I0 = Incident PAR on the canopy
Ire = Reflected PAR by the canopy
It = Transmitted PAR through the canopy
Irg = Reflected PAR from the ground.

Heat use efficiency (HUE)

Heat use efficiency is also represented by thermal time use efficiency (TTUE), which indicates the amount of dry matter produced per unit of growing degree days or thermal time. This was computed by using the following formula:

$$\text{HUE } (g/m^{2}\,{}^{0}C\ day^{-1}) = \frac{\text{Biomass } (g/m^2)}{\text{GDD } ({}^{0}C\ days)}$$

Where, GDD is growing degree days.

Results and Discussion

Accumulated Growing Degree Days (AGDD)

The accumulated growing degree days (AGDD) to reach various growth stages and showed relative variation among two crop growing seasons which are presented in Table-1. 2^{nd} season (2019) crop higher accumulated of growing degree days at various phenophases (9820^0C day) whereas, 1^{st} growing season shows less accumulated GDD(9608^0C day). Table-1 shows that because crop was transplanted earlier in season 2019 as compare to season 2018. So, first season crop phases high temperature an all the phases and thus duration of maturity was shortened.

Accumulated Helio-thermal Units (AHTU)

The accumulated helio-thermal units (AHTU) accumulated by the crop to attain under different phenophases in both growing seasons are shown in Table-1. The 2nd growing season (2019) crop accumulated highest AHTU (55602^{0}C day)whereas, 1st growing season crop less accumulated (46830^{0}Cday) and the mean accumulated HTU was calculated 51216^{0}C day of both crops growing season. Reduction in HTU under late growing season from the normal sowing time indicated that the crop used more heat units under crop sown early rather than later crop growth stages. Similar results were reported by Solanki *et al.,* 2015.

Accumulated Photo-thermal Units (APTU)

The accumulated photo-thermal units (APTU) showed considerable variation under two growing seasons where, 2ndgrowing season (2019) crop accumulated highest APTU (117911^{0}C day) whereas, 1stgrowing season crop less accumulated (117162^{0}C day) and the mean accumulated PTU was calculated 117537 ^{0}C day of both crops growing season. In 2nd season transplanted crop, higher values of agrometeorological indices (GDD, HTU and PTU) were accumulated to attain physiological maturity as compared to 1stseason crop sown.

Phenothermal Index (PTI)

The phenothermal index (PTI) showed least variation under two growing season and the results obtained are presented in Table 1. The 1st growing season (2019) crop Index was highest PTI (158) whereas, 2nd growing season crop was obtained less (156) index. And the mean PTI was calculated 157 Index of both crops growing season.

Radiation Use Efficiency (RUE)

The most important aspect of crop development affecting the dry matter production that is concerned with the development of leaf canopy and its effect on the efficiency of radiation interception. Radiation use efficiency (RUE) of Rice showed relatively least variations and are presented in Table-2.

RUE at 1st growing season was observed 0.52, 1.29, 1.27, 1.33, 1.39, 1.53 g/MJ and second growing season 0.64, 1.47, 1.55, 1.53, 1.72, 1.87 g/MJ at 30, 45, 60, 75, 90 and physiological maturity days growth interval respectively. RUE based on biological yield was highest in 2nd growing season (1.46 g/MJ) whereas lowest in 1st growing season (1.22g/m^2/^{0}C day).

During the reproductive phases of crop growth period was obtained highest RUE in both the crop growing season. RUE arose variation due to the differential in dry matter production in two seasons while intercepting different amount of radiation because of variation in canopy surface and the LAI.

Heat Use Efficiency (HUE)

The Heat use efficiency (HUE) of rice crop for biomass production under two different growing seasons are presented in Table-2. HUE at 1st growing season was observed 0.36, 0.58, 0.68, 0.64, 0.59, 0.47 g/m^2/^{0}Cday and second growing season 0.37, 0.65, 0.71, 0.66, 0.62, 0.49 g/m^2/^{0}Cday at 30, 45, 60, 75, 90 and physiological maturity days growth interval respectively.

Table.1 Comparison of AGDD, AHTU, APTU and PTI to attain various phenophases in two growing season 2018-19 & 2019-20 of rice crop

Crop season	Sowing	Emergence date	Transplanting date	Tillers	Panicle initiations	Flowering	Milking	Dough	Maturity	Total
AGDD										
2018	21	139	402	727	1109	1504	1637	1875	2194	9608
2019	20	139	315	810	1189	1641	1739	1868	2100	9820
Mean	20	139	359	768	1149	1572	1688	1872	2147	9714
AHTU										
2018	48	1098	1648	4725	2329	4812	10315	8252	13603	46830
2019	57	293	520	2065	2021	11322	11216	10368	17741	55602
Mean	52	695	1084	3395	2175	8067	10766	9310	15672	51216
APTU										
2018	273	1835	5306	9304	14196	18496	20139	21942	25670	117162
2019	257	1840	4161	10367	14501	20018	20345	21857	24565	117911
Mean	265	1838	4734	9835	14349	19257	20242	21899	25118	117537
PTI										
2018	0	23	19	20	19	19	19	19	19	158
2019	0	23	20	19	19	19	19	19	19	156
Mean	0	23	19	19	19	19	19	19	19	157

Table.2 Comparison of Radiation use efficiency (RUE) and Heat use efficiency (HUE) to obtained various growth interval in two growing season 2018-19 & 2019-20

Crop season	30	45	60	75	90	Maturity	Mean
RUE (g/MJ)							
2018	0.52	1.29	1.27	1.33	1.39	1.53	1.22
2019	0.64	1.47	1.55	1.53	1.72	1.87	1.46
Mean	0.58	1.38	1.41	1.43	1.55	1.70	
HUE (g/m^2/^{0}Cday)							
2018	0.36	0.58	0.68	0.64	0.59	0.47	0.55
2019	0.37	0.65	0.71	0.66	0.62	0.49	0.58
Mean	0.37	0.62	0.69	0.65	0.60	0.48	

The highest mean (0.58 g/m^2/^{0}Cday) HUE for dry matter production in 2nd growing season whereas, low mean (0.55 g/m^2/^{0}Cday) HUE in 1st growing season was obtained. Among these two growing seasons the reproductive phases of the crop reported highest HUE due to the high LAI and highest photosynthetic rate in this growth period. It means that the early sown crop used heat, more deficiency as compare to late sown crop. The early sown crop has highest heat use efficiency and it decreased with delay in sowing (Keerthi *et al.*, 2016).

The present study indicated that the timely sowing played important role in determining the arrival of different phenological stages and grain yield. The timely crop sowing took higher thermal times as compared to delayed sowing. The heat units *viz.* accumulated growing degree days, photo thermal unit, helio thermal unit, radiation use efficiency and heat use efficiency were recorded highest in crop sown on second season as compared to first season. It can be concluded that variability on weather parameter occurs from one season to another season which affect the production and productivity of crop.

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