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Research Article

EVALUATION OF GROWING DEGREE DAYS (GDD) VALUES OF EARLY, NORMAL AND LATE SOWING DATES IN DIFFERENT GENOTYPES OF RICE (*Oryza sativa* L.)

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Abstract- Rice is the most important food crop which feeds more than half of world population. Rice is not only major staple food crop but also has shaped the culture, diet and economy of thousands of millions of people all around the globe. A field experiment on rice (*Oryzae sativa* L.) taking three sowing dates *viz.*25th May, 2014, (Early sown) 12th June, 2014 (normal sown), 27th June, 2014 (Late sown) and fifteen rice genotypes namely IET20924, IET22569, IET22580, IET23275, IET23299, IET23300, IET23324, PHY1, PHY2, PHY3, LALAT, MTU1010, PR113, SASYASREE and IR64 were conducted at Norman E. Borolaug Crop Research Centre & Department of Plant Physiology, Govind Ballabh Pant University of Agriculture and Technology, Pantnagar, Udham Singh Nagar (Uttarakhand) during kharifseason for the purpose to evaluate the heat efficiency of rice crop. Mostly the farmer's use calendar days for prediction of plant growth and development and calendar days could be misleading for the prediction of crop growth for different crop management decisions as temperature varies widely from year to year. Growing degree days (GDD) are the simple and accurate method to predict that when a particular plant stage will occur. Growing degree days (GDD), sometimes also called thermal days, are a unit of measure describing the amount of accumulated heat through the growing season. From this study, we concluded that genotypes sown under early condition were given best results in term of yield parameters this is because early sown genotypes accumulated more number of growing degree days as compared to normal and late sown genotypes which is positively related to all yield attributes.

Key word- Growing degree days (GDD), Heat units, Calendar days, Thermal days.

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Introduction

Rice is the most important food crop of the world and a primary source of food for more than half of the world's population. More than 90% of the total rice is grown and consumed in Asia where 60% of the world's population lives. Rice is being planted on about 154 million hectares annually and which is about 11% of the world's cultivated area. Rice provides more than 20% of the total calories. Rice is good source of carbohydrates especially, brown rice. Rice also offers high fiber, vitamin B and proteins. Rice can be included in a balance diet as it has no fat, no cholesterol and it is free from sodium. Rice also provides a good amount of vitamins and minerals such as thiamine, niacin, iron, riboflavin, vitamin D, calcium, and fiber. Brown rice contains a good amount of insoluble fiber that is believed to be helpful in protecting human body from cancer [1].

Most of the farmers used calendar days to predict the plant growth and development. Calendar days could be misleading for the prediction of crop growth for different management decisions because temperature varies greatly from year to year. Growing degree days (GDD) are the simple and accurate method to predict that when a particular plant stage will occur. Each developmental stages of the crop have its own heat requirement. Crop development can be estimated by accumulated degree days throughout the season. Delayed sowing not only restricts the accumulation of heat units but also slows down the vegetative growth and leads to forced maturity due to onset of winter which leads to decrease in yield [2].

The objective of our study was:

1. To calculate GDD values for early, normal and late sown genotypes of rice.
2. To evaluate biological yield, economical yield of early, normal and late sown genotypes of rice.

Material and Methods

The field experiment was carried out at Norman E. Borolaug Crop Research Centre & Department of Plant Physiology, Govind Ballabh Pant University of Agriculture and Technology, Pantnagar, Udham Singh Nagar (Uttarakhand) during kharifseason for the purpose to evaluate the photothermic behavior of early (25th May, 2014), normal (12th June, 2014) and late (27th June, 2014) sowing dates in different genotypes of rice (*Oryza sativa* L.).

General description of the experimental area

Experimental area

The field experiment was conducted at the time of kharif season and the experimental site was rice physiology block of Norman E. Borolaug Crop Research Centre & Department of Plant Physiology, Govind Ballabh Pant University of Agriculture and Technology, Pantnagar, Udham Singh Nagar (Uttarakhand). Geographically, the site lies in Tarai plains about 30 km southwards of foothills of Shivalik range of the Himalayas at 29° N latitude, 79° 29'E longitude and at an altitude of 243.8 meter above the mean sea level.

Experimental material

The rice genotypes namely IET20924, IET22569, IET22580, IET23275, IET23299, IET23300, IET23324, PHY1, PHY2, PHY3, LALAT, MTU1010, PR113, SASYASREE and IR64 were obtained from the Directorate of Rice Research, Rajendranagar, Hyderabad. The field experiment was carried out in three separate independent split plot designs with three replications.

Statistical design and layout

The field experiment was carried out with three treatments and three replications of each entry in split plot design. The main plot treatments were the date of sowings and the subplot treatments were the different genotypes. The plots were separated from each other with proper spacing (20x20) and the experimental field was bordered by proper bunds.

Experimental details

There were three sowing dates as the main treatment i.e. early sowing (25th May 2014), normal sowing (12th June2014) and late sowing (27thJune2014). Transplantation of 21 days seedling was done at interval of 15 days in all the three sowing dates.

Design	:	Split Plot Design (SPD)
Gross plot Size	:	540m^2
Individual plot size	:	1m^2
Number of rows	:	15
Number of columns	:	9
Number of replications	:	3
Number of treatments	:	3
Spacing between rows	:	20cm
Spacing between hills	:	20cm
Number of entries	:	15

Accumulated growing degree days (GDD)

Growing degree days is a way of assigning a heat value to each day. The values are added together to give an estimate of the amount of seasonal growth of plants.

GDD = Σ [(Tx + Tn) / 2 – Base temperature]

Tx=Daily maximum temperature

Tn=Daily minimum temperature

Base temperature is the lowest temperature where metabolic processes result in a net substance gain in aboveground biomass.

n= actual sunshine hour.

Grain Yield / Economic yield (g/m^2)

Economic yield is the grain yield of the crop and it was recorded from each plot after harvesting.

Biological yield (g/m^2)

Biological yield refers to the total yield of the plant material. Each plant from all subplots was uprooted from the ground level at the time of maturity and the weight of the whole plant before thrashing was recorded as biological yield.

Harvest index (%)

The term "harvest index" is defined as the yield of a crop species versus the total amount of biomass that has been produced.

$$\text{Harvest index} = \frac{\text{Economical Yield}}{\text{Biological Yield}} \times 100$$

Result and Discussion

Accumulated growing degree days (GDD)

Prevailing weather and climatic conditions greatly influence the agricultural productivity of the crop. Crop yield of a particular area depends on its climatic conditions, temperature, sunshine hours, light intensity and radiation. Rice development depends on temperature and light and it requires a specific amount of heat to switch over from one growth stage in their lifecycle to another, such as from seeding to the harvest stage. Temperature plays a very important role for the biological processes and hence the growth and development of plants. Various forms of temperature summations, commonly referred to as thermal units or growing degree days, have been utilized in numerous studies to predict phenological events for different crops. Growing degree days is a method of assigning a heat value to each day. Heat units are involved in several physiological processes. Plants required specific amount of heat at each stage in its life cycle. Its values are different for different varieties. Growing degree days are used to find out the suitability of a particular region for the production of a particular crop, determine the growth stages of crops, predict the best timing for application of fertilizer, herbicide and plant growth regulators, estimate heat stress accumulation on crops, predict physiological maturity and harvesting dates [3]. Growing degree days (GDD) was calculated for different genotypes at maturity stage under early, normal and late sowing dates. Data presented in [Table-1] and [Fig-1] reflects GDD values of different genotypes of rice at maturity stage in three sowing dates.

Table-1 *Accumulated growing degree days (GDD) values at maturity stage under early, normal and late sown conditions in different genotypes of rice. (± indicates SE)*

Genotypes	Growing degree days (GDD) at maturity stage			
	Early	Normal	Late	Mean
IET20924	2667.43±210.78	2488.80±22.70	2267.83±4.52	2474.68
IET22569	2540.31±12.22	2437.23±99.74	2281.50±107.68	2419.68
IET22580	2486.95±136.53	2305.15±6.25	2236.51±7.92	2342.87
IET23275	2381.91±33.34	2399.43±45.91	2317.65±7.28	2366.33
IET23299	2419.50±27.15	2296.35±39.70	2189.40±13.13	2301.86
IET23300	2401.15±22.51	2256.73±147.22	2194.11±16.92	2284.00
IET23324	2363.30±16.94	2272.55±35.27	2227.11±19.77	2287.65
PHY1	2528.25±6.18	2348.10±75.55	2265.76±33.48	2380.70
PHY2	2657.26±111.94	2493.33±27.23	2342.45±29.13	2497.68
PHY3	2425.83±28.55	2263.63±34.98	2164.53±23.28	2284.66
LALAT	2763.51±31.68	2488.95±12.11	2340.43±162.77	2530.96
MTU1010	2400.80±31.09	2290.03±25.56	2213.63±9.23	2301.48
PR113	2540.31±157.18	2488.80±135.60	2279.50±23.03	2436.20
SASYASREE	2883.81±31.43	2571.56±18.95	2361.41±18.24	2605.60
IR64	2405.60±56.23	2262.96±26.23	2247.66±9.10	2305.41
Mean	2524.42	2377.57	2261.96	2387.98
	Treatment (T)	Variety (V)	T X V	
S.Em. ±	40.65	70.11	70.25	
CD at 5%	114.32	198.02	203.83	

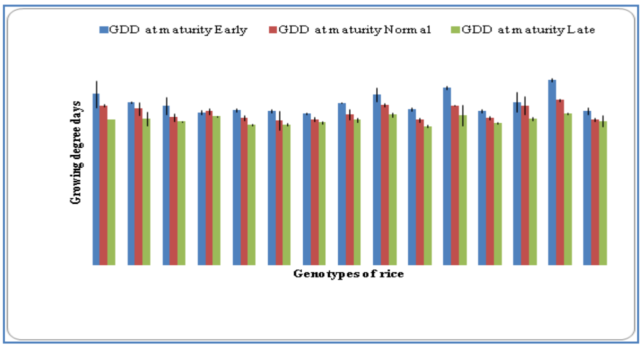

Fig-1 Accumulated growing degree days (GDD) values at maturity stage under early, normal and late sown conditions in different genotypes of rice. (± indicates SE)

Biological and Grain yield (g/m^2)

Biological yield is the total biomass produced by the plant. The yield capacity of the rice is primarily dependent on both vegetative and reproductive phase. The actual yield is determined during flowering and grain filling stages. During anthesis the capacity for photosynthesis is high and that photosynthesis is not limiting during grain filling. Grain yield is closely related to the net photosynthetic assimilation of CO_2 throughout an entire season. Large increases in the yield can be obtained by increasing the rates of net photosynthesis and translocation of carbohydrates and enlarging the storage capacity by selection and breeding programs. Flowering is very important parameter in rice as flowering leads to grain formation. In addition, flowering behavior serves as a criterion for identifying those genotypes which are photoperiod sensitive. Spikelets per panicle, percentage of filled spikelets, and the number of filled grains are determined by the source capacity and translocation efficiency of the plant. Temperature affects the filled-grain percentage by controlling the capacity of the grains to accept carbohydrates and also affects the length of the ripening period, which is inversely proportional to the mean daily temperature [4]. Different yield components such as the number of panicles per unit land area, the number of spikelets per panicle, the percentage of filled spikelets, and 1000-grain weight determines the grain yield. The number of panicles has marked effect on the grain yield, but there is a negative correlation between the number of panicles per unit land area and spikelets per panicle and between spikelets per unit land area and filled-grain percentage or 1000-grain weight [5]. High temperature stress reduces the photosynthetic production capabilities of rice and this is one of the major reasons for the reduction of the grain yield [6]. Data presented in [Table-2] and [Fig-2] demonstrates the biological yield of the crop in g/m^2. These findings show the similarity with the work done by earlier scientists [7]. Data presented in [Table-3] and [Fig-3] demonstrates the grain yield of the rice crop under three different sowing conditions. These results showed similarity with the work done by earlier workers [8]. Genotypes grown under early sown condition were recorded best yields both in terms of biological yield and economical yield. Delayed sowing not only decreased the yield but also affected grain quality. Decrease in yield attributes like and biological yield are due to delay in sowing dates which contributes to overall decrease in grain yield of the crop. Main reason for the decrease in yield is decrease in growing degree days, longer photoperiod and higher temperature during reproductive stage. The late sown genotypes matures in shorter period of time as compared to early and normal sown genotypes as there was onset of winter. Thus late sown crops takes less number of growing degree days due to which different yield components decreases and hence economic yield of the crop suffers negatively [9]. Breeding for the photo insensitive varieties would be one of the objectives of the rice breeders to overcome this problem. In current circumstances, varieties suitable for late sowing are the need of the growers in order to avoid yields losses due to delayed sowing.

Table-2 *Biological yield (g/m^2) of the crop under early, normal and late sown conditions in different genotypes of rice. (± indicates SE)*

Genotypes	Biological yield (g/m^2)			
	Early	Normal	Late	Mean
IET20924	2216.66±98.24	2333.33±154.33	2025.00±80.36	2191.66
IET22569	2200.00±80.36	2108.33±87.00	1700.00±101.03	2002.77
IET22580	2058.33±91.66	1966.66±116.66	1750.00±0.00	1925.00
IET23275	2191.66±12.44	1941.66±96.10	1641.66±74.06	1925.00
IET23299	2125.00±90.13	2116.66±46.39	1525.00±62.91	1922.22
IET23300	2091.66±126.10	1733.33±101.37	1483.33±30.04	1769.44
IET23324	1833.33±91.66	2150.00±144.33	1641.66±71.20	1875.00
PHY1	2250.00±152.06	1875.00±112.73	1708.33±41.66	1944.44
PHY2	2275.00±187.63	1875.00±80.36	1833.33±83.33	1944.44
PHY3	1375.00±80.36	1373.33±64.57	1433.33±87.28	1393.88
LALAT	2881.66±151.66	2508.33±108.33	1933.33±112.11	2441.11
MTU1010	2116.66±129.36	1750.00±80.36	1358.33±68.21	1741.66
PR113	1608.33±115.77	2058.33±121.04	1425.00±66.14	1697.22
SASYASREE	3225.00±284.31	2516.66±108.33	2091.66±46.39	2611.11
IR64	1791.66±72.64	1683.33±46.39	1358.33±87.00	1611.11
Mean	2149.33	1999.33	1660.55	1936.40
	Treatment (T)	Variety (V)	T X V	
S.Em. ±	52.59	90.71	101.80	
CD at 5%	147.90	256.18	316.52	

Solar radiation is the primary energy source, which is one of most important processes for the soil and the plants, such as evapotranspiration, biomass partitioning, stomatal conductance, carbon exchange and water use efficiency. The requirements of Growing Degree days (GDD) values for early sowing conditions were higher than of normal and late sowing conditions with few exceptions. The variation of sunshine hours recorded at different developmental stages of rice has affected the magnitudes of the heliothermal unit (HTU). The influence of temperature on phenology and yield of the crop are expressed through accumulated heat unit system. The unusual weather during reproductive period of a crop adversely affects the crop productivity. Although the climate is the least manageable part of environmental resources, yet a better understanding of the climatic resources and their interactions with agricultural parameters can help to increase the crop productivity [10].

Table-3 *Grain yield (g/m^2) of the crop under early, normal and late sown conditions in different genotypes of rice. (± indicates SE)*

Genotypes	Grain Yield(g/m^2)			
	Early	Normal	Late	Mean
IET20924	1050.00±73.01	978.33±73.83	726.66±42.60	918.33
IET22569	904.33±21.83	753.66±113.69	692.66±13.67	783.55
IET22580	912.66±88.24	846.66±39.85	723.33±17.32	827.55
IET23275	1005.33±20.51	857.00±64.25	638.33±37.88	833.55
IET23299	908.33±45.57	949.66±42.14	630.33±55.75	829.44
IET23300	938.00±47.43	820.00±34.82	523.66±33.41	760.55
IET23324	772.00±32.04	1046.00±81.09	774.00±35.93	864.00
PHY1	875.00±33.06	818.00±70.19	739.66±32.17	810.88
PHY2	613.33±10.83	498.00±46.36	449.00±336.50	520.11
PHY3	534.00±26.00	592.00±26.05	457.00±30.00	527.66
LALAT	1179.33±74.29	1056.66±32.19	709.00±13.45	981.66
MTU1010	888.00±50.71	720.33±46.39	559.66±13.86	722.66
PR113	734.66±50.01	926.00±45.08	604.33±45.95	755.00
SASYASREE	1289.00±89.60	985.33±14.99	737.33±15.62	1003.88
IR64	679.00±20.88	759.66±38.61	623.66±13.42	687.44
Mean	885.53	840.48	639.24	788.42
	Treatment (T)	Variety (V)	T X V	
S.Em. ±	24.80	42.77	44.26	
CD at 5%	69.74	120.80	131.24	

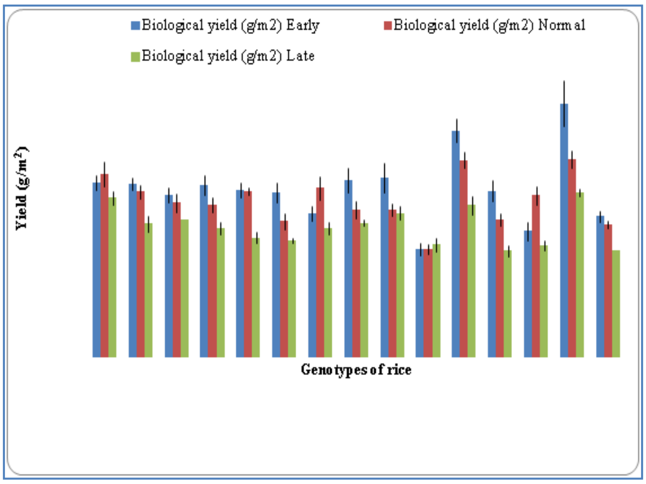

Fig-2 Biological yield (g/m^2) of the crop under early, normal and late sown conditions in different genotypes of rice. (± indicates SE)

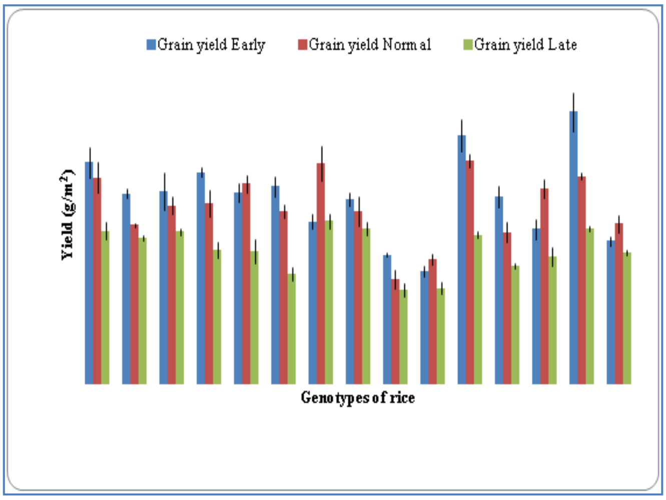

Fig-3 Grain yield (g/m^2) of the crop under early, normal and late sown conditions in different genotypes of rice. (± indicates SE)

Harvest index

Harvest index is a measure of efficient partitioning of the assimilated sugars. An improvement in the harvest index means the improvement in the economic portion of the plant. In reproductive stage a portion of the plant biomass get partitioned into various yield components which determines the crop harvest index. Harvest index is the ratio of grain yield to the total biomass. Harvest index is considered as a measure of efficiency of crop in partitioning its assimilated photosynthates to the harvestable product. Harvest index of the crop can be improved if the genotypes are grown with optimal management practices. Harvest index of rice is the result of various integrated processes which involves the number of panicles per unit area, the number of spikelets per panicle, the percentage of fully ripened grains, and thousand grains weight. It was found that harvest index was negatively correlated with the plant height and positively correlated with the grain number per panicle, test weight of grains and yield per plant [11]. Harvest index is highly influenced by the environmental factors such as soil condition, stemperature and solar radiation.

Data presented in [Table-4] and [Fig-4] reflects the harvest index of rice genotypes grown under different sowing conditions.

Table-4 *Harvest index (%) under early, normal and late sown conditions in different genotypes of rice. (± indicates SE)*

Genotypes	Harvest Index (%)			
	Early	Normal	Late	Mean
IET20924	47.36±1.61	41.92±2.80	35.88±2.78	41.72
IET22569	41.10±2.97	35.74±1.17	40.74±3.38	30.19
IET22580	44.33±3.34	43.05±2.41	41.33±0.99	42.90
IET23275	45.87±1.08	44.13±0.81	38.88±0.70	42.96
IET23299	42.74±0.79	44.85±1.13	41.33±0.81	42.97
IET23300	44.84±1.41	47.30±2.58	35.30±2.83	42.48
IET23324	42.10±1.71	48.65±1.03	47.14±3.38	45.96
PHY1	38.88±1.37	43.62±1.15	43.29±1.56	41.93
PHY2	26.95±2.25	26.56±2.64	24.44±2.61	25.98
PHY3	38.83±0.47	43.10±0.59	31.88±0.84	37.93
LALAT	40.92±1.42	51.33±1.05	36.67±1.85	42.97
MTU1010	41.95±3.40	41.16±1.33	41.20±1.49	41.43
PR113	45.67±4.08	44.98±1.00	42.40±3.72	44.35
SASYASREE	39.96±0.72	39.15±1.18	35.25±1.04	38.12
IR64	37.89±1.33	45.12±1.97	45.91±2.80	42.97
Mean	41.29	42.71	38.77	40.32
	Treatment (T)	Variety (V)	T X V	
S.Em. ±	0.11	1.90	2.02	
CD at 5%	3.10	5.37	6.15	

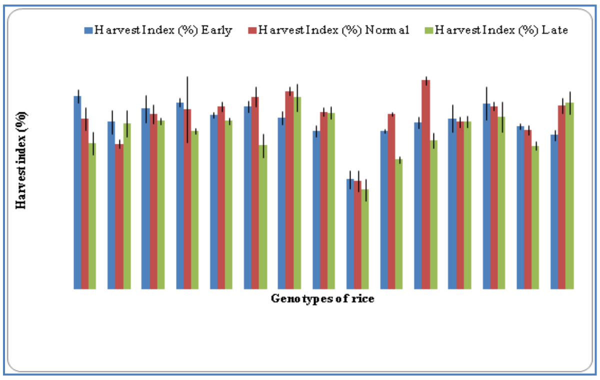

Fig-4 Harvest index (%) under early, normal and late sown conditions in different genotypes of rice. (± indicates SE)

Conclusion

Rice genotypes grown under early sowing conditions received longer photoperiod and accumulated higher number of GDD so they produce good biological yield as compared to normal and late sown rice genotypes. But in case of harvest index some normal and late sown genotypes attains good harvest index this was due to good source and sink relationship. Short photoperiod induces high partitioning of assimilates to rice grains. The information obtained in this study is extremely important for timely incorporation of various agricultural operations and prediction of best varieties suited for particular region.

Application of Research: In future farmers can use growing degree days values for prediction of best suitable varieties for particular regions and can utilize these values for appropriate management practices like fertilizer application and irrigation.

Research Category: Agriculture and Environment

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Author Contributions: All author equally contributed

Author statement: All authors read, reviewed, agree and approved the final manuscript

Conflict of Interest: None declared

Ethical approval: This article does not contain any studies with human participants or animals performed by any of the authors.

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