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Evaluation of photothermic indexing in early, normal and late sowing dates in different rice genotypes

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Abstract
Rice *(Oryza sativa* L.*)* is the main staple food of our country as well as two third of the world's population. In Asia, it is feeding about 3.5 billion people which accounts for more than 90% of total rice production. Both biotic and abiotic factors affect the production of rice. Temperature and light have their simultaneous effects on the growth and development of the rice crop. For successful rice production, suitable transplanting dates can result into vigorous vegetative as well as reproductive growth. The response of rice genotypes to sowing date is very important when looking for the best varieties for a particular region. To understand physiological and biochemical basis of grain yield in rice (*Oryza sativa* L.) different rice varieties were grown in early (25th May), normal (12th June) and late sown (27th June) conditions and the field experiment was conducted at Norman E. Bourlog Crop Research Center, G. B. Pant University of Agriculture and Technology, Pantnagar during kharif season 2014 with different rice genotypes, namely, IET20924, IET22569, IET22580, IET23275, IET23299, IET23300, IET23324, PHY1, PHY2, PHY3, LALAT, MTU1010, PR113, SASYASREE and IR64. Differences of about fifteen days were kept in sowing dates of early, normal and late sown conditions. After critical analysis, it was observed that early sown condition was best suited for higher grain production because in early sown condition the crop gets more time for vegetative growth and a better light and temperature coordination for its strong establishment.

Keywords: sowing dates, reproductive growth, early sown genotypes

1. Introduction

Globally rice is the second most important cereal crop following only maize. About 482 million metric tons of husked rice was produced in the last harvesting year worldwide. China was the world's leading producer of paddy, with a production volume of over 210 million metric tons in 2017 followed by India. 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. In India, rice is cultivated in almost all states and it covers more than 30% of the total cultivated land. The cultivation of rice is mainly localized in coastal regions, river valleys deltas of north eastern and southern regions of India. States like Andhra Pradesh, Assam, West Bengal, Kerala, Bihar, Uttar Pradesh, Orissa, Tamil Nadu, Maharashtra, Chhattisgarh and Karnataka are popularly known for the rice cultivation and also contribute 97% of total India's rice production (Khush, 2005) [1].

Photosynthetic products lead to more than 90% of total biomass in case of rice. So by improving photosynthetic efficiency will increase the crop yields (Makino, 2011) [2]. Photosynthesis, biomass production and grain yield can be improved by increasing crop growth duration for capturing more amount of solar radiation. Sowing dates for paddy cultivation affects performance of the crop. For obtaining good yield it is very important to transplant rice at optimum period of time. Too early transplanting slows down germination rate, emergence and increases risk of soil born diseases. Transplanting rice after optimum sowing dates offers a short vegetative period which may results into decrease yields, lodging and possibly cold damage (Mosavi *et al.*, 2012) [3]. Shifting in transplanting dates can also be used as a strong tool for the improvement in rice yield (Darko *et al.* 2013) [4]. Considering the impacts related to studies of light and temperature in rice growth and development the present investigation was carried out with the objectives of evaluating yield components, physiological and biochemical caracterization in different genotypes of rice under early, normal and late sown conditions.

2. 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 kharif season of 2014 for the purpose to evaluate the photothermic behavior of early, normal and late sowing dates in different genotypes of rice (*Oryza sativa* L.).

2.1 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 design with three replications.

2.2Nursery preparation
Seeds were raised in nursery by dry bed method. The nursery was continuously examined for the pest and disease infection.

2.3 Field preparation and transplanting
Before one week of transplanting the field was harrowed. Layout of the field was made with proper spacing and bunds. The field was divided into nine rows, three rows early sown, three rows of normal sown and three rows of late sown seedlings with proper randomization. Within each plot row spacing of 20x20 cm was maintained. Transplanting was done 21 days after sowing. Before transplanting the field was puddle with water.

2.4 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 (20cmx20cm) and the experimental field was bordered by proper bunds.

2.5 Experimental details

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

2.6 Agronomical, morphological and physiological observations
Three plants were randomly selected from each subplot and observations were recorded. The following traits have been taken into consideration

2.6.1 Number of tillers per plant
This stage extends from the appearance of the first tiller to the appearance of the maximum tiller. Tiller emerges from the auxiliary bud of the nodes from main stem. After emerging, primary tiller gives rise to the secondary tiller and it takes around 30 days from date of transplanting. The number of tillers was recorded by taking average number of shoots of three randomly selected plants from each entry at maximum tillering stages.

2.6.2 Days to panicle initiation
Days to panicle initiation is the number of days from date of sowing to the date of appearance of the panicle primordial. Initially panicle appears to be dome shaped structure and can be observed by dissecting the base of the tiller with the help of the blade.

2.6.3 Total dry matter (g/m^2) at different stages
The dry matter is the measurement of the mass of something when it is completely dry. The dry matter of the rice plant is its solid contents i.e. all its constituents except water. Total dry matter was recorded at three growth phases including maximum tillering, 50% flowering and maturity. TDM can be calculated by placing the plant sample in oven at 65^0C for three days.

2.6.4 Primary and secondary branches per panicle
Primary branches extend from panicle base to the apex. From primary branch secondary branches develop. Three panicles at the end of flowering stage were taken from each hill. The primary and secondary branches per panicle were counted and estimated by taking average.

2.6.5 Days to maturity
Stage of maturity was attained when 90% of the panicles turned yellow. Days to maturity were recorded by calculating the number of days from the date of sowing to the date of maturity.

2.6.6 Thousand grains weight
One thousand well developed dried grains were randomly selected from each replication and weighed. Thousand grains weight were recorded in grams up to two decimal place.

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

2.6.8 Amylose content of grains
Amylose content of grains was estimated in rice grain by using the method described by **McCready and Owens, 1950.**

Reagents
- **Distilled ethanol**
- **Sodium hydroxide (1N NaOH):** 40 g NaOH dissolved in 1000 ml distilled water.
- **Phenolphthalein (0.1%):** 0.1 g phenolphthalein in 100 ml distilled water.
- **Iodine reagent:** 1 g iodine and 10 g KI was dissolved in water and volume was made up to 500 ml.
- **Amylose standard:** 100 mg amylose was dissolved in 10 ml 1N NaOH and volume was made upto 100 ml with distilled water.

Standard curve
Standard amylose solution ranging from 100-1000µg was taken in different clean and dry test tubes and 20 ml distilled water was added and then three drops of phenolphthalein.

After this, 0.1 N HCl was added drop by drop until the pink color just disappeared. Then 1 ml of iodine reagent was added and volume was made upto to 50 ml with distilled water and absorbance was recorded at 590 nm using dilute iodine reagent (dilute 1 ml of iodine reagent to 50 ml with distilled water) as blank. The standard curve was prepared and used for amylose estimation**.**

Amylose extraction

Rice grains were dehulled and grind with the help of pestle & mortar. 500 mg of powered sample was weighed, and 1 ml of distilled ethanol was added followed by 10 ml of 1N NaOH and volume was made up to 50ml and left it for overnight. 2.5 ml of the extract was taken and 20 ml distilled water was added followed by three drops of phenolphthalein. After this, 0.1 NHCl was added drop by drop until the pink colour just disappeared. Then 1 ml of iodine reagent was added and the volume was made upto 50 ml and absorbance was recorded at 590 nm using dilute iodine reagent as blank. Amylose content was calculated by using standard.

3. Result and Discussion

3.1 Number of tillers per hill

Tillers are the extra shoots that develop at the stage of 4-5 leaves. More tillers start developing from the main stem and each one is called a new tiller. Tillering in rice is very important trait for the high grain production. Effective tillers are specialized grain bearing branches that are formed on the unelongated basal internodes. These tillers grow independently of the mother stem by means of its adventitious roots. The extent of tillering depends on different environmental factors such as spacing, light, temperature, nutrient supply and cultural practices.

Maximum number of tillers per hill was attained by early sown genotypes followed by normal and late sown genotypes. The results at the present investigation followed the similar trend as reported by earlier workers (Khalifa *et al.,* 2012) [6].

At 3-5 weeks after sowing, temperature slightly affects the tillering and relative growth rate. Tiller numbers per hill determines the panicle number per plant which is the important factor in determination of grain yield. Early sown rice genotypes recorded high number of tillers per hill shows a greater inconsistency in mobilizing assimilates and nutrients throughout the plant and resulting in variations in grain yield as they get the sufficient time for their vigorous vegetative growth (Yoshida, 1983) [7].

Table 1: Number of tillers per hill at maximum tillering stage under early, normal and late sown conditions in different genotypes of rice (±indicates SE)

Genotypes	Tiller number per hill			
	Early	Normal	Late	Mean
IET20924	13.53±0.56	11.10±0.58	6.55±0.10	10.39
IET22569	13.76±0.55	10.74±0.42	9.33±0.50	11.27
IET22580	11.22±0.88	10.16±0.80	9.55±0.22	10.31
IET23275	12.66±0.88	10.73±0.59	10.77±0.77	11.39
IET23299	12.88±0.55	9.73±0.86	8.88±0.48	10.50
IET23300	11.66±0.19	9.50±0.58	8.77±0.39	9.97
IET23324	11.44±0.58	11.2±0.58	8.55±0.29	10.39
PHY1	14.66±0.19	10.76±0.39	11.21±0.29	12.21
PHY2	11.53±0.78	9.30±0.51	6.99±0.19	9.27
PHY3	12.54±0.39	10.06±0.39	10.66±0.38	11.09
LALAT	15.53±0.48	10.33±0.66	11.88±0..94	12.58
MTU1010	12.21±0.10	10.30±0.17	10.44±0.29	10.98
PR113	12.10±0.29	8.73±0.46	7.88±0.39	9.57
SASYASREE	15.10±0.39	10.30±0.17	10.88±0.29	12.09
IR64	12.77±0.39	10.06±0.23	9.88±0.48	10.91
Mean	12.90	10.20	9.48	10.86
	Treatment (T)		Variety (V)	T X V
S.Em. ±	0.25		0.42	9.48
CD at 5%	0.71		1.23	1.61

3.2 Days to panicle initiation (PI)

Panicle initiation of the rice is the initial stage of the reproductive phase. It is the stage when dome shaped head begins to form in the base of the stems. Panicle formation indicated the ending of tillering or the vegetative stage and the beginning of the reproductive stage (Kabir *et al.*, 2017) [16]. Panicle initiation is defined as when 3 out of 10 tillers have a panicle of 1 to 2mm long. High temperature after the active tillering stage decreases the number of panicles per plant. At very early stage of growth the growing points of leaves, tillers and panicles remain under water and flooded water also affects initiation of the panicle. The duration of panicle development in case of early maturing varieties is short as compared to the late maturing varieties (Peng *et al.*, 2004) [10].

Data presented in Table 2 demonstrates the days to panicle initiation under early, normal and late sown situations in different genotypes of rice. In case of early sown condition, rice genotype IET22569 took maximum (83days) number of days to reach to the panicle initiation. In normal sown condition, rice genotype namely Sasyasree took maximum (83.33days) days to reach to panicle initiation. Maximum number of days to panicle initiation stage was attained by rice genotype Sasyasree (73.66days) under late sown situation.

Table 2: Days to panicle initiation under early, normal and late sown conditions in different genotypes of rice. (± indicates SE)

Genotypes	Days to Panicle Initiation			
	Early	Normal	Late	Mean
IET20924	73.66±1.33	66.33±0.66	62.33±0.33	67.44
IET22569	83.00±0.57	75.00±4.16	59.66±7.53	72.55
IET22580	74.00±1.15	65.00±1.15	60.66±1.33	66.55
IET23275	77.33±1.85	68.66±0.33	65.33±3.33	70.44
IET23299	71.33±2.02	72.33±5.36	60.00±1.52	67.88
IET23300	71.66±1.20	67.00±0.57	60.00±3.60	66.22
IET23324	66.33±2.33	56.00±5.56	64.00±2.08	62.11
PHY1	73.33±1.20	65.00±0.57	57.33±2.33	65.22
PHY2	83.00±3.00	72.00±6.50	61.66±7.35	72.22
PHY3	66.00±3.21	62.00±3.05	57.00±4.00	61.67
LALAT	77.66±3.84	69.66±2.90	70.33±4.17	72.55
MTU1010	72.00±1.15	63.66±0.33	62.33±3.52	66.00
PR113	82.00±1.52	76.00±5.68	66.33±3.84	74.78
SASYASREE	79.33±2.18	84.33±0.66	73.66±0.88	79.11
IR64	69.33±1.20	66.33±0.88	58.00±2.51	64.56
Mean	74.66	68.62	62.57	68.62
	Treatment (T)		Variety (V)	T X V
S.Em. ±	1.838		3.171	3.170
CD at 5%	5.171		8.957	9.180

3.3 Total dry matter (g/m^2)

Total dry matter in crop plants is generally associated with higher yields and higher nutrient use efficiency. The yield of rice is primarily dependent on the both vegetative (number of panicles per unit area) and reproductive (number of spikelets per panicle) phases (Newman *et al.*, 2001) [11].

At maturity stage, the total dry matter was found maximum (2886.00g/m^2) in the rice genotype IET23299 under early sown condition. In case of normal sown condition, maximum total dry matter was in rice genotype namely IET23300 (2613.83g/m^2). Under late sown condition, maximum total dry matter was found in Lalat (2301.25g/m^2) (Table 3).

Table 3: Total dry matter at maturity stage under early, normal and late sown conditions in different genotypes of rice. (± indicates SE)

Genotypes	Total dry matter at maturity (g/m^2)			
	Early	Normal	Late	Mean
IET20924	2305.5±237.50	2111.00±74.67	1837.16±35.23	2084.55
IET22569	2568.00±94.44	2077.75±57.79	1979.00±43.89	2208.25
IET22580	1997.16±232.54	2134.66±254.00	1786.00±106.08	1972.61
IET23275	2705.50±373.48	2037.50±83.22	1831.91±92.70	2191.63
IET23299	2886.00±119.41	2462.41±468.82	2094.41±76.49	2480.94
IET23300	2258.25±47.32	2613.83±286.10	1788.83±68.56	2220.30
IET23324	2608.33±228.48	2229.00±68.84	2113.91±198.52	2317.08
PHY1	2402.66±101.91	2130.50±113.97	2073.50±68.59	2202.22
PHY2	2413.75±54.88	2449.91±92.44	1908.33±68.59	2257.33
PHY3	1588.25±120.70	1916.58±159.08	1888.88±78.71	1797.88
LALAT	2579.08±95.00	2334.66±218.29	2301.25±82.84	2405.00
MTU1010	2076.33±79.02	2269.16±141.92	1576.00±46.38	1973.83
PR113	2011.08±121.75	1974.91±67.09	1911.00±15.54	1965.67
SASYASREE	2374.91±62.45	2301.33±81.46	2106.91±49.57	2261.05
IR64	1830.50±328.72	1644.33±8.4	1847.16±131.62	1774.00
Mean	2307.02	2179.17	1936.28	2140.82
	Treatment (T)		Variety (V)	T X V
S.Em. ±	89.77		154.85	159.01
CD at 5%	252.48		437.31	469.17

3.4 Number of primary and secondary branches per panicle

The different branches of the rice are borne on the pedicel which is a short stalk that is an extension of the panicle axis. Rachis branching system which is primary and secondary branching system is one of the most important factors for determining yield. Rachis branching system in a panicle is very important factor in determination of the crop yield. High yielding varieties have relatively large number of primary branches as compared with the low yielding varieties. Spikelet number per unit area is highly affected by the climatic conditions such as solar radiation and temperature. Shading during the reproductive period has a pronounced effect on the spikelet number (Yoshida, 1981). Primary rachis-branches (PRBs) are the branches that are connected to the central rachis of a panicle, while the secondary rachis-branches (SRBs) refer to the branches that are connected to primary branches (Park *et al.*, 2010) [12].

The more number of primary and secondary branches per panicle in case of early sowing was due to the crop experienced the favorable climatic conditions especially at the time of tillering, flowering stage. In case of late sown condition the reproductive stage coincided with the onset of the winter and low temperature at the time of spiklet development cause sterility of the spikelets and it is also related with the decreased pollen germination. Sterility caused by low temperatures at the flowering stage is greatly affected by both temperature and sunshine. Flowering is usually related to daily maximum air temperatures. The optimum daily maximum air temperature is 31-32^{0}C. Data presented in Table 4.1 and Table 4.2 represents primary branches per panicle and secondary branches per panicle respectively.

Table 4.1: Number of primary branches per panicle under early, normal and late sown conditions in different genotypes of rice. (± indicates SE)

Genotypes	Number of primary branches per panicle			
	Early	**Normal**	**Late**	**Mean**
IET20924	12.66±0.69	12.99±0.19	11.22±0.22	12.29
IET22569	12.44±0.94	12.55±0.79	11.99±0.69	12.33
IET22580	11.44±0.58	11.44±0.40	11.66±0.03	11.51
IET23275	10.44±0.44	11.11±0.94	9.77±0.11	10.44
IET23299	13.10±0.44	12.33±0.38	11.66±0.51	12.36
IET23300	12.77±0.48	12.10±0.22	10.44±9.86	11.77
IET23324	11.22±0.22	11.66±0.50	11.11±0.10	11.33
PHY1	9.44±10.99	9.77±0.29	11.77±0.11	10.32
PHY2	12.10±0.90	11.55±0.39	10.22±1.21	11.29
PHY3	11.33±0.84	10.55±0.48	10.88±0.86	10.92
LALAT	11.66±0.88	12.55±0.29	11.44±0.40	11.88
MTU1010	12.44±0.77	12.77±0.55	10.33±0.69	11.84
PR113	12.77±1.12	12.77±0.11	10.77±1.09	12.10
SASYASREE	12.11±0.10	11.88±0.61	11.33±0.33	11.77
IR64	10.99±0.77	10.10±0.86	11.44±0.22	10.84
Mean	11.79	11.74	11.07	11.53
	Treatment (T)		Variety (V)	T X V
S.Em. ±	0.35		0.60	0.59
CD at 5%	0.99		1.72	1.69

Table 4.2: Number of secondary branches per panicle under early, normal and late sown conditions in different genotypes of rice. (± indicates SE)

Genotypes	Number of secondary branches per panicle			
	Early	**Normal**	**Late**	**Mean**
IET20924	49.11±3.57	45.33±1.01	28.36±1.48	40.93
IET22569	41.44±2.81	34.88±4.08	35.21±0.55	37.18
IET22580	42.88±2.31	39.66±1.34	36.66±2.00	39.73
IET23275	49.11±5.03	40.10±4.77	35.22±2.62	41.47
IET23299	48.55±2.51	33.10±5.08	34.44±2.56	38.70
IET23300	48.99±3.17	46.22±0.94	33.88±0.61	43.03
IET23324	44.77±3.98	37.77±3.66	34.88±2.32	39.14
PHY1	34.33±1.83	28.10±4.73	31.66±1.89	31.36
PHY2	42.22±4.15	40.10±3.75	30.88±2.29	37.73
PHY3	38.44±5.39	31.55±5.39	36.77±3.04	35.59
LALAT	44.10±4.15	36.55±2.88	33.88±2.73	38.18
MTU1010	46.10±2.13	38.44±3.39	36.55±2.62	40.36
PR113	43.44±2.16	32.44±2.11	31.77±1.17	35.85
SASYASREE	47.44±1.36	34.99±1.64	35.22±1.61	39.22
IR64	34.88±1.44	30.44±3.55	36.44±1.06	33.92
Mean	43.72	36.64	34.12	38.16
	Treatment (T)		**Variety (V)**	**T X V**
S.Em. ±	1.60		2.76	2.88
CD at 5%	4.51		7.81	8.59

3.5 Days to maturity

The grain filling, ripening or maturation stage follows ovary fertilization and is characterized by grain growth. During this period, the grain increases in size and weight. Starch and sugars starts to translocate from the culms and leaf sheaths where they have accumulated to the developing grains. Grain changes its color from green to gold or straw color at maturity and the leaves of the rice plant begin to senescence. Light intensity is very important during this interval since 60 percent or more of the carbohydrates used in grain filling are photosynthesized during this time interval. This period is also affected by temperature and high temperature reduces the grain filling period and may reduce the grain yield. Low temperature tends to increase the time required for the grain filling and ripening but ripening period may be ceased after the significant frost. Data presented in Table 5 demonstrates the days to maturity. In case of early sown condition, maximum days to maturity were taken by the rice genotype Sasyasree (145.66days) and under normal sown condition, the maximum days to maturity were recorded for Sasyasree (138.00days). In case of late sown condition, the maximum day to maturity was taken by Sasyasree (127.66). Maximum days to maturity were recorded under early sown conditions.

Table 5: Days to maturity under early, normal and late sown conditions in different genotypes of rice. (± indicates SE)

Genotypes	Days to maturity			
	Early	**Normal**	**Late**	**Mean**
IET20924	126.66±1.45	131.66±6.00	120.33±0.33	126.22
IET22569	128.33±5.81	128.33±4.40	121.33±0.66	126.00
IET22580	125.33±2.33	119.33±0.33	117.66±0.66	120.77
IET23275	119.66±1.76	125.33±2.90	124.33±0.66	123.11
IET23299	121.66±1.45	119.33±2.33	114.66±0.88	118.55
IET23300	120.66±1.20	116.66±1.66	115.00±6.42	117.44
IET23324	118.66±6.11	118.00±7.81	117.66±1.45	118.00
PHY1	127.66±0.33	122.66±4.80	119.33±1.76	123.22
PHY2	135.00±3.60	132.00±2.00	126.33±2.40	131.11
PHY3	122.00±1.52	117.00±1.73	113.00±1.52	117.33
LALAT	141.66±1.85	131.66±0.88	126.00±0.57	133.11
MTU1010	120.66±1.66	119.00±1.52	116.33±0.66	118.66
PR113	128.33±0.66	131.66±1.66	121.33±1.85	127.11
SASYASREE	145.66±2.40	138.00±4.16	127.66±1.33	137.11
IR64	121.00±3.05	118.66±0.88	119.00±8.32	119.55
Mean	126.86	124.62	119.97	123.82
	Treatment (T)		Variety (V)	T X V
S.Em. ±	1.83		3.16	3.11
CD at 5%	5.17		8.96	8.95

3.6 Thousand grains weight

Grain weight is very essential yield component and it is under strong control and influenced by environmental factors. Grain weight in the cereal crops is positively enhanced by the appropriate applications of nitrogen and phosphorous fertilizers and negatively affected by environmental stresses. Small seed with low weight are associated with the reduced seedling vigor. Grain weight provides information about the density of the grains. Grains of different densities mill differently and retain moisture differently and also cook differently. Uniform grain weight is important for consistent grain quality. Rice genotypes with high yield potential have their grain weights in the range of 20–30 g and grain weight generally follows the order of maturity within a panicle and the first maturing grain being the heaviest. High temperature can increase the grain growth rate, but decrease the grain filling period.

Data presented in Table 6 demonstrates the thousand grain weight of the rice genotypes under different sowing situations. In case of early sown condition, the rice genotype PR113 acquired maximum thousand grains weight (28.48g) and under normal sown condition, the rice genotype IET20924 acquired maximum thousand grains weight (26.25g). In case of late sown condition, PR113 acquired maximum thousand grains weight (26.37g). These results show the similarity with the work done by earlier scientists (Mosavi *et al.*, 2012) [3]. Thousand grain weights also called test weight which refers to weight of the thousand grains. Test weight is the important predictor of the milling yield of rice.

Table 6: Thousand grains weight (g) under early, normal and late sown conditions in different genotypes of rice. (± indicates SE)

Genotypes	Thousand grains weight (g)			
	Early	Normal	Late	Mean
IET20924	26.25±1.99	26.98±0.93	21.57±0.90	24.93
IET22569	19.53±0.17	18.58±0.29	16.54±0.90	18.22
IET22580	20.40±0.20	19.55±0.44	19.60±0.26	19.85
IET23275	26.44±1.11	24.33±1.22	24.71±0.13	25.16
IET23299	21.55±0.64	25.45±0.93	20.94±0.54	22.65
IET23300	21.29±0.14	21.06±0.41	20.23±1.06	20.86
IET23324	19.04±0.12	19.78±0.58	18.68±0.73	19.16
PHY1	25.76±0.59	26.14±1.13	24.77±0.18	25.55
PHY2	24.45±2.86	21.40±2.99	18.67±0.08	21.51
PHY3	22.99±0.41	23.40±0.09	20.56±0.21	22.31
LALAT	23.82±0.32	23.63±0.53	23.81±0.76	23.75
MTU1010	22.97±1.13	23.12±0.34	23.16±0.95	23.08
PR113	28.26±2.14	21.80±2.55	26.37±0.67	25.47
SASYASREE	26.48±1.20	22.81±0.14	22.25±0.69	23.85
IR64	24.16±0.68	23.40±0.36	21.15±0.45	22.90
Mean	23.56	22.76	21.53	22.62
	Treatment (T)	Variety (V)	T X V	
S.Em. ±	0.63	1.84	1.08	
CD at 5%	1.77	3.07	3.11	

3.7 Biological yield 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. 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.Data presented in Table 7.1 demonstrates the biological yield of the crop in g/m^2. In case of early sown condition, the rice genotype Sasyasree had given the maximum yield (3225.00g/m^2) and the rice genotype PHY3 had given the minimum yield (1375g/m^2). Under normal sown condition, Sasyasree again recorded to produce maximum yield (2516.66g/m^2). Under late sown condition, the rice genotypes Sasyasree recorded to attained maximum yield (2091.66g/m^2). Overall maximum biological yield was highest in case of early sown condition (2149.33g/m^2) which gradually decreased to 1999.33g/m^2 in case of normal sown genotypes and further decreased to 1660.55g/m^2 in case of late sown conditions. These findings show the similarity with the work done by earlier scientists (Darko *et al.*, 2013) [4].

Data presented in Table7.2 demonstrates the grain yield of the rice crop under three different sowing conditions. In case of early sown condition, maximum grain yield (1289.00g/m^2) was recorded for the rice genotype Sasyasree. Under normal sown condition, the maximum grain yield (1056.66g/m^2) was recorded for the Lalat and under late sown condition, the maximum grain yield (739.66g/m^2) was attained by the rice genotype IET23324 and the minimum grain yield (449.00g/m^2) was attained by the rice genotype PHY2. The overall maximum grain yield (885.53g/m^2) was recorded under early sown condition which gradually decreased to (840g/m^2) in case of normal sown condition and further delayed in sowing decreased the yield in late sown conditions (639.24g/m^2) Table7.2. These results showed similarity with the work done by earlier workers (Mosavi *et al.*, 2012) [3]. 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 (Munyithy *et al.*, 2017) [15].

Table 7.1: 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	

Table 7.2: 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	

3.8 Total amylose content
Starch mainly consists of two molecular types, amylose and amylopectin. Amylose has straight chain and amylopectin have branched chain. The amylose amylopectin ratio is the major factor involved in determining cooking and eating quality. Starch directly affects the stickiness and the texture of grains after cooking, tendency of the grains to break and different processing characteristics. As the amylose-amylopectin ratio increases, gelatinization temperature also increases whereas the water uptake decreases. High amylose content in the rice grains usually cooked dry, fluffy and gets separated after cooking. Low amylose containing variety usually cook tender, cohesive and glossy (Shen *et al.,* 2004) [13].

Data presented in Table 8 shows the total amylose content of the rice genotypes under early, normal and late sown conditions. In case of early sown condition, the rice genotype IET20924 recorded maximum amylose content (26.00%) and in case of normal sown condition, the rice genotype IET20924 recorded maximum amylose content (24.00%). Under late sown condition, the rice genotype IET20924 was recorded maximum amount of the amylose (23.20%). The higher environmental temperature (30°C) decreased the amylose content in endosperm of rice genotypes. The fine structure of amylopectin was also affected by the environmental temperature, higher the temperature more is the proportion of the β-chains of amylopectin in non waxy starches (Asoaka *et al.,* 1985) [14].

Table 8: Total amylose content under early, normal and late sown conditions in different genotypes of rice. (± indicates SE)

Genotypes	Amylose content (%)			
	Early	Normal	Late	Mean
IET 20924	26.00±0.19	24.00±0.50	23.20±0.89	24.40
IET 22580	21.60±1.00	20.80±0.99	20.00±0.20	20.80
IET 23275	22.00±1.70	22.80±0.80	20.80±1.80	21.86
IET23299	21.20±0.69	20.80±0.90	20.40±1.10	20.80
IET23300	23.00±1.79	18.80±0.40	20.00±0.29	20.60
LALAT	22.40±1.39	20.00±0.40	20.80±0.10	21.06
MTU1010	22.90±0.29	21.50±0.10	20.60±0.10	21.66
PR113	23.20±0.39	20.80±0.80	20.00±0.50	21.33
Mean	22.78	21.18	20.72	21.55
	Treatment (T)		Variety (V)	T X V
S.Em. ±	0.47		0.81	0.82
CD at 5%	1.40		2.43	2.74

4. Conclusion
Early sown rice genotypes recorded good physiological, morphological and yield parameters as they got the sufficient time for their vegetative growth and are very efficient in transforming the photosynthetic potential to actual grain weight (Buhong *et al.,* 2006). Short duration varieties usually give lower yields due to insufficient vegetative growth for the maximum yield levels (Yoshida, 1976) [8]. 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 (Xie *et al.,* 2011). 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 (Lone *et al.*, 1999; Praveen *et al.*, 2013). 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

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