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Research Article

GUTTATIVE FLUID AS A PHYSIOLOGICAL MARKER FOR PHOTOTHERMIC INDEXING IN RICE (*Oryza sativa* L.)

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Abstract- Guttation is the physiological phenomenon resulting in loss of xylem sap on the tips and edges of leaves through hydathodes. Field research was conducted during kharif season of 2014 to evaluate the correlation of guttation fluid with photothermic indexing. Every crop has GDD ; growing degree days values for the life cycle of entire crop. Number of days required from sowing till harvest solely is a reflection of photothermic index *i.e*., perception of light and temperature for crop growth and development. Different physiological parameters of rice likedays to panicle initiation, days to flowering, total dry matter at maturity and yield (g/m^2) were taken for the study. The experiment was arranged as split plot design with three treatments and three replications. Guttative fluid from three flag leaves was collected from fifteen genotypes of rice grown under early, normal and late sown dates. For this experiment the field was kept ponded with 5cm of standing water throughout tillering and reproductive stage. Genotypes with more guttative fluid show higher yields. Sowing performed in month of May recorded higher yield (g/m^2) and more amount of guttative fluid followed by normal and late sown genotypes. All rice genotypes showed the positive correlation between guttation fluid and days to panicle initiation, days to flowering, total dry matter at maturity and yield (g/m^2). Further studies provide good opportunities to identify and clone the genes controlling the rate of guttation and inserting them into desirable genotypes through transgenic technology and creating efficient rice plants.

Keywords- Guttation, Photothermic indexng, GDD.

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Introduction

Rice is most widely consumed staple food crop for about two third of the world's population. Rice is having third-highest worldwide production after sugarcane and maize. Rice crop has created culture, history, and economy of people of Asia. Rice is very important crop as it provides more than one fifth of total calories [1]. To cope up with the growing demands of human population rice needs to be produced 50% more than what is produced now. Scientists working on rice have tangled themselves in developing high yielding varieties to increase the productivity of rice.

The yield of rice mainly depends on temperature, solar radiations in terms of photothermic features and soil fertility for their growth and nutritional requirements [2]. Grain quality is very important factor in determining the yield components in rice. Grain weight is the important factor which determines grain quality and it depends on source sink concept. Source organs are net exporters of the photo assimilates which mainly include mature leaves and sink organs. Yield of the crop are controlled by carbon assimilation and partitioning [3]. Canopy architecture and leaf geometry also plays a crucial role in determining yield attributes in crop. Both erect and V- shaped leaves provide an excellent opportunity for higher photosynthetic rate, leads to high biomass production. Higher grain yield can be achieved by transplanting rice in optimum period of time [4]. Different growth stages of rice like panicle initiation, flowering, panicle exertion from flag leaf sheath and partitioning are highly affected by planting dates. Scientists are engaged in breaking various yield barriers to enhance the rice productivity by improving plant physiological efficiency of converting solar energy into biomass and transferring more proportion of it to grains [5]. It's a challenge for scientists to accelerate the production of new and improved rice varieties in order to meet the needs of a growing world population and of the farmers.

Selections of suitable marker are important for the breeding material. Guttation fluid may be taken as one of the important physiological marker. Guttation is the loss of xylem sap on the tips and edges of leaves through hydathodes, on the other hand if the water is lost from the plant body in the form of water vapors, then the phenomenon is called transpiration. Hydathodes are specialized structures and are responsible for secreting water in liquid form. They are generally restricted to the apex and edges of leaves. Guttation occurs because of root pressure, which is osmotic pressure within the cells of a root system that causes sap to rise through a plant stem to the leaves. At high moisture level root pressure occur in xylem of the plants. At night due to root pressure guttation of xylem sap occur from the tips and edges of leaves. Because of high pressure, xylem sap exudes from pores through hydathodes present at the tips and edges of rice leaves. High rate of guttation indicates more amounts of xylem exudates which contains high concentration of cytokinins and other nutrients essential for plants. Cytokinins are associated with delay in leaf senescence which provides opportunities for the leaves to maintain a good photosynthetic rate [8]. Considering the importance of guttation, the guttative fluid is taken as a physiological marker in order to develop a correlation between sowing interval and fluid content.

Materials and Methods

The field experiment was conducted at Dr Norman E. Borlaug Crop Research

Centre, G. B. Pant University of Agriculture and Technology, Pantnagar (Uttarakhand), during kharif season of 2014.
According to geographical parameter Pantnagar lies in Tarai belt about 30 km southwards of hills of shivalik range of Himalayas at 28.97^0 N 79.41^{0}E longitude and at an altitude of 243.8 meter above mean sea level. The purpose of study was to find relation of guttation fluid with respect to early, normal and late sowing dates in different genotypes of rice (*Oryza sativa* L.). Following genotypes of rice were taken for the study through the kind courtesy of Directorate of Rice Research, Indian Council of Agricultural Research, Hyderabad, India.

S.No.	Genotypes	S. No.	Genotypes
1.	IET 20924	9.	PHY 2
2.	IET 22569	10.	PHY 3
3.	IET 22580	11.	LALAT
4.	IET 23275	12.	MTU 1010
5.	IET 23299	13.	PR 113
6.	IET 23300	14.	SASYASREE
7.	IET 23324	15.	IR 64
8.	PHY 1		

The field experiment was laid out with three treatments and three replications of each in a split plot design. The main treatment consists of three dates of sowing early, normal and late and the sub treatment consists of fifteen genotypes of rice with three replications of each. The gross plot size was 540m^2 and sub plot size was 1 x1m. The 21 days old seedlings were transplanted in the each subplot with 20x20cm spacing keeping 15 days difference in sowing of each early, normal and late genotypes.
Nitrogen in the form of urea was sprouted in three dozes as 50% at 15 days after sowing, 25% at the time of tillering and the remaining at the time of panicle initiation stage. Single Super Phosphate and Muriate of Potash were given as basal doses @ 60kg/ha and @ 40kg/ha respectively. Attempts were made to keep the field ponded with 5cm of water. The phenomenon of guttation was under regular observation. The guttation fluid was collected in a good sunny day at 10:30-11:30 am to avoid the confusion with the dew drops.

Dates	Early sown genotypes	Normal sown genotypes	Late sown genotypes
Sowing	25th May 2014	12th June 2014	27th June 2014
Transplanting	18th June 2014	3rd July 2014	18th July 2014

Collection of guttation fluid was done at flowering stage of rice. Guttation fluid of three flag leaves were collected with the help of very fine quality filter paper pieces held by forceps very efficiently before falling down of drops from leaves. The filter papers were kept in the butter paper envelopes to prevent the fluid losses from evaporation [16]. Initial and final weight of butter paper envelops were taken.

$$W \text{ (Weight of exuded droplets)} = W_1 - W_2$$

Where W_1 is the initial weight of butter paper and W_2 is a final weight of butter paper
Weights of exudates were expressed in grams. Phenological data in terms of days to panicle initiation, days to flowering, total dry matter at maturity and grain yield were recorded in all the sets of experiment. The correlation among these parameters was calculated. The data was analyzed statistically at 5% level of significance [5].

Table-1 *Days to panicle initiation and days to flowering in early, normal and late sown genotypes of rice.*

Entries	Days to panicle initiation				Days to flowering			
	Early	Normal	Late	Mean	Early	Normal	Late	Mean
IET 20924	73.67	66.33	62.33	67.44	100.00	95.33	92.66	96.00
IET 22569	83.00	75.00	59.67	72.55	102.33	94.00	90.00	95.44
IET 22580	74.00	65.00	60.67	66.55	98.00	88.33	87.33	91.22
IET 23275	77.33	68.66	65.33	70.44	108.33	96.67	93.00	99.33
IET 23299	71.33	72.33	60.00	67.88	96.00	89.67	83.33	89.67
IET 23300	71.67	67.00	60.00	66.22	96.33	89.00	84.33	89.89
IET 23324	66.33	56.00	64.00	62.11	90.00	83.67	83.66	85.78
PHY 1	73.33	65.00	57.33	65.22	97.33	86.33	84.67	89.44
PHY 2	83.00	72.00	61.67	72.22	102.33	91.00	94.66	96.00
PHY 3	66.00	62.00	57.00	61.67	91.33	85.33	82.33	86.33
LALAT	77.67	69.67	70.33	72.55	114.00	97.00	103.3	104.77
MTU 1010	72.00	63.67	62.33	66.00	94.00	86.00	84.00	88.00
PR 113	82.00	76.00	66.33	74.78	103.33	100.00	92.33	98.56
SASYASREE	79.33	84.33	73.67	79.11	122.00	122.67	106.0	116.89
IR 64	69.33	66.33	58.00	64.56	91.33	85.33	81.66	86.11
Mean	74.67	68.57	62.57	68.62	100.44	92.68	89.56	94.22
	Sowing	Entries	S X E	E X S	Sowing	Entries	S X E	E X S
S.E.M. ±	0.814	1.838	3.171	3.170	0.503	0.875	1.509	1.542
CD (p=5%)	3.187	5.171	8.957	9.180	1.970	2.461	4.262	4.535

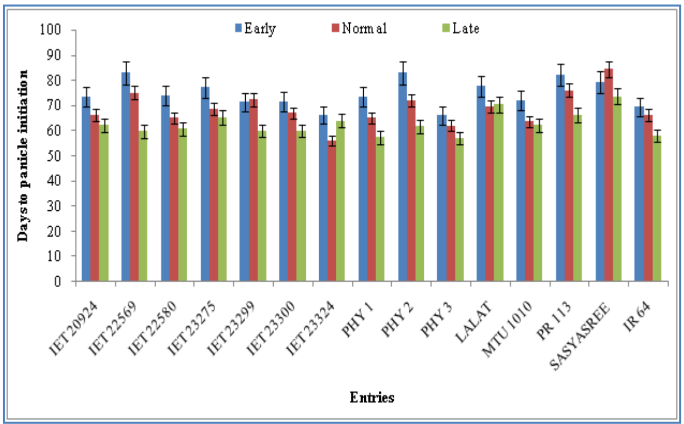

Fig-1 Days to panicle initiation in early, normal and late sown genotypes of rice

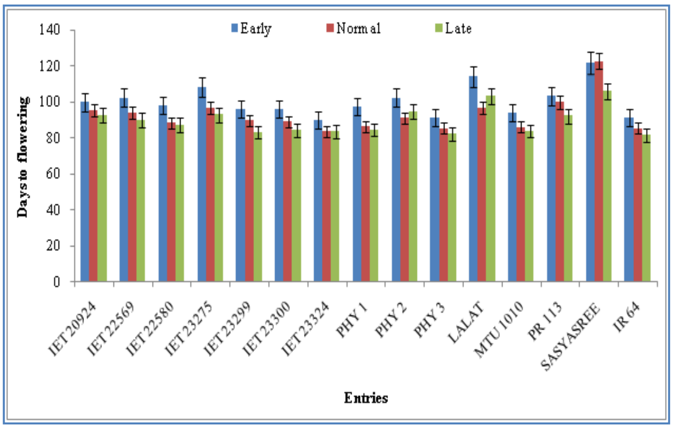

Fig-2 Days to flowering in early, normal and late sown genotypes of rice

Table-2 *Total dry matter at maturity and yield in early, normal and late sown genotypes of rice.*

Entries	T.D.M at maturity (g/m²)				Yield (g/m²)			
	Early	Normal	Late	Mean	Early	Normal	Late	Mean
IET 20924	2305.50	2111.00	1837.16	2084.55	1050.00	978.33	726.67	918.33
IET 22569	2568.00	2077.75	1979.00	2208.25	904.33	753.67	692.67	783.56
IET 22580	1997.10	2134.67	1786.00	1972.61	912.67	846.67	723.33	827.56
IET 23275	2705.50	2037.50	1831.91	2191.63	1005.33	857.00	638.33	833.56
IET 23299	2886.00	2462.41	2094.41	2480.94	908.33	949.67	630.33	829.44
IET 23300	2258.50	2613.83	1788.83	2220.30	938.00	820.00	523.67	760.55
IET 23324	2608.33	2229.00	2113.91	2317.08	772.00	1046.00	774.00	864.00
PHY 1	2402.66	2130.50	2073.50	2202.22	875.00	818.00	739.67	810.88
PHY 2	2413.75	2449.91	1908.33	2257.33	580.00	498.00	449.00	509.00
PHY 3	1588.25	1916.58	1888.83	1797.88	534.33	592.00	467.00	531.11
LALAT	2579.08	2334.67	2301.25	2405.00	1179.33	1056.67	709.00	981.66
MTU 1010	2076.33	2269.16	1576.00	1973.83	888.00	720.33	560.00	722.77
PR 113	2011.08	1974.91	1911.00	1965.67	735.00	926.00	604.33	755.11
SASYASREE	2374.91	2301.33	2106.91	2261.05	1289.00	985.33	737.33	1003.88
IR 64	1830.50	1644.33	1847.16	1774.00	673.00	759.67	620.33	684.33
Mean	2307.02	2179.17	1936.28	2140.82	882.95	840.48	639.71	787.71
	Sowing	Entries	S X E	E X S	Sowing	Entries	S X E	E X S
S.E.M. ±	54.10	89.77	154.85	159.01	21.40	28.42	49.02	51.93
CD (p=5%)	211.54	252.48	437.31	469.17	83.68	79.93	138.45	156.32

Table-3 *Amount of guttation fluid of three flag leaves in early, normal and late sown genotypes of rice.*

Entries	Amount of guttation fluid of three flag leaves (g)			
	Early	Normal	Late	Mean
IET 20924	0.314	0.287	0.284	0.295
IET 22569	0.409	0.343	0.330	0.361
IET 22580	0.317	0.221	0.240	0.259
IET 23275	0.284	0.318	0.307	0.303
IET 23299	0.298	0.342	0.358	0.333
IET 23300	0.333	0.318	0.244	0.298
IET 23324	0.377	0.290	0.192	0.286
PHY 1	0.311	0.276	0.158	0.248
PHY 2	0.265	0.225	0.205	0.231
PHY 3	0.338	0.300	0.322	0.320
LALAT	0.355	0.352	0.302	0.336
MTU 1010	0.266	0.226	0.182	0.224
PR 113	0.274	0.279	0.210	0.254
SASYASREE	0.349	0.319	0.316	0.328
IR 64	0.309	0.240	0.235	0.261
Mean	0.320	0.289	0.259	0.289
	Sowing	Entries	S X E	E X S
S.E.M. ±	0.0052	0.0126	0.022	0.021
CD (p=5%)	0.0203	0.0357	0.061	0.062

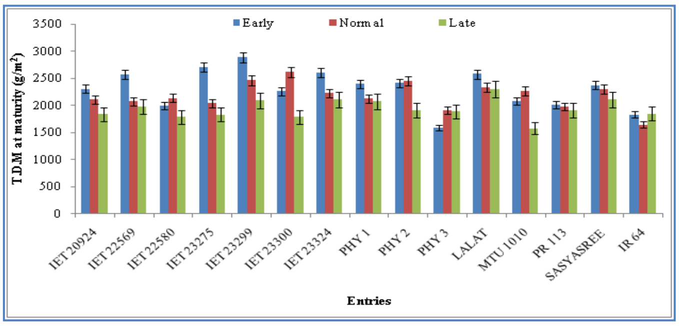

Fig-3 TDM at maturity in early, normal and late sown genotypes of rice

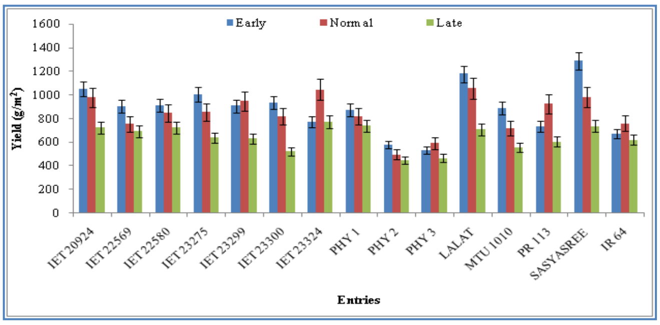

Fig-4 Yield in g/m² in early, normal and late sown genotypes of rice.

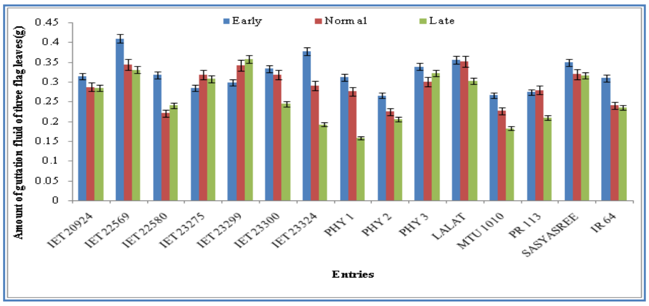

Fig-5 Amount of guttation fluid in early, normal and late sown genotypes of rice.

Results and Discussion

Attempts were made to study the correlation of guttation fluid with days to panicle initiation, days to flowering, total dry matter at maturity and yield (g/m^2). It is fascinating to note that a positive significant correlation of guttation fluid was found with these parameters. The genotypes with high yield parameters exude more amount of guttative fluid as compared to the genotypes with low yield. More amount of guttation fluid during flowering period signifies that the plant is rational enough to gain more dry matter by attaining higher photosynthetic rate [18].It is clear from the fact that more flux of cytokinin, synthesized in the roots of rice plants are transported through xylem to the leaves and helps to attain higher photosynthetic rate and delays leaf senescence [14]. Sowing done in the month of May were recorded higher yield (g/m2) followed by normal and late sowing. Early, normal and late sowing directly reflects the harnessing of solar energy and better photoperiod.

Days to panicle initiation

Days to panicle initiation were significantly affected by delayed sowing dates. Days to panicle initiation showed decreasing trend as the sowing were delayed. Early sowing took more number of days to reach the panicle initiation stage followed by normal and late sown dates [Fig-1]. The maximum days to panicle initiation was recorded in genotypes IET22569 and PHY2 (83 days) in early sown, Sasyasree (84 days) in normal sown and Sasyasree (73 days) in late sown rice genotypes [Table-1]. It is interesting to note that there is a positive significant correlation between amount of guttative fluid and days to panicle initiation. As the vegetative phase of the genotypes increases, the amount of guttation fluid also increases. The vegetative growth phase is characterized by active tillering, a gradual increase in plant height and leaf emergence at regular intervals. Long vegetative period signifies more tillering, vigrous growth and efficient photosynthetic rates [9].

Days to flowering

Early and normal sown genotypes have taken equal number of days to flowering followed by late sown genotypes [Fig-2]. In case of early sown genotypes Sasyasree took 122 days to reach to flowering stage, in normal sown conditions Sasyasree again took 122 days to flower and in late sown this was decreased to 106 days [Table-1].

Total dry matter at maturity

Dry matter is an indicator of the amount of nutrients that are available and measured in g/m^2. Total dry matter was correlated with the guttation fluid. The highest was recorded for the early sown rice genotypes and the least was for late sown genotypes [Fig-3]. It was highest of 2886.0g/m^2 for IET 23299 in early sown, 2613.83g/m^2 for IET23300 of normal sown and 2301.2g/m^2 for late sown genotypes [Table-2]. It was due to long vegetative phase in early sowing and higher leaf area per plant at active tillering which is important for better light interception. There is a significant positive correlation between the leaf area per plant at active tillering and dry matter production at maturity [12]. This suggests that long and vigorous vegetative stage is important for dry matter production. Positive significant correlation was found between total dry matter at maturity and amount of guttation fluid.

Grain Yield

More than 90% of the grain yield was derived from photosynthetic products. Therefore, many rice scientists believed that enhancing photosynthesis at the level of the single leaf would increase grain yields. Early sown genotypes had experienced more exposure to sunlight as result of better radiation use efficiency. Whereas the delay in sowing results in short vegetative phage, poor emergence and reduction in heading panicle/m^2 ultimately leads to reduction in grain yield [13]. Rice genotype Sasyasree recorded grain yield of 1289g/m^2, in Lalat it was 1056g/m^2 at normal sown, while 774g/m^2 yield was recorded in IET23324 in case of late sown genotypes of rice [Fig-4 and Table-2].

Guttation Fluid

The phenomenon of guttation varies from species to species. Out of 11 different botanical families only rice is found to guttate heavily [23]. In rice itself there are varietal differences in guttation which may be due differences in activity of aquaporins, variation in forced upward movement of water under root pressure which contains organic solutes. The highest amount of guttation fluid recorded was 0.409g for IET22569 of early sown, 0.352g for Lalat in normal sown and 0.352g for IET23299 in case of late sown rice genotypes [Fig-5] [Table-3].

Conclusion

The amount of guttation fluid is positively correlated with different physiological parameters of rice and ample scope for improving the genetic yield potential of rice is feasible. This could be achieved by improving the plant physiological efficiency of converting solar energy into biomass and partioning greater part of it to grains. Genes responsible for guttation could be further explored for its role in better growth and productivity. Cross talks between root pressure, xylem exudates and phytohormones signaling can be evaluated for treating guttative fluid as an important physiological marker in metabolic signaling.

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Abbreviations: Guttative fluid as a physiological marker.

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