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Response of Aerobic Rice to Agrometeorological Indices

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ABSTRACT

A field experiment was conducted during *Rabi* season from September 2013 to February 2014 at Agronomy eastern farm of Pandit Jawaharlal Nehru College of Agriculture and Research Institute (PAJANCOA & RI), Karaikal, Union Territory of Puducherry to investigate the performance of rice varieties at different dates of sowing. The treatments were evaluated in factorial concept of RBD, replicated thrice. The results indicated that among the three rice varieties, TRY 1 produced higher grain yield of 4,337 kg ha^{-1} and among the dates of sowing, crop sown on 20th September produced higher grain yield of 4,549 kg ha^{-1}. The analysis indicated that the derived weather parameters *viz.*, total GDD, HTU, PTU were significantly contributing to the rice grain yield. From the study it was evident that during *Rabi* season, under aerobic condition, the optimum sowing date for Improved White Ponni, TRY 1 and ADT 39 was September 20th and the rice varieties TRY 1 and ADT 39 are recommended. For later sowing TRY 1 alone was found the best choice for *Rabi* season under aerobic condition at the coastal deltaic region of Karaikal.

Key words: *Aerobic rice, Agormeteorological indices, Grain yield, Sowing dates.*

Rice is a unique crop among the major food crops by virtue of its extent and adaptability to wider range of climatic, edaphic and cultural conditions. It is also the major staple food for more than half of the world's population (FAO, 2013). Rice consumes 30 per cent of all fresh water used worldwide. The productivity of Asian irrigated rice system is increasingly threatened by water scarcity. Aerobic rice system had been developed in mid eighties and now aerobic rice is grown commercially in Brazil and Northern China (Pinheiro *et al.,* 2006).

Aerobic rice refers to growing rice in condition of non flooded and non puddled low lands with supplemental irrigation. The optimum sowing time and selection of improved cultivars play a remarkable role in exploiting the yield potential of the crop under any particular agro climatic condition. It governs the crop phenological development and the efficient conversion of biomass into economic yield. Delay in sowing causes early maturity resulting in drastic reduction of yield as compared to normal sowing. Growing of suitable varieties at an appropriate time is essential for ensuring optimum crop productivity. Being a thermo sensitive crop, choice of suitable variety for different seeding times of rice in future gets prime importance. Hence, it becomes imperative to generate knowledge on exact duration of phenological stages in a particular crop-growing environment and its impact on yield of crop. Therefore, an experiment was conducted to determine the phenology and weather requirement for rice varieties under aerobic.

MATERIAL AND METHODS

A field experiment was conducted during *rabi* season at Agronomy Eastern Farm in Pandit Jawaharlal Nehru College of Agriculture and Research Institute, Karaikal, Union Territory of Puducherry. It is situated at 10^{o}55^{I} N latitude and 79^{o} 49^{I} E longitude with an altitude of 4 m above Mean Sea Level (MSL). The soil of the experimental site was loamy sand having alkalinity ie., p^{H} 8.2, EC 0.09 dSm^{-1}, organic carbon 0.24 %, available N (97.21 kg ha^{-1}), available P (30.96 kg ha^{-1}) and K (161.28 kg ha^{-1}). The experiment was laid out in factorial RBD with three replications and the treatments combination consisted of three varieties *viz.,* Improved White Ponni, TRY 1 and ADT 39 under five dates of sowing at weekly intervals *viz.,* September 20th, September 27th,

October 4th, October 11th and October 18th. Seeds were direct sown in line manually with 20 X 10 cm spacing in the well prepared field. Irrigation was given immediately after sowing. Later, life saving irrigations were given when hair line cracks were formed. Recommended fertilizer (150:50:50 NPK) was applied in splits (Phosphorus as basal, nitrogen and potassium at 15 DAS, tillering phase, panicle initiation and flowering phase equally). Additionally $ZnSO_4$ was applied @ 25 kg ha^{-1}at tillering phase and panicle initiation phase. Meteorological data *viz.,* maximum and minimum temperature and total bright sunshine hours were recorded from Agro-meteorological observatory of PAJANCOA&RI, Karaikal for various phenophases *viz.,* seedling phase, vegetative, reproductive and maturity phases of the respective treatments to study their influence on aerobic rice.

The Agro-meteorological indices *viz.,* Growing degree Day(GDD), Helio Thermal units (HTU), Photo Thermal Units (PTU) were calculated using the following formula:

$$GDD = \sum_{i=1}^{n} [T_i - T_b]$$

Where,

T_i = Mean temperature of i^{th} day

T_b = Base temperature of rice, A base temperature of 13°C was adopted for rice reported (Arjunan *et al.* 1993).

HTU (°C day hour) = GDD x Bright sunshine hours

PTU = GDD x Mean day length (N)

RESULTS AND DISCUSSION

Effect on growth of aerobic rice

In case of dry matter production the rice variety Improved White Ponni (IWP) produced higher DMP followed by TRY 1 and ADT 39 during all growth phases, especially at flowering stage (4126 kg ha^{-1}). Among the sowing dates, the crop sown at later dates significantly produced higher DMP. This might be due to the prevalence of

Table 1. Mean maximum temperature (° C) prevailed at different phases of aerobic rice.

Rice genotypes & Phenophases	Date of sowing (D)					
	D_1	D_2	D_3	D_4	D_5	Mean
Improved White Ponni (V_1)						
1	34.93	34.34	33.71	32.54	31.43	33.39
2	31.10	30.65	29.87	29.49	29.34	30.09
3	28.80	28.72	28.38	28.31	28.39	28.52
4	28.71	28.86	29.28	29.62	29.73	29.24
5	30.88	30.64	30.31	29.99	29.72	30.30
TRY 1 (V_2)						
1	34.93	34.34	33.71	32.54	31.43	33.39
2	31.10	30.59	29.84	29.56	29.35	30.08
3	28.87	28.68	28.48	28.32	28.45	28.56
4	28.83	29.05	29.33	29.70	29.93	29.36
5	30.93	30.66	30.34	30.03	29.79	30.35
ADT 39 (V_3)						
1	34.93	34.34	33.71	32.54	31.43	33.39
2	31.10	30.65	29.76	29.70	29.41	30.12
3	29.27	28.72	28.78	28.35	28.29	28.68
4	28.45	28.65	28.87	29.07	29.52	28.91
5	30.93	30.59	30.28	29.91	29.66	30.27

1.Seedling phase 2. Vegetative phase 3. Reproductive phase 4. Maturity phase
5. Sowing to maturity phase

Table 2. Mean minimum temperature (°C) prevailed at different phases of aerobic rice.

Rice genotypes & Phenophases	Date of sowing (D)					
	D_1	D_2	D_3	D_4	D_5	Mean
Improved White Ponni (V_1)						
1	25.31	25.17	25.04	24.92	24.33	24.95
2	24.08	23.81	23.04	22.47	22.18	23.11
3	21.65	21.24	20.71	20.84	20.92	21.07
4	20.72	20.75	20.39	20.00	20.05	20.38
5	22.94	22.74	22.29	22.05	21.87	22.37
TRY 1 (V_2)						
1	25.31	25.17	25.04	24.92	24.33	24.95
2	24.12	23.76	23.06	22.60	22.14	23.13
3	21.57	21.02	20.76	20.71	21.13	21.03
4	20.78	20.60	20.30	20.09	20.09	20.37
5	22.94	22.63	22.29	22.08	21.92	22.37
ADT 39 (V_3)						
1	25.31	25.17	25.04	24.92	24.33	24.95
2	24.12	23.81	23.19	22.86	22.43	23.28
3	22.23	21.34	20.60	20.21	20.85	21.04
4	20.90	20.81	20.86	20.73	20.07	20.67
5	23.14	22.78	22.42	22.18	21.92	22.48

relatively higher maximum temperature and minimum temperature during earlier phases (Table 1 and 2). Sunil (2000) reported that plant biomass increase due to higher levels of maximum temperature. The low temperature in early growth stages retarded the development of seedlings and consequently reduced the dry matter production in rice. In the present investigation the prevailed temperature was relatively higher during seedling and vegetative phases, which might be the reason for increased DMP (Table 3 and 3a). These results corroborate the findings of Murthy (2106).

Effect on grain and straw yield

In grain yield, there was significant difference between varieties and dates of sowing. Among the varieties, TRY 1 produced significantly higher yield of 4337 kg ha^{-1}, which was 11 per cent and 9 per cent higher than ADT 39 and IWP respectively (Table 4). In general, among the dates of sowing earlier dates of sowing *viz.,* D_1 (September 20th) recorded a grain yield of 4549 kg ha^{-1}, which was about 18 per cent higher than the later date of sowing D_5 (October 18th). The variation in grain yield of IWP between early and late sowing date was meagre. For all the three varieties, 20th September (D_1) was the optimum sowing date to obtain higher yield. Similar trend was also observed for the straw yield though slight variation was observed for varieties. It was also interesting to note that earlier sowing on September 20th was the best sowing time for all the varieties and when sowing was delayed, the poor performance of ADT 39 was visualized compared to TRY 1 and IWP. The variation in grain yield of IWP between early and late sowing dates was meager. Gildayal and Jana (1967) revealed that the grain yield of rice increase with decreasing trend of relative humidity during reproductive phase, which was also observed in the present investigation for TRY 1 during earlier sowing dates(Fig. 1). The low grain yield in treatments was associated with relatively poor yield attributes of rice which could be cited as an evidence as reported by Narayanan (2004).

Effect on phenophase

Date of sowing and different varieties had significant difference in days from sowing to maturity (Fig. 2). The phenological studies revealed that, TRY 1 had longer duration when compared to

Table 3. Effect of varieties and times of sowing on mean dry matter production (kg ha^{-1}) of aerobic rice at different phases.

Treatments	Seedling phase	Vegetative phase	Flowering phase	Harvest
Varieties (V)				
V_1 : I.W.Ponni	246.3	1913.8	4126.4	19441.2
V_2 : TRY 1	225.3	1711.4	3323.3	14276.2
V_3 : ADT 39	224.8	1716.0	3308.6	14236.0
S Ed	14.65	173.53	283.42	1213.97
CD (P=0.05)	NS	NS	580.58	2486.78
Dates of Sowing (D)				
D_1 : September 20th	232.1	1245.0	3036.2	15363.8
D_2 : September 27th	234.5	1774.7	2557.1	18821.7
D_3 : October 4th	245.3	1499.1	3868.2	13465.8
D_4 : October 11th	240.2	2124.6	4552.4	18011.6
D_5 : October 18th	208.5	2258.5	3916.6	14259.2
S Ed	18.91	224.03	365.89	1567.23
CD (P=0.05)	NS	458.91	749.52	3210.42
Interaction (V x D)				
S Ed	32.76	388.03	633.75	2714.53
CD (P=0.05)	NS	NS	1298.22	NS

NS : Non significant

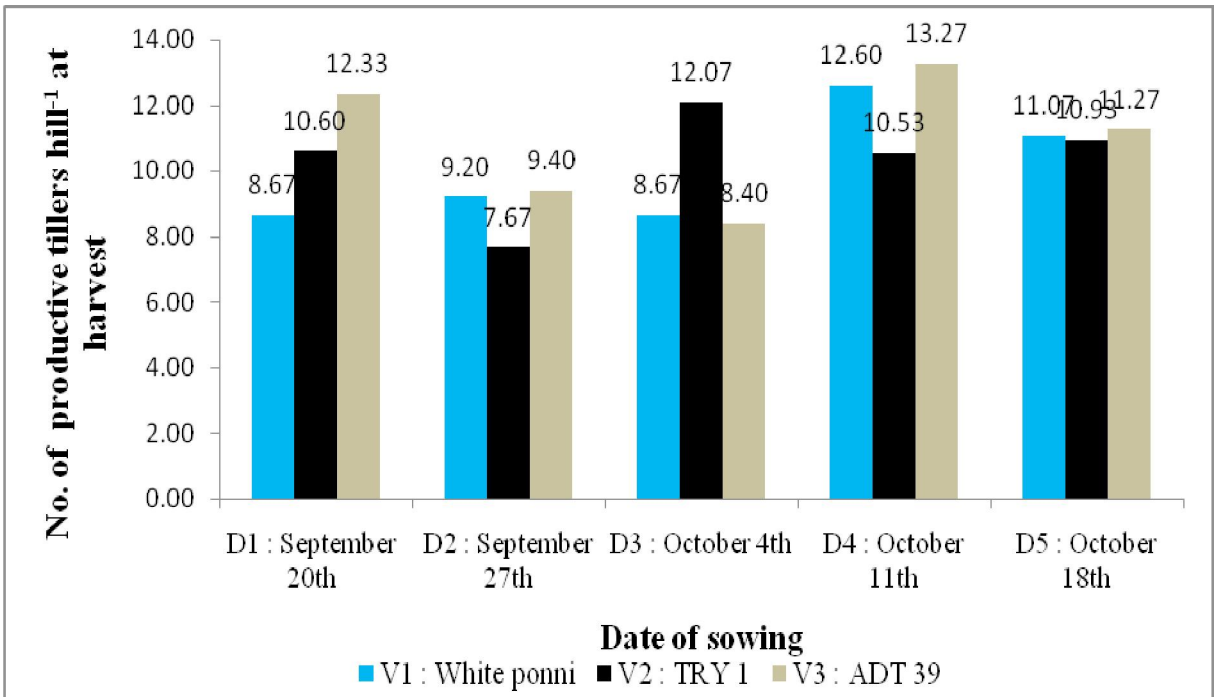


Fig 1. Effect of varieties and dates of sowing on number of productive tillers hill^{-1} at harvest

Table 3a. Interaction effect between varieties and times of sowing on mean dry matter production (kg ha^{-1}) of aerobic rice at flowering phase.

Dates of Sowing (D)	Varieties (V)			Mean
	V_1 : I.W.Ponni	V_2 : TRY 1	V_3 : ADT 39	
D_1 : September 20th	3456.6	2878.3	2773.6	3036.2
D_2 : September 27th	2777.6	2291.3	2602.3	2557.1
D_3 : October 4th	4187.6	4562.0	2855.0	3868.2
D_4 : October 11th	4621.3	3781.6	5254.3	4552.4
D_5 : October 18th	5589.0	3103.3	3057.6	3916.6
Mean	4126.4	3323.3	3308.6	3586.1
Interaction	S Ed	CD (P=0.05)		
V	283.42	580.58		
D	365.89	749.52		
V x D	633.75	1298.22		

Table 4. Effect of varieties and times of sowing on mean grain yield (kg ha^{-1}), straw yield (kg ha^{-1}) and harvest index (%) of aerobic rice at harvest.

Treatments	Grain yield (kg ha^{-1})	Straw yield (kg ha^{-1})
V_1 : I.W.Ponni	3978.3	16816.3
V_2 : TRY 1	4336.8	16586.6
V_3 : ADT 39	3877.6	12221.3
S Ed	137.20	660.27
CD (P=0.05)	281.06	1352.53
D_1 : September 20th	4549.2	18455.4
D_2 : September 27th	4171.0	15952.8
D_3 : October 4th	3784.0	16253.8
D_4 : October 11th	3964.4	12504.3
D_5 : October 18th	3852.6	12874.1
S Ed	177.13	852.40
CD (P=0.05)	362.85	1746.11
S Ed	306.80	1476.40
CD (P=0.05)	628.48	3024.36

other varieties though the seedling phase was same. Higher variation in phenophase was observed especially in reproductive phase than other phases. The later sown crop consumed lesser number of days for maturity period for all the varieties than the earlier sown crop, which could be one of the reasons for the possibility of higher movement of photosynthates from source to sink as evidenced by Narayanan (2004).

Growing Degree Day (GDD)

Growing degree days required for different phenophase varied with date of sowing (Table 5). GDD was larger value at seedling and vegetative phase for early sown crop, whereas, it was reversed for later sown crops . The highest total GDD for whole life span was observed for TRY 1 when sown on 20th September (D_1) and lowest GDD was with

Table 4a. Effect of varieties and times of sowing on mean grain yield (kg ha^{-1}) of aerobic rice at harvest.

Dates of Sowing (D)	Varieties (V)			Mean
	V_1 : I.W.Ponni	V_2 : TRY 1	V_3 : ADT 39	
D_1 : September 20th	4128.0	4579.3	4940.3	4549.2
D_2 : September 27th	4128.0	4257.0	4128.0	4171.0
D_3 : October 4th	3741.0	3999.0	3612.0	3784.0
D_4 : October 11th	3870.0	4540.3	3483.0	3964.4
D_5 : October 18th	4024.6	4308.3	3225.0	3852.6
Mean	3978.3	4336.8	3877.6	4064.2
Interaction	S Ed		CD (P=0.05)	
V	137.20		281.06	
D	177.13		362.85	
V x D	306.80		628.48	

Table 4b. Effect of varieties and times of sowing on mean straw yield (kg ha^{-1}) of aerobic rice at harvest.

Dates of Sowing (D)	Varieties (V)			Mean
	V_1 : I.W.Ponni	V_2 : TRY 1	V_3 : ADT 39	
D_1 : September 20th	19478.8	22123.3	13764.2	18455.4
D_2 : September 27th	17930.8	18575.8	11351.9	15952.8
D_3 : October 4th	16511.9	15608.9	16640.8	16253.8
D_4 : October 11th	16253.9	12745.1	8513.9	12504.3
D_5 : October 18th	13906.1	13880.3	10835.9	12874.1
Mean	16816.3	16586.6	12221.3	15208.1
Interaction	S Ed		CD (P=0.05)	
V	660.27		1352.53	
D	852.40		1746.11	
V x D	1476.40		3024.36	

ADT 39 when the crop was sown on 18th October (D_5). Murthy (2016) also reported lower consumption of heat units under delayed sowing in rice. Among the varieties, TRY 1 utilized higher GDD when compared to other varieties *viz.,* improved white ponni and ADT 39.

Photo Thermal Units (PTU)

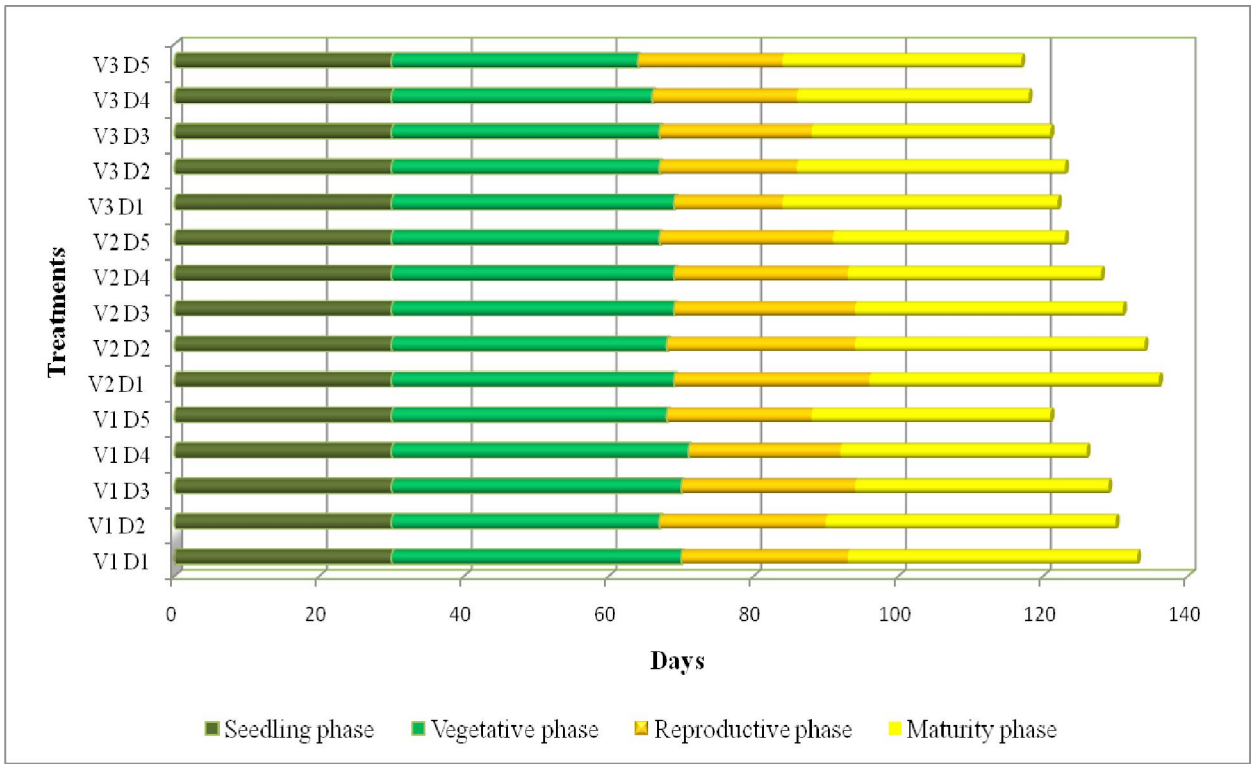
The variation in PTU in different treatments from sowing to maturity phase has been presented in (Table 6). The varieties sown on September 20th required maximum PTU till maturity which was higher as compared to rest of the sowing dates. The highest PTU was obtained during vegetative phase of TRY 1 during all dates of sowings, later the higher PTU was experienced by IWP followed by ADT 39. The higher PTU value in early sown crop may be due to fact that crop took longer duration to reach different phenological stages.

Helio Thermal Units (HTU)

Accumulated Helio Thermal Units required to attain different phenological stages of rice genotypes are presented in (Table 7). The total HTU 12885.8 ^{o}C day hour recorded was higher with TRY 1 when compared to other varieties, especially when

Table 5. Total Growing Degree Days (day ^{o}C) prevailed at different phases of aerobic rice.

Rice genotypes & Phenophases	Date of sowing (D)					
	D_1	D_2	D_3	D_4	D_5	Mean
Improved White Ponni (V_1)						
1	513.7	502.8	491.4	471.9	446.5	485.26
2	583.8	526.6	538.3	532.3	485.1	533.22
3	281.3	275.6	277.1	243.2	233.1	262.06
4	468.7	472.4	414.3	401.8	392.5	429.94
5	1847.5	1777.4	1721.1	1649.2	1557.2	1710.48
TRY 1 (V_2)						
1	513.7	502.8	491.4	471.9	446.5	485.26
2	569.9	538.8	524.8	510.4	471.8	523.14
3	330.1	308.1	290.7	276.5	283.0	297.68
4	472.2	473.1	437.3	416.3	384.3	436.64
5	1885.9	1822.8	1744.2	1675.1	1585.6	1742.72
ADT 39 (V_3)						
1	513.7	502.8	491.4	471.9	446.5	485.26
2	569.9	526.6	498.7	478.2	439.9	502.66
3	241.3	228.7	245.5	225.7	231.4	234.52
4	443.8	434.2	391.8	381.0	389.5	408.06
5	1768.7	1692.3	1627.4	1556.8	1507.3	1620.50



V_1 : I.W. Ponni, V_2 : TRY 1, V_3 : ADT 39; D_1 : September 20th sowing, D_2 : September 27th sowing, D_3 : October 4th sowing, D_4 : October 11th sowing, D_5 : October 18th sowing

Fig 2. Duration of major phenophase of aerobic rice

Table 6. Total Photo Thermal Unit (PTU) (degree) prevailed at different phases of aerobic rice.

Rice genotypes & Phenophases	Date of sowing (D)					
	D_1	D_2	D_3	D_4	D_5	Mean
Improved White Ponni (V_1)						
1	6119.0	5954.2	5792.3	5542.9	5224.1	5726.5
2	6810.4	6122.9	6229.7	6150.8	5598.7	5061.1
3	3238.1	3169.9	3193.2	2808.7	2696.1	3021.2
4	5426.2	5480.9	4827.2	4691.6	4589.5	5003.0
5	21593.7	20727.9	20042.4	19194.0	18108.4	19933.2
TRY 1 (V_2)						
1	6119.0	5954.2	5792.3	5542.9	5224.1	5726.5
2	6649.8	6263.2	6673.9	5898.3	5445.8	6186.2
3	3800.1	3543.7	3349.0	3192.8	3274.2	3431.9
4	5475.5	5503.2	5098.6	4865.6	4500.1	5088.6
5	22044.4	21264.3	20913.8	19499.6	18444.2	20433.2
ADT 39 (V_3)						
1	6119.0	5954.2	5792.3	5542.9	5224.1	5726.5
2	6649.8	6122.9	5774.3	5528.6	5078.3	5830.7
3	2203.9	2630.0	2823.8	2600.3	2671.9	2585.9
4	5126.9	5026.0	4546.4	4431.9	4544.1	4735.0
5	20099.6	19733.1	18936.8	18103.7	17518.4	18878.3

the crop was sown on 20th September (D_1). Among the phenophases, there existed a higher value of HTU during early phases like seedling and vegetative for early sown crops (September 20th and 27th), whereas, the trend slightly differed for later date of sowing (October 11th and 18th). This might be due to delayed maturity in early sown crop as compared to late sown rice crop. It

Conclusion:

From the present investigation it can be concluded that crop sown on 20th September produced higher grain yield and also it took maximum calendar days, GDD, PTU and HTU for maturity. The reduction in yield was significant with subsequent delay in sowing times. The highest grain yield was recorded in variety TRY 1 as compared to other varieties (ADT 39 and Improved White Ponni) tested in the investigation.

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