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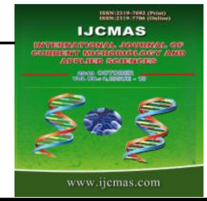

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Original Research Article

Morphophysiological and Phenological Effects of Cultivation Systems and Planting Dates of Rice Genotypes in the Coastal Plains of Orissa, India

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A B S T R A C T

Field experiments were conducted in *Kharif* of 2009 and 2010 in the East and South East Coastal Plain zone of Odisha to study the morphophysiological and phonological effects of dates of sowing and systems of cultivation of rice genotypes. The experimental site in particular was located at 86^0 22’ E longitude, 20^0 17’ N latitude, 14 m above the mean sea level, and at a 25.6 km air distance from the Bay of Bengal in the East. The location of the experiment is characterized by a warm and moist climate with a hot and humid summer and normal cold winter. The experiment was carried out in a split-split plot design with 18 treatment combinations and three replications. The treatments consisting of three dates of sowing viz. 20 June (early), 5 July (normal) and 20 July (late) were assigned to the main plots, three systems of cultivation such as best management practice (BMP), the system of rice intensification (SRI) and modified SRI (MSRI) were allotted to 3 subplots and two medium duration rice genotypes viz. high yielding variety Tapaswini and hybrid Ajay were grown in sub-subplots. Early sowing of rice resulted in the tallest plants, highest tiller and leaf count per unit area, maximum shoot biomass, crop growth rate and longer duration for attaining phenophases such as panicle initiation, 50% flowering and physiological maturity. Among the systems of rice cultivation, MSRI recorded superior morphophysiological parameters and longer duration to attain phenophases except for plant height as SRI resulted in the tallest ones. Hybrid Ajay was better than Tapaswini in all such parameters but the phenophases were longer in the latter one. Early sowing of hybrid rice Ajay under MSRI could be recommended to the farming community in the coastal Orissa for achieving the best morphophysiological response of rice.

Keywords

Phenophase, Growth rate, System of Rice Intensification, Dates of sowing, Hybrid rice

Introduction

Rice, a semi-aquatic annual cereal crop is the most important staple food for about half of the human race (Hawksworth, 1985 and David, 1989). The current level of annual rice production of around 545 million (M) t needs to be increased to about 700 M t to feed an additional 650 M rice eaters by 2025 using less water and less land is indeed a great challenge in Asia (Dawe, 2003). In Asia, irrigated agriculture accounts for 90% of total diverted fresh water and more than 50% of it is used to irrigate rice (Barker *et al.*, 1998). Flooded rice requires 900 to 2,250 mm (average 1,500 mm) of water depending on water management and soil and climatic factors. Almost 90% of global rice is produced under inundated conditions during the major part of the growing season but recently, inundated rice has come under pressure due to declining availability of water and labour, increasing demand for rice and other food items, increasing claims on limited land resources and increasing concern for environmental pollution. These changes in ecological, social and economic conditions call for transformation in rice cultivation to comply with current and future developments.

Rice plants are known to be capable of growing under both flooded and non-flooded conditions (Teare and Peet, 1983) and irrigation methods can vary from continuous submergence to intermittent flooding (Ustimenko-Bakumovsky, 1983). Efforts are being made in many countries to reduce the water requirements for growing rice. Concerns about sustainability and, the social and technical shortcomings of the green revolution have triggered a number of alternative crop production strategies like the "System of Rice Intensification", popularly known as "SRI". The use of hybrids and water-saving approach like SRI may help in increasing rice productivity. The use of young seedlings, single plant plantation, wider spacing in square geometry, use of organic manure, limited irrigation instead of flood irrigation and mechanical weeding as followed in SRI needed to be compared with the best-recommended management practices.

Although, the benefits of SRI in and around Orissa compared to the continuously flooded traditional farmers' practices are well established, studies on the effect of the "Best Management Practices" (BMP) and "Modified System of Rice Intensification" (MSRI) on the physiological effects on rice genotypes such as hybrid Ajay and ruling cultivar Tapaswini sown at different dates during *Kharif* need through evaluation in coastal Orissa.

Materials and Methods

Experimental site

The experiments were conducted during *Kharif* of 2009 and 2010 in the Agro-climatic zone of 'East and South East Coastal Plain' at a 25.6 km air distance from the Bay of Bengal in the East. The experiment site in particular was located at 86^0 22' E longitude, 20^0 17' N latitude and 14 m above the mean sea level. The soil parameters were tested and are depicted in Table 1. The location of the experiment is characterized by a warm and moist climate with a hot and humid summer and normal cold winter. Broadly, the climate falls in the 'moist hot' group (Lenka, 1976). The mean annual rainfall is 1,333.9 mm and nearly 62% of rainfall is received between June and October (827 mm). The monsoon usually sets in around mid-June and recedes by the first week of October. July and August are the wettest months, while December is the driest one during the cropping season.

The range of maximum (36.38 ^{0}C) and minimum (14.96 ^{0}C) temperatures during the experimental cropping years were more or less the same as the long-term average. The daily mean sunshine hours during the period of investigation was more or less the same as the long-term average and ranged from 1.82 to 7.84 hours.

Experimental details

The experiment was carried out in a split-split plot design with 18 treatment combinations replicated thrice (R_1, R_2 and R_3). The treatments consisting of three dates of sowing (D_1, D_2 and D_3) were assigned to the main plots, three systems of cultivation of rice (S_1, S_2 and S_3) were allotted to 3 subplots and two rice genotypes, one medium duration high yielding variety (G_1) and one medium duration hybrid (G_2) were grown in sub-subplots. The details of the treatments are in Table 2.

Description of genotypes

Tapaswini (IET 12168)

It is a semi-dwarf medium duration (135-140 days) High Yielding Variety (HYV) with medium slender grains, favourable for cultivation in the irrigated ecosystem, and developed at Central Rice Research Institute (CRRI), Cuttack through hybridization of Jagannath x Mahsuri followed by selection in the segregating generations. It was released by the Orissa State Variety Release Committee (OSVRC) in 1996 and notified by the Govt. of India in 1997. It is tolerant to white-backed plant hopper, bacterial leaf blight, moderately tolerant to leaf folder and gall midge having a yield potential of 5.5 t ha^{-1}.

Ajay (CRHR-7, IET 18166)

It is a semi-dwarf (110 cm), non-lodging and medium duration (135 days) hybrid with moderate tillering habit and high spikelet fertility (>85%) developed at the Central Rice Research Institute, Cuttack and subsequently released by the OSVRC and notified in 2005. This is an F1 hybrid developed through a three-line system of hybrid rice breeding from the cross CRMS 31A X IR 42266-29-3R. The yield potential of this hybrid is 6.5 t ha^{-1} when cultivated in *Kharif* and 7.5 t ha^{-1} in *Rabi*.

Agronomic practices of rice crop

For each date of sowing under BMP (S_1), three beds of 5 m X 1 m were prepared by raising the nursery bed 15 cm above the ground level and the beds were separated by channels in-between. In each bed, 15 kg of FYM, 50 g of MOP and 100 g of SSP were applied at the time of final land preparation.

In each bed, 0.75 kg of sprouted seeds of Tapaswini and Ajay were sown separately. After 15 days of sowing, 50 g of urea was applied to each bed. For each date of sowing under SRI (S_2) and MSRI (S_3) cultivation three beds of 2.5 m X 1 m for each genotype were prepared through the mixing of 1 part sand, 1 part well decomposed FYM and 2 parts of topsoil in between two parallel bamboos separated at 1 m width. In each bed, 50 g of MOP and 100 g of SSP were applied at the time of final bed preparation before sowing. The bed top was levelled and 0.25 kg of sprouted seeds of Tapaswini and Ajay were sown separately and duly labelled for easy identification. The seeds were covered with a soil mixture of 1 cm thickness and irrigated by sprinkling water over it.

For transplanting under S_1, seedlings from the raised nursery beds were uprooted at 25 days old stage. The beds were irrigated before uprooting for smooth lifting of the seedlings. Two seedlings hill^{-1} were transplanted in the main field at 25 cm X 12.5 cm spacing in lines.

For transplanting under S_2 and S_3, seedlings from the raised bamboo beds were uprooted at 10 days by scooping the seedlings in bulk at 2 to 3 cm below the nursery bed surface along with the moist mother soil. Due care was taken up to reduce damage to the root system of the seedlings during uprooting.

The seedlings were then carried away to the main field by trays without much delay and the transplanting was carried out preferably within half an hour of uprooting. Single seedlings hill^{-1} in S_2 and two seedlings hill^{-1} in S_3 were then transplanted in lines in the main field at 25 cm X 25 cm and 25 cm X 12.5 cm spacing, respectively.

After laying out the main field, well decomposed FYM of calculated mass was applied to different plots. In S_1 subplots FYM @ 5 t ha^{-1} along with total phosphorous and 1/3rd of the total recommended dose (100:50:50 kg ha^{-1} of $N:P_2O_5:K_2O$) of the nitrogenous and potassic fertilizers was applied before final puddling. Rest of the nitrogenous and potassic fertilizers were applied in two equal halves i.e.1/3rd at maximum tillering (40 DAS) and 1/3rd at the PI stage (70 DAS). However, in S_2 and S_3 systems of plantings, FYM @ 15 t ha^{-1} along with total phosphorous and 1/4th of the total (50:50:50 kg ha^{-1} of $N:P_2O_5:K_2O$) nitrogenous and potassic fertilizers were applied before final puddling.

The rest of the nitrogenous and potassic fertilizers were applied in three equal splits i.e. 1/4th each at 25, 40 and 70 DAS. The share of the nitrogenous fertilizer from the chemical source has been reduced to half of the recommended dose keeping in view its availability from the 10 t extra FYM applied to the field at the time of final land preparation.

In S_2 and S_3 systems of cultivation, four weeding operations at 20, 30, 40 and 50 DAS were carried out by using a conoweeder. In $S_{2,}$ the weeder was operated in a criss-cross manner and the weeds were incorporated into the soil. However, in S_3, the weeder was run in an east-west direction only. In the S_1 system of cultivation, three hand weeding operations at 40, 55 and 70 DAS were carried out incorporating the weeds *in situ*.

In the S_1 system of cultivation, water was allowed to stand in the plots since planting of the seedlings by irrigating on alternate days so as to maintain a layer of 5 to 8 cm depth of water during the entire crop period till 15 days before harvest. In S_2 and S_3 systems of cultivation, water was not allowed to stand in the plots and special care was taken to avoid submergence of 10 days' old tiny seedlings just after transplanting in the main field.

The soil was kept moist above the field capacity by irrigating the sub-sub-plots as per requirement till the PI was attained. These plots were first irrigated 5 days after transplanting to moisten the field without ponding. Second irrigation was given on the evening of the 9th day after planting at a ponding depth of 2 to 5 cm and the next morning first weeding was performed by using a cono-weeder. Thereafter alternate wetting and drying method of irrigation was practiced and subsequent irrigation was applied 3 days after the disappearance of the ponded water or immediately after the development of hair cracks on the soil surface. However, after the PI stage, the plots were allowed to hold standing water of 5 cm height up to two weeks before harvest.

Methods of recording observations

Plant height

The height of the main shoot was measured at 40, 55, 70, 85, 100 DAS and finally, at harvest. It was measured from the ground level up to the tip of the topmost leaf before flowering. However, after flowering and at harvest, the plant height up to the tip of the topmost panicle of the primary tiller from the ground level was taken into consideration.

Tillers

The number of tillers of five marked hills from each sampling unit was counted and the average was worked out to find out the mean number of tillers hill^{-1} at 40, 55, 70, 85 and 100 DAS. The number of tillers thus obtained was then multiplied by their corresponding number of hills m^{-2} to work out the number of tillers m^{-2}.

Leaf number

The total number of active leaves present in demarcated sample hills of each plot was counted at successive growth stages and the average was worked out to get the mean number of active leaves hill^{-1}. Values thus obtained were converted into the number of leaves m^{-2} by multiplying with their corresponding number of hills m^{-2}.

Leaf area index (LAI)

The five hills uprooted for dry matter studies were also used for the determination of LAI. Rolled leaves and leaves with more than 50% yellow or necrotic areas were not included. The leaf area of five uprooted hills was measured by the Licor-300 leaf area meter and their average was taken to find out the leaf area hill^{-1}. Values thus obtained were converted into the number of leaves m^{-2} by multiplying with their corresponding number of hills m^{-2}. The formula adopted for determining LAI is furnished below.

$$LAI = \frac{\text{Total leaf area } (m^2)}{\text{Unit land area } (m^2)}$$

The leaf area and LAI were determined at 40, 55, 70, 85 and 100 DAS.

Mean crop growth rate (CGR)

The mean CGR of a unit area of a canopy at any interval time (t) is defined as the increase of plant materials (dry matter) per unit of time. It was calculated by using the following formula.

$$CGR = \frac{W_2 - W_1}{t_2 - t_1}$$

Where W_1 and W_2 indicate total dry matter per unit area at times t_1 and t_2. It is expressed as g m^{-2} d^{-1}. The CGR was calculated at successive stages of crop growth (Radford, 1967; Buttery, 1970).

Mean relative crop growth rate (RGR)

It indicates the increase in dry weight per unit dry weight of the crop plant at a time interval 't'. The calculations on RGR have been done by using the following formula as suggested by Fisher (1925).

$$RGR = \frac{Log_e W_2 - Log_e W_1}{t_2 - t_1}$$

Where, W_1 and W_2 in the equation connote the total dry weight of the plant per unit area at times t_1 and t_2, respectively. It is usually expressed as $g\ g^{-1}\ m^{-2}\ d^{-1}$. The RGR like CGR was calculated at successive fortnight intervals.

Flag leaf characteristics

Flag leaf characteristics like area, width, and dry weight were recorded by the Licor-300 leaf area meter at the early ripening stage (100 DAS).

Phenological studies

Observations on days to the PI, 50% flowering and PM were marked in the sample plants of each plot and the dates were recorded correctly as per the guidelines by Reddy and Reddi (1992).

Statistical analysis

All the biometrical data collected in the pre-harvest and post-harvest studies were arranged in appropriate tables and analysed statistically by applying the analysis of variance technique (ANOVA) laid down by Panse and Sukhatme (1978); Cochran and Cox (1977); Fisher (1925) and Gomez and Gomez (1984).

Results and Discussion

Plant height

Rice plant height increased up to the crop harvest irrespective of sowing time (Fig. 1). However, the maximum increase was between 55 to 70 DAS, coinciding with the stem elongation stage. This followed a general pattern of growth in crops including rice (Leopold, 1964). Early sown rice plants were taller up to 40 DAS, but the rate of increase in height was proportionately reduced with the advancement of growth stages till 85 DAS. Thereafter, its height increased and became the tallest (121.27 cm) at harvest. On the other hand, the delayed sown rice was taller during the early and middle stages but finally lagged behind at harvest. Enhancement of height of delayed sown crop during 70 to 85 DAS could be attributed to the reduction in crop duration from seed to seed leading to earlier stem elongation.

This corroborated the earlier findings of Babu (1988); Reddy *et al.*, (1989); Kumar and Subramaniam (1991) and Dwibedi and Panda (1995). The height of rice plants in all systems of cultivation of rice progressively and consistently increased up to the harvest. Among the systems, SRI had the tallest (122.52 cm) and BMP had the shortest (113.59 cm) plants throughout the growth period.

Such an advantage of SRI over BMP could be attributed to the planting of younger seedlings earlier with more spacing between individual hills. This system thus resulted in more vigorous plant growth leading to the relative increase in stem elongation in the former one. However, the superiority of SRI over MSRI could be due to lesser inter-plant competition in double-spaced square-type plant geometry in SRI, leading to a more vigorous root system, which could have supported better individual plant growth and thus taller plants in SRI. The present result was in accordance with the findings of Vijayakumar *et al.,* (2006); Mahajan and Sarao (2009); Saha and Bharati (2010) and Thakur *et al.,* (2011). Both genotypes differed significantly in height at all stages of crop growth. Between the genotypes, hybrid rice Ajay at harvest persistently produced taller (128.59 cm) plants while cv. Tapaswini was shorter (107.55 cm) in height. The taller plants in Ajay thus obtained were perhaps due to their intrinsic ability and larger root volume. Such elevated plant height in Ajay compared to Tapaswini was also observed by Jena and Gulati (2008) in Bhubaneswar.

Tiller number

The number of tillers m^{-2} increased up to 70 DAS on each date of sowing and then gradually declined at the later part of plant growth, irrespective of sowing dates, systems of cultivation, and genotypes (Fig. 3). The reduction in the number of tillers could be due to the consequence of the reduction of tertiary tillers at the latter stages of crop growth.

Early sowing of rice had the advantage of recording more tillers throughout the growth stages except at 40 DAS when this was at par with normal sowing. Late sowing lagged behind at all growth stages in this aspect. Reduction in tillering in early sowing at 40 DAS could be due to the non-availability of growth supplementing plant nutrients and soil moisture. Increased tillering of early sowing over subsequently delayed sowings could be attributed to the harvesting of a relatively larger quantum of bright sunshine hours during the active tillering stage. Similar findings were recorded by Singh and Ghosh (1990); Mohanty and Pasupalak (1994) and Dwibedi and Panda. (1995). The effect of systems of cultivation on tiller number m^{-2} was significant at all dates of observation. The tiller number m^{-2} of rice in MSRI was significantly more than both BMP and SRI throughout the crop growth.

Among systems of cultivation, SRI lagged behind at all growth stages except at 40 DAS, thereafter SRI was having more tillers m^{-2} than BMP. Lower tillering in BMP at 40 DAS could primarily be due to the late planting of aged seedlings. Although planting of younger seedlings earlier in both SRI and MSRI surpassed BMP at the initial growth stage in recording the total number of tillers m^{-2} subsequently, BMP geared up and surpassed SRI. It could be due to the consequence of the production of tertiary tillers at the latter stages of growth in BMP.

However, the number of tillers $hill^{-1}$ when looked into, SRI showed its superiority throughout the crop growth. Thus, the increased tiller number per unit area in MSRI and BMP could be due to closer spacing. This result was supported by the findings of Thakur *et al.,* (2011) and Anitha and Chellappan (2011). In between the two genotypes, the number of tillers m^{-2} in hybrid Ajay was significantly more saved at 70 DAS when tiller productions were at par with each other.

The nutritional status of the plants and supply of carbohydrates to tiller-primordium at the node could influence tillering behaviour of transplanted rice. Moreover, the increase in the number of tillers per unit of time should be proportional to the total number of tillers present (Yoshida and Hayakawa, 1970). This could be the reason for higher tillering in hybrid Ajay, superseding cv. Tapaswini.

Leaf number

Scrutiny of the observations on the leaf number m^{-2} increased up to 70 DAS and then gradually declined at the later part of plant growth, irrespective of sowing dates, systems of cultivation, and genotypes (Fig. 4). An in-depth study indicated that the production of leaves continuously increased up to 70 DAS and thereafter decreased due to the senescence of older persistent leaves. The effect of dates of sowing on leaf number m^{-2} was significant at all five stages of crop growth. In general, early sowing (20 June) produced significantly more leaves than was followed by normal sowing (5 July) at all dates of observation save at 40 DAS. The number of leaves m^{-2} produced in late-sown rice (20 July) was not so promising. The effect of MSRI could significantly override both the BMP and SRI in producing leaf number m^{-2} irrespective of growth stages. The BMP was then followed by SRI in recording such character with significant differences at all stages of growth except at 55 DAS which was at par and significantly less than MSRI. The number of leaves m^{-2} (Fig. 4) and consequently, the LAI (Table 3) were higher in MSRI throughout the rice crop growth probably due to the production of more tillers m^{-2}. BMP lagged behind SRI in producing the number of leaves m^{-2} till 55 DAS and it surpassed at subsequent dates of observation. LAI of SRI was higher than BMP at all growth stages. This could be due to the production of more number of smaller leaves m^{-2} in BMP compared to SRI producing a relatively less number of leaves m^{-2} but having a large area. However, the number of leaves $hill^{-1}$ in SRI was outstanding throughout crop growth. The present result was in line with the earlier report of Anitha and Chellappan (2011). An in-depth study of the number of leaves produced by varying genotypes indicated significant differences at all stages of crop growth. The hybrid rice Ajay was significantly superior to the variety Tapaswini in recording such characters. The number of leaves m^{-2} was influenced by tillering behaviour so also LAI as a function of the number of leaves per unit area and leaf size which were significantly higher in Ajay than Tapaswini.

Leaf area index (LAI)

LAI is a function of the total number of tillers m^{-2}, number of leaves $m^{-2,}$ and leaf area. The number of leaves m^{-2} (Table 3) and consequently, the LAI (Table 3), increased up to 70 DAS and thereafter it declined gradually at subsequent growth stages. Early, normal and delayed sowing had LAI significantly different throughout crop duration. Early sowing had greater and delayed sowing had a smaller effect on LAI at all growth stages. The reduction in the number of functional leaves m^{-2} and LAI in later stages of plant growth could be attributed to a decrease in the number of total tillers and senescence of lower leaves. Rice sown by 20 June recorded the highest LAI due to a higher number of tillers. This reason could be applied to a reduction in the number of leaves and LAI in delayed sowing. The present result was in line with earlier reports by Kumar and Subramaniam (1991) and Dwibedi and Panda (1995). The effect of systems of cultivation on LAI of rice, when studied, had a progressive increase in values up to

70 DAS and decreased thereafter. There was a sharp increase in LAI during 55 to 70 DAS. LAI value of MSRI was more than both SRI and BMP throughout crop growth duration while BMP was of lower order. Higher LAI and interception of more sunshine could be the reasons for higher crop growth rates in MSRI and SRI compared to BMP. However, the relative growth rate of BMP was higher at all stages of growth probably due to the production of more and more tillers and leaves m^{-2} over time. LAI of hybrid Ajay was higher than cv. Tapaswini. In both genotypes, LAI values were higher at 70 DAS and the values declined at later growth stages. Area, length, and weight except for the width of the flag leaf in Ajay were significantly higher compared to Tapaswini. Flag leaf characteristics are although more intrinsic but could have been influenced positively by the interception of more solar radiation through increased LAI in Ajay. Moreover, heavier flag leaves with increased photosynthetic rate per unit area might be the reason for higher panicle and grain weight in Ajay compared to Tapaswini (Yoshida, 1978).

Shoot dry matter

The quantum of dry matter accumulated at each stage was different with variations in the date of sowing of rice (Fig. 2). Early sowing by 20 June lagged behind at 40 DAS in recording dry matter but surpassed other dates in subsequent growth stages. The reduction in dry matter at the early stage could be due to reduced tillering and less number of leaves. The present result was in accordance with the earlier report of Ghadekar *et al.,* (1988). The amount of dry matter m^{-2} accumulated above ground in MSRI was of the highest order throughout the growth of rice followed by SRI and BMP, respectively. Thus the reduced dry matter m^{-2} in BMP could be ascribed to inferior morphology and lesser activity of roots under submerged conditions. The reduction in the accumulation of dry matter in SRI could be due to the reduction of plant population per unit area owing to the doubling of intra-row spacing. However, the dry matter of individual hills in SRI surpassed other systems probably due to favourable interception of solar radiation by leaves with open geometry (Thakur *et al.,* 2011). This finding is in agreement with the report of Subbaiah *et al.,* (2007). The dry matter in hybrid Ajay was consistently higher than cv. Tapaswini at each date of observation. The crop growth rate of Ajay remained at higher order during 40-55 and 55-70 DAS. However, there was no significant genotypic difference between 70-85 and 85-100 DAS. Higher LAI and interception of more sunshine could be the reasons for the higher crop growth rate in Ajay compared to Tapaswini.

Mean crop growth rate (CGR)

The mean CGR of rice recorded at fortnight intervals from 40 to 100 DAS indicated higher values during 55-70 DAS irrespective of dates of sowing (Table 4). But, there was a sharp decline in CGR with the ageing of the crop.

However, early sowing by 20 June was better and significantly higher than that of sowing on 5 and 20 July during 40-55, 55-70, and 70-85 DAS except during 85-100 DAS when normal sowing had the highest CGR which was significantly more than late sowing but at par with early sown crop. The CGRs during 40-55 and 55-70 DAS for normal and late sown crops were statistically at par but were significantly lower than early sown crops.

Table.1 Physico-chemical properties of the experimental soil

Year	pH	Sand (%)	Silt (%)	Clay (%)	Organic Carbon (%)	EC (ds m^{-1})	Available N (kg ha^{-1})	Available P_2O_5 (kg ha^{-1})	Available K_2O (kg ha^{-1})
2008-09	5.6	42.8	28.7	28.5	0.79	0.96	457.5	22.6	192.8
2009-10	5.5				0.87	0.98	488.8	24.3	200.2
Methods followed	Beckman pH meter method (Jackson, 1958)	Bouyoucos Hydrometer method (Bouyoucos, 1951)			Volumetric method (Walkley and Black, 1947)	Digital electrical conductivity Bridge method (Jackson, 1973)	Alkaline permanganate method (Subbiah and Asiha, 1956)	Brays' method No.1 (Bray and Kurtz, 1945)	Flame photometer method (Muhr *et al.*, 1965)

Table.2 Details of treatment and symbols used

Treatments	Symbols used
The main plot (Dates of sowing)	
20 June (early)	D_1
5 July (normal)	D_2
20 July (delayed)	D_3
Subplot (Systems of planting)	
Best management practice (BMP)	S_1
System of Rice Intensification (SRI)	S_2
Modified System of Rice Intensification (MSRI)	S_3
Sub-subplots (Genotypes)	
HYV Tapaswini	G_1
Hybrid Ajay	G_2

Table.3 Effect of treatments on flag leaf characteristics at early ripening stage (100 DAS) and Leaf area index of rice

Treatments	Flag leaf				Leaf area index (LAI)				
	Area (cm^2)	Length (cm)	Width (cm)	Dry weight	40 DAS	55 DAS	70 DAS	85 DAS	100 DAS
Dates of sowing									
20 June	41.41a	38.64	1.44a	0.178a	1.19b*	3.38a	4.68a	4.49a	3.76a
5 July	39.27b*	38.19	1.38b	0.168b	1.33a	2.98b	4.21b	3.92b	3.15b
20 July	38.06b	37.46	1.33b	0.162b	1.04c	2.46c	3.97c	3.49c	2.74c
S.Em (±)	0.41	0.44	0.02	0.003	0.01	0.04	0.03	0.04	0.03
C.D. (0.05)	1.34	NS	0.05	0.008	0.04	0.14	0.09	0.14	0.11
C.V. (%)	6.22	6.87	6.77	7.84	6.08	8.94	3.89	6.38	6.50
Systems of cultivation									
BMP	36.61b	35.35c	1.37	0.156b	0.85c	2.49c	3.59c	3.19c	2.80c
SRI	44.47a	41.56a	1.40	0.190a	1.07b	2.79b	4.24b	3.92b	3.05b
MSRI	37.65b	37.37b	1.38	0.163b	1.64a	3.54a	5.03a	4.79a	3.81a
S.Em (±)	0.46	0.55	0.02	0.003	0.04	0.05	0.06	0.10	0.05
C.D. (0.05)	1.34	1.61	NS	0.007	0.12	0.13	0.17	0.28	0.14
C.V. (%)	6.94	8.68	7.64	6.90	21.42	9.36	8.11	14.70	8.77
Genotypes									
Tapaswini	37.24b	36.31b	1.42a	0.153b	1.11b	2.74b	3.92b	3.64b	3.01b
Ajay	41.91a	39.88a	1.35b	0.186a	1.26a	3.14a	4.66a	4.29a	3.43a
S.Em (±)	0.27	0.22	0.01	0.001	0.02	0.02	0.03	0.05	0.03
C.D. (0.05)	0.76	0.62	0.03	0.004	0.04	0.06	0.09	0.15	0.08
C.V. (%)	4.92	4.19	5.37	5.85	9.68	5.26	5.58	9.51	6.43

* Means followed by common letters did not differ significantly up to the 5% level.

Table.4 Effect of treatments on mean crop growth rate and relative growth rate during different growth stages of rice

Treatments	Mean crop growth rate ($g\ m^{-2}\ d^{-1}$)				Relative growth rate ($g\ g^{-1}\ m^{-2}\ d^{-1}$)			
	Days after sowing							
	40-55	55-70	70-85	85-100	40-55	55-70	70-85	85-100
Dates of sowing								
20 June	17.35a	22.84a	16.94a	10.26a	0.1054a	0.0482b	0.0206	0.0107a
5 July	14.87b*	21.11b	15.47ab	10.27a	0.0910c	0.0475b	0.0216	0.0112a
20 July	14.55b	20.29b	14.51b	6.66b	0.1012b	0.0524a	0.0211	0.0084b
S.Em (±)	0.140	0.44	0.58	0.58	0.0007	0.0010	0.0006	0.0007
C.D. (0.05)	0.46	1.43	1.88	1.89	0.0024	0.0033	NS	0.0022
C.V. (%)	5.38	12.30	22.16	38.27	4.44	12.13	17.86	39.42
Systems of cultivation								
BMP	11.13c	18.41c	15.91	8.56	0.1099a	0.0578a	0.0255a	0.0115
SRI	16.59b	21.60b	14.16	9.18	0.0950b*	0.0456b	0.0186b	0.0098
MSRI	19.04a	24.23a	16.85	9.44	0.0927b	0.0447b	0.0192b	0.0089
S.Em (±)	0.47	0.78	1.27	0.93	0.0028	0.0021	0.0019	0.0010
C.D. (0.05)	1.36	2.28	NS	NS	0.0082	0.0062	0.0055	NS
C.V. (%)	17.99	21.90	48.66	61.57	16.98	25.75	53.15	58.10
Genotypes								
Tapaswini	14.35b	20.46b	15.33	9.45	0.0989	0.0507	0.0211	0.0110
Ajay	16.83a	22.37a	15.95	8.67	0.0995	0.0481	0.0211	0.0092
S.Em (±)	0.21	0.27	0.45	0.60	0.0010	0.0007	0.0005	0.0007
C.D. (0.05)	0.61	0.77	NS	NS	NS	NS	NS	NS
C.V. (%)	9.95	9.25	20.90	48.48	7.73	10.37	17.63	51.90

* Means followed by common letters did not differ significantly up to the 5% level.

Fig.1 Effect of treatments on plant height (pooled value) at different growth stages of rice. The vertical bars indicate the corresponding standard error values

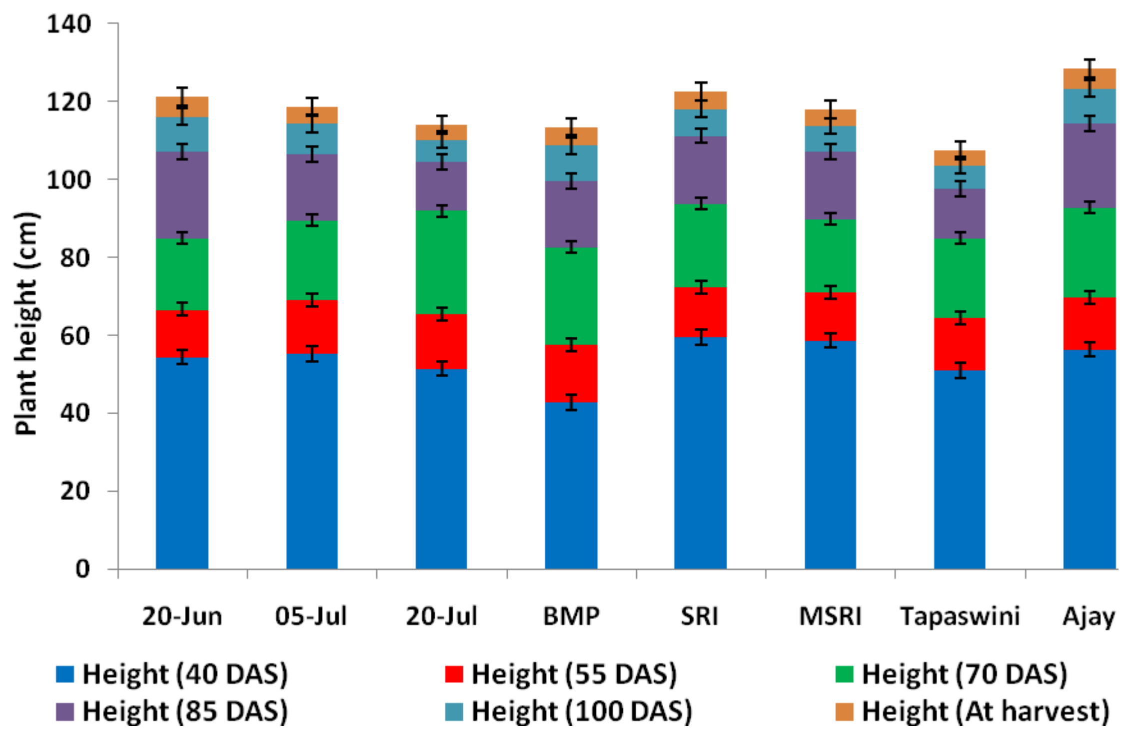


Fig.2 Effect of treatments on dry matter m^{-2} at different growth stages of rice

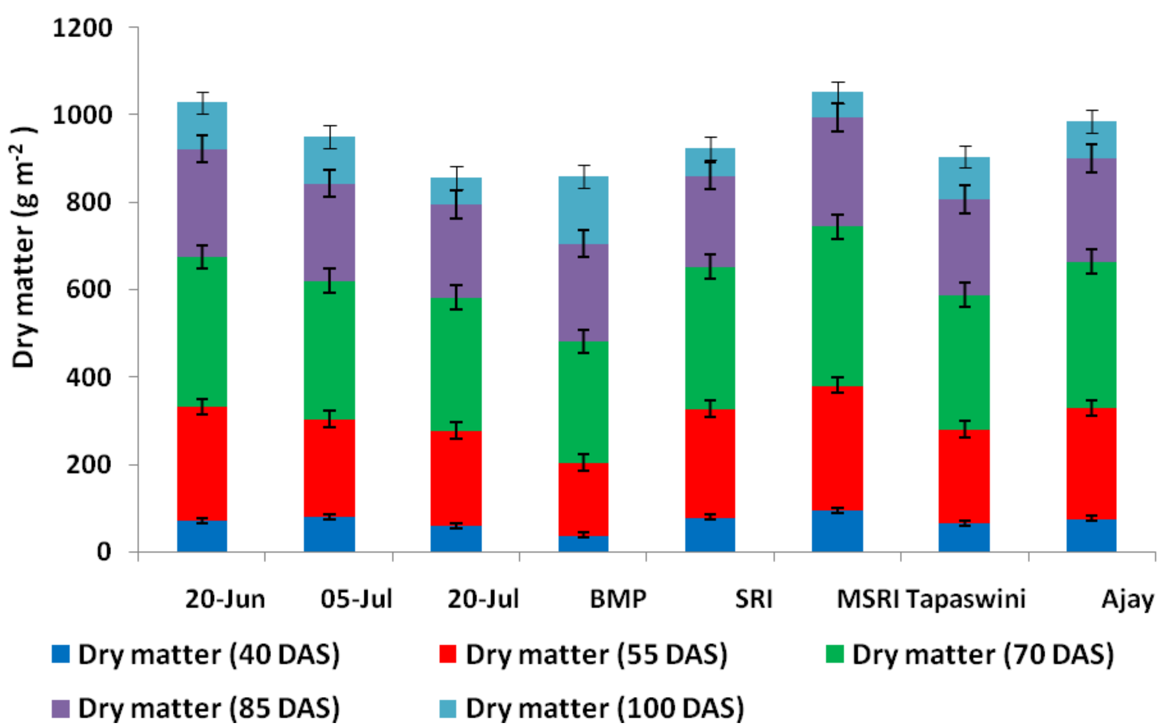


Fig.3 Effect of treatments on tillers m^{-2} at different growth stages of rice

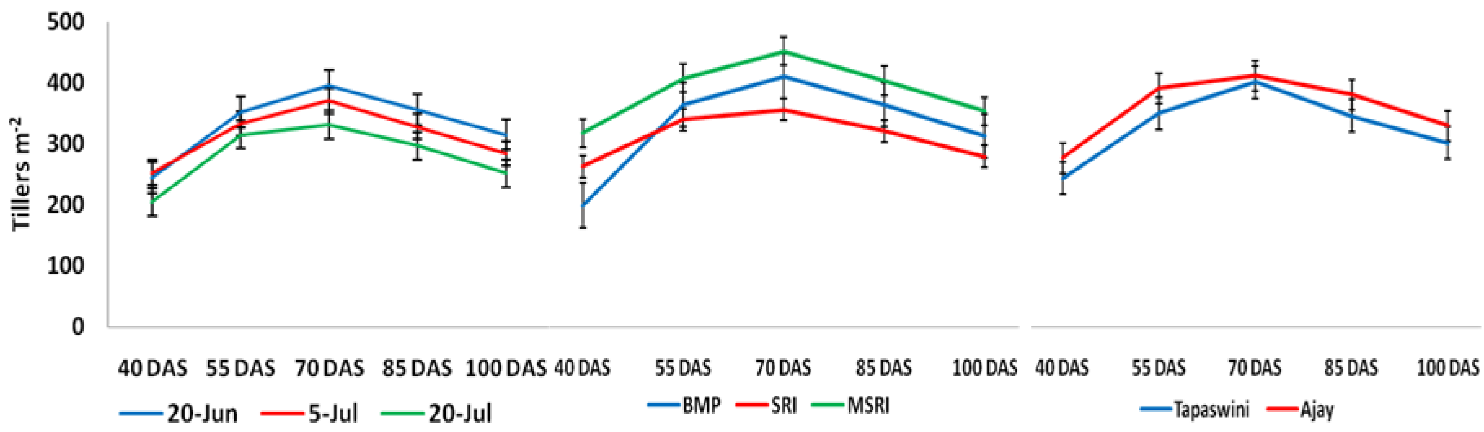


Fig.4 Effect of treatments on the number of leaves m^{-2} at different growth stages of rice

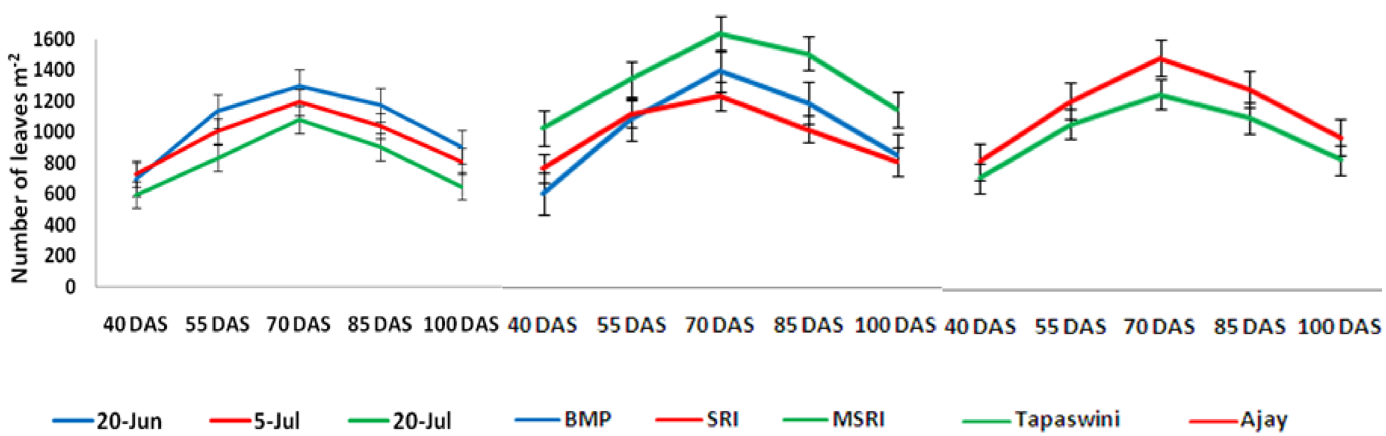
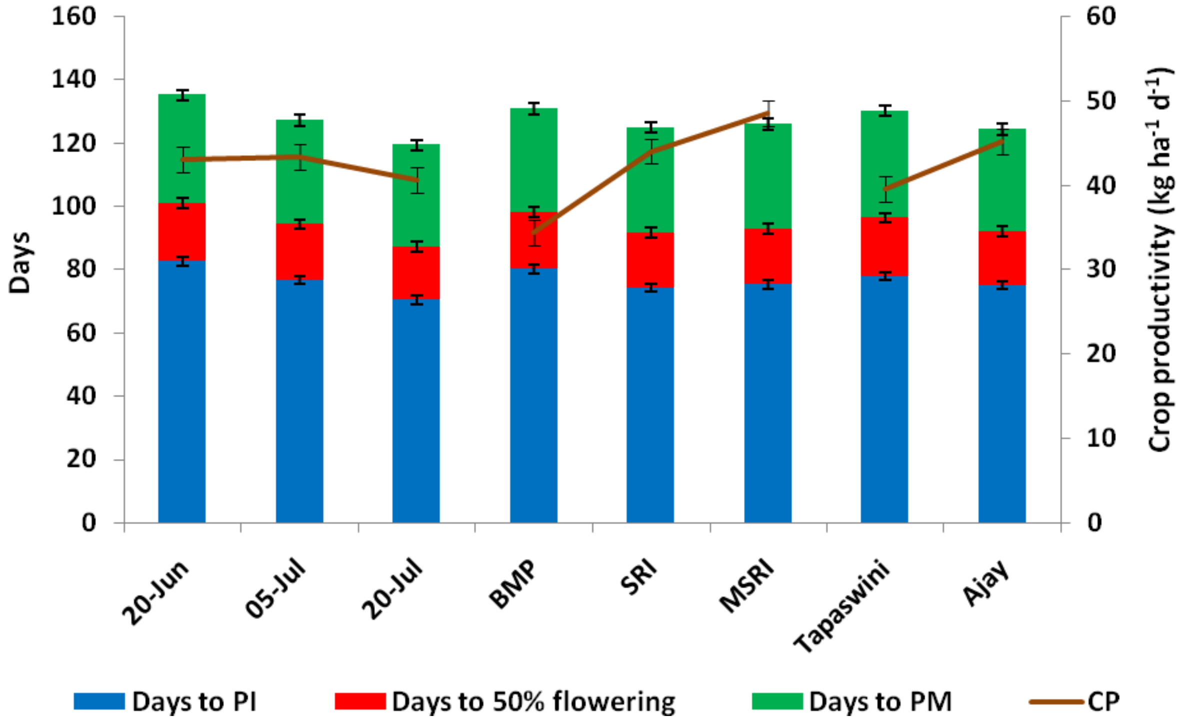


Fig.5 Effect of treatments on days to different growth stages and crop productivity of rice



The CGR values of all three systems of cultivation varied significantly during early growth stages up to 55-70 DAS and reached the peak and subsequently declined. The CGR values during 70-85 and 85-100 DAS under all three systems of cultivation remained equivalent. The CGR of MSRI superseded SRI during 40-55 and 55-70 DAS. The CGR of Ajay was significantly higher during the early phase till 55-70 DAS and it remained at par with Tapaswini during subsequent stages of growth. The rate of dry matter accumulation increased to 55-70 DAS which sharply declined with the ageing of both genotypes.

Mean relative growth rate (RGR)

RGR values of rice recorded at fortnight intervals from 40 to 100 DAS were higher in early sowing at 40-55 DAS (Table 4). This was followed by late sowing. Delayed sowing had higher RGR during 55-70 DAS while during 85-100 DAS values were less. Higher LAI and more sunshine hours could be the reasons for higher crop growth rate and relative growth rate at the very early date of sowing by 20 June. The present result corroborated the findings of Rao (1987) and Yogeswar Rao (1989). RGR of BMP could ride over SRI and MSRI which however remained at par during all growth stages. Ajay and Tapaswini were having almost similar RGR throughout the growth period and were at par, statistically.

Flag leaf characteristics at the early ripening stage (100 DAS)

Flag leaf characteristics like area, width, and dry weight were significantly higher in earlier sown rice (Table 3). Normal and late sowing were at par with respect to such parameters. However, the length of the flag leaf did not differ due to variations in the sowing time of rice. The positive points of flag leaf characteristics in the early date of sowing could be due to more interception of bright solar radiation than that of subsequent dates of sowing. Flag leaf characteristics like area, length, and weight were significantly higher in SRI. However, MSRI and BMP were at par with regard to flag leaf characters like area and weight but were significantly different in its length. The width of the flag leaf did not differ statistically among systems of cultivation. The positive flag leaf characteristics in SRI might be due to the uniform distribution of bright solar radiation in crop canopy and thereby its higher interception compared to that of other systems of cultivation. There were significant differences between the two genotypes with respect to all four flag leaf characteristics. Hybrid Ajay recorded a higher flag leaf area (41.91 cm^2), length (39.88 cm), and weight (0.186 g) whereas the flag leaf width was higher in the variety Tapaswini (1.42 cm).

Duration to growth stages

The growth duration of a genotype is highly location-specific and season specific because of the interaction between the genotype’s photoperiod and temperature sensitivity and weather conditions (Yoshida, 1978). Days to the PI, 50% flowering and PM were of higher order in early-sown rice compared to further delay in sowing (Fig. 5). Such reduction in growth duration in late-sown rice might be due to a progressive decrease in soil and air temperature and a decline in bright sunshine hours when sown beyond 20 June. Early sown rice received favourable solar radiation levels and temperature regimes (Halder *et al.*, 2004; Sha and Linscombe, 2005). The BMP, MSRI, and SRI were in diminishing order in recording days to the PI, 50% flowering, and PM of rice. The reduction in phenological duration of rice in SRI and MSRI might be due to favourable growth factors in soil and better light interception by open canopy enhanced growth cycle to complete life earlier. However, rice in BMP having been deprived of such conditions might have toiled hard to complete its growth cycle with delayed growth stages. A little delay in attaining the growth stages of rice in MSRI could be attributed to the availability of relatively less favourable factors compared to SRI. The present result was in agreement with the report of Krishna *et al.*, (2008); Ganesh *et al.*, (2006) and Shekhar *et al.*, (2009). Ajay was relatively faster in achieving growth stages *viz.* panicle initiation, 50% flowering, and physiological maturity are probably due to their intrinsic genetic character.

Field experiments were conducted during *Kharif* 2009 and 2010 to study the morphophysiological and phenological effects of sowing dates and systems of cultivation on rice genotypes in the coastal Orissa. Early sowing of rice by 20 June produced the tallest plants, highest tiller count and leaf count per unit area, leaf area index, and individual flag leaf area at the early ripening stage (100 DAS). The delayed sowing was inferior to both early (20 June) and normal (5 July) sowing dates of rice. Among the systems of cultivation, the modified system of rice intensification (MSRI) resulted in the maximum dry matter, tillers, and leaves per unit area, the maximum leaf area index and the crop growth rate. However, plants under SRI were the tallest ones and under the best management practices (BMP) had the shortest plants. Under early sowing by 20 June, rice phenophases such as panicle initiation, 50% flowering and physiological maturity stages were attained late compared to the normal (5 July) and delayed sowing (20 June) whereas phenophases in the BMP were delayed and under the SRI, plants attained these growth stages the earliest. Among the genotypes, hybrid Ajay was superior in recording parameters such as plant height, tiller number, shoot dry matter, leaf count and leaf area index whereas the phenophases in cv. Tapaswini these phenophases were delayed and thus it took more time to mature than hybrid Ajay. From the above results, it could be recommended to adopt the early sowing of hybrid rice Ajay under the modified SRI in coastal Orissa.

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