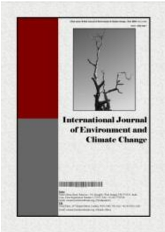

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Effect of Sowing and Harvesting Times on Growth Characters and Grain Yield of Rabi Rice (*Oryza sativa* L.)

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Authors' contributions

This work was carried out in collaboration among all authors. All authors read and approved the final manuscript.

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ABSTRACT

Aim: To determine the optimum sowing and harvesting times to realize better performance of growth characters and higher grain yield in rice during *rabi*.
Study Design: Strip plot.
Place and Duration of Study: Rice Research Centre, Agricultural Research Institute, Rajendranagar, Hyderabad between November 2021 to May 2022.
Methodology: The experiment was assigned in eighteen treatments,laid out in strip plot with three replications.Treatments included were 3 treatments of varieties (i) M_1=Telangana sona (short slender) (ii) M_2= Jagtial rice 1(Medium sender) (iii) M_3= Chintu (short slender) and 6 sowing and harvesting times (i) S_1 = Normal sowing time (November 15) and harvesting at physiological maturity (ii) S_2= Normal sowing time (November 15) and harvesting at 7 days after physiological

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maturity(iii) S_3 = Delay sowing by 15 days (November 30) and harvesting at physiological maturity (iv) S_4 = Delay sowing by 15 days (November 30) and harvesting at 7 days after physiological maturity(v) S_5 = Delay sowing by 30 days (December 15) and harvesting at physiological maturity(vi) S_6= Delay sowing by 30 days (December 15) and harvesting at 7 days after physiological maturity randomly placed in subplots of the main plot.

Results: Significantly higher plant height (93.8 cm), dry matter accumulation (14263 kg ha^{-1}), grain yield (6127 kg ha^{-1}) was observed in Telangana sona (M_1), while significantly higher number of tillers m^{-2} (566) were found in Chintu (M_3). Similarly, maximum plant height (94.4 cm), number of tillers m^{-2}(462), dry matter accumulation (14501 kg ha^{-1}), grain yield (6235 kg ha^{-1}) was noticed at Delay sowing by 30 days (December 15) and harvesting at physiological maturity (S_5). The lowest plant height, dry matter accumulation, grain yield was recorded in Chintu (M_3), while lowest number of tillers were recorded in Jagtial rice 1 (M_2) and above parameters were recorded lowest at Normal sowing time (November 15) and harvesting at 7 days after physiological maturity (S_2).

Conclusion: Among varieties, Telangana sona (M_1) performed better in terms of growth characters and grain yield. Delay sowing by 30 days (December 15) and harvesting at physiological maturity (S_5) revealed better performance in terms of growth characters and grain yield under the present study during *rabi* conditions.

Keywords: Rice varieties; sowing and harvesting times; growth characters; grain yield.

1. INTRODUCTION

Rice (*Oryza sativa* L.) is one of the world's most important food crop, providing 70% direct employment in rural India and forming the staple diet of billions of people saha et al. [1]. Rice cultivation is critical to Asia's food security because it accounts for more than 90% of rice production and consumption. Rice provides 32-59% of dietary energy and 25-44% of dietary protein. Rice demand is expected to rise by 70% in the next 30 years to maintain current per capita availability (69 kg yr^{-1}), while keeping land productivity constant Patra and Haque [2]. Rice production is the world's single largest land use for food production, covering 164 M ha and producing about 750 million tonnes of paddy each year FAO [3]. India is the second largest producer of rice after China. In India, rice is cultivated in 45.7 M ha with production of 124.3 million tonnes and productivity of 2717 kg ha^{-1} GOI [4].

The timing of transplanting in rice is critical to ensure adequate vegetative growth during a period of moderate temperature and high solar radiation. Proper transplanting date for each cultivar ensures that the cold sensitive stage occurs when the minimum night temperatures have historically been the warmest and planting at the right time ensures that grain filling occurs when temperatures are more likely to be mild, resulting in high-quality grain Farrell et al. [5]. Transplanting too soon or too late reduces yields in ways that no other input or practice can compensate for Kapoor et al. [6]. Temperatures that are too high or too low can affect flowering and prevent pollen shedding, resulting in high infertility and chaffy grain production, resulting in yield loss. To achieve a maximum yield level and quality of grain, it is necessary to optimise transplanting time.The harvesting of the crop at the right time ensures the maximum quantity and quality of rice. Harvesting the crop too early may result in a lower yield of the crop with poor quality grains as there will be a number of green or immature grains. If the rice crop is harvested too late, the grains may shatter and be eaten by birds and rodents, resulting in grain loss. Grains develop sun cracks as a result of over-maturity and over-drying in the field, resulting in severe breakage during milling. A critical evaluation of the optimal harvest stage is considered necessary for farmers to maximize the return on their produce.

Of the total rice crop area of 45.7 M ha in India, the *kharif* and *rabi* percentages are 88.18 and 11.81 respectively, where as in Telangana, the rice crop area in *kharif* and *rabi* season are almost same (20.99 M ha and 20.78 M ha) which as a unique GOT [7]. Traditionally, Telangana farmers used to cultivate market demand fine grain varieties to the tune of 40% in *kharif*, where as in *rabi*, almost 90% of rice area with long slender grain type varieties.The long slender grain varieties are procured by government through Indira kranthi pathakam right from the villages. Telangana *rabi* rice season is typical with sunny days, cold nights (large diurnal variations) and temperatures raising sharply from March onwards with low relative humidity. These weather conditions though very good for higher yields, at the same time limits the quality of rice (Low head rice recovery). To minimize the broken rice percentages, millers practices paraboiling for *rabi* rice.This rice is exported to Kerala,Tamil Nadu and other southern states for grain consumption. But those too have started cultivation of long sender varieties to meet their needs. As a result, there is no market for long slender varieties. As the buffer stocks (268.32 mt) are sufficient, the Food Corporation of India is not showing much interest to purchase parboiled rice during the *rabi* FCI [8]. With the change of central government policy of not to procure parboiled rice is big jolt to the farming community of Telangana state.

The farmers in Telangana starts *rabi* nursery sowing from 10th November to 20th January, subjecting the rice crop to wide environmental variations. Though some studies were carried out regarding performance of long slender rice varieties in *rabi* season. pertaining to yield Anil and Siddi [9], no research studies were conducted with market demand fine grain rice varieties especially under delayed sowings/harvestings, which is a common problem in most of the farmers fields. By considering all the above facts, the following work was put forth.

2. MATERIALS AND METHODS

A Field experiment was conducted during *rabi* season of 2021 at Rice Research Centre, Agricultural Research Institute, Rajendranagar, Hyderabad with eighteen treatments laid out in strip plot design with three replications shown in Fig. 1.The soil of experimental site was clay loam in texture and slightly alkaline in reaction (pH 7.8), low in organic carbon (0.48%) and available nitrogen (213 kg ha^{-1}), high in available phosphorus (27.2 kg ha^{-1}) and potassium (453.1 kg ha^{-1}). Treatments included were 3 treatments of varieties (i) M_1=Telangana sona (ii) M_2= Jagtial rice 1 (iii) M_3= Chintu and 6 sowing and harvesting dates (i) $S_{1=}$ Normal sowing time (November 15) and harvesting at physiological maturity (ii) S_2= Normal sowing time (November 15) and harvesting at 7 days after physiological maturity(iii) S_3 = Delay sowing by 15 days (November 30) and harvesting at physiological maturity (iv) S_4=Delay sowing by 15 days (November 30) and harvesting at 7 days after physiological maturity(v) S_5=Delay sowing by 30 days (December 15) and harvesting at physiological maturity(vi) S_6 =Delay sowing by 30 days (December 15) and harvesting at 7 days after physiological maturity randomly placed in subplots of the main plot. Telangana sona is a short slender (fine) grain variety with a duration of 135 days during *rabi* and high yielding (6500 to 7500kg ha^{-1}) possessing blast resistance. Jagtial rice 1 is a long bold (coarse) grain variety with a duration of 135-140 days during *rabi,* having high yield potential (7500-8000 kg ha^{-1}) with tolerance to brown plant hopper, cold, salinity lodging and grain shattering. Chintu is a short slender (fine) grain variety having yield potential (6500-700 kg ha^{-1}) with a duration of 130-140 days possessing blast resistance. Though some studies were carried out regarding performance of coarse grain rice varieties in *rabi* season. pertaining to yield, no research studies were conducted with market demand fine grain rice varieties such as Telangana sona and Chintu during *rabi*. Jagtial rice 1 was selected in order to know whether coarse grain or fine grain variety performs best. Nursery of three varieties *i.e.,* Telangana sona, Jagtial rice 1 and Chintu was raised as per the dates of sowing *i.e.,*15th November, 30th November, 15th December. The sprouted seeds were broadcasted on well prepared raised beds adopting seed rate of 50 kg ha^{-1}, 62.5 kg ha^{-1} and 15 kg ha^{-1} respectively maintaining a spacing of 15 cm × 15 cm. The crop was fertilized with 150-60-40 Kg ha^{-1} N, P_2O_5 and K_2O in the form of urea, DAP and MOP.

3. RESULTS AND DISCUSSION

3.1 Growth Parameters

3.1.1 Plant height

The data presented in Table 1 shows that at 30 days after transplanting, significantly higher plant height was observed in M_1 (Telangana sona) and was on par with M_2 (Jagtial rice 1), which was again on par with M3 (Chintu). At 60 days after transplanting Significantly higher plant height was observed in M_1 (Telangana sona) over all other varieties followed by M_2 (Jagtial rice 1), which was on par with M_3 (Chintu). At 90 DAT, similar trend was observed like that of 30 DAT. At harvest, similar trend was observed like that of 60 DAT. It may be due to the genetic character of the variety. The results consistent with the findings of Nizamani et al. [10] and Suleiman et al. [11], who observed plant height, differed significantly among the varieties. At 30 DAT, S_5 (Delay sowing by 30 days (December 15) and harvesting at physiological maturity) shown significantly higher plant height and was on par with S_6 (Delay sowing by 30 days (December 15) and harvesting at 7 days after physiological maturity), which was again on par with S_3 (Delay sowing by 15 days (November 30) and harvesting at physiological maturity) and S_4 (Delay sowing by 15 days (November 30) and harvesting at 7 days after physiological maturity). The lowest values of plant height were observed in S_2 (Normal sowing time (November 15) and harvesting at 7 days after physiological maturity). At 60 DAT, significantly higher plant height was observed in S_5 (Delay sowing by 30 days (December 15) and harvesting at physiological maturity) and was on par with S_6 (Delay sowing by 30 days (December 15) and harvesting at 7 days after physiological maturity), followed by S_3 (Delay sowing by 15 days (November 30) and harvesting at physiological maturity),which was in turn on par with S_4 (Delay sowing by 15 days (November 30) and harvesting at 7 days after physiological maturity).The lowest plant height was recorded in S_2 (Normal sowing time (November 15) and harvesting at 7 days after physiological maturity). At 90 DAT, S_5 (Delay sowing by 30 days (December 15) and harvesting at physiological maturity) shown significantly higher plant height and was on par with S_6 (Delay sowing by 30 days (December 15) and harvesting at 7 days after physiological maturity), followed by S_3 (Delay sowing by 15 days (November 30) and harvesting at physiological maturity) , which was again on par with S_4 (Delay sowing by 15 days (November 30) and harvesting at 7 days after physiological maturity) and S_1 (Normal sowing time (November 15) and harvesting at physiological maturity). The lowest plant height was observed in S_2 (Normal sowing time (November 15) and harvesting at 7 days after physiological maturity). At harvest, similar trend was observed like that of 90 DAT. Plant height is directly proportional to the length of the vegetative phase of the crop. Koireng et al. [12] reported that significantly different responses of different genotypes to various management variable and environments with respect to growth attributes due to inherent characteristics. The interaction effect was found nonsignificant for plant height among varieties and different sowing and harvesting dates.

3.1.2 Number of tillers m^{-2}

The data presented in Table 2 shows that at 30 DAT, M_3 (Chintu) shown significantly higher number of tillers m^{-2} over all other varieties followed by M_2 (Jagtial rice 1), which was on par with M_1 (Telangana sona). At 60 DAT, significantly higher number of tillers m^{-2} were observed in M_3 (Chintu) over all other varieties followed by M_1 (Telangana sona), which was on par with M_2 (Jagtial rice 1). Similar trend like that of 60 DAT was observed at 90 DAT, at harvest.

The number of tillers m^{-2} varied among the cultivars It might be due to differences in genetic makeup of these rice varieties. The results are in close conformity with Mali and Choudhary [13] ,Sarwar et al. [14]. At 30 DAT, S_5 (Delay sowing by 30 days (December 15) and harvesting at physiological maturity) shown significantly higher number of tillers m^{-2} over all other treatments followed by S_6 (Delay sowing by 30 days (December 15) and harvesting at 7 days after physiological maturity), which was on par with S_3 (Delay sowing by 15 days (November 30) and harvesting at physiological maturity). The lowest values of number of tillers m^{-2} were observed in S_2 (Normal sowing time (November 15) and harvesting at 7 days after physiological maturity).At 60 DAT, Significantly higher number of tillers m^{-2} were observed in S_5 (Delay sowing by 30 days (December 15) and harvesting at physiological maturity) and was on par with S_6 (Delay sowing by 30 days (December 15) and harvesting at 7 days after physiological maturity), however S_6 (Delay sowing by 30 days (December 15) and harvesting at 7 days after physiological maturity) was again on par with S_3 (Delay sowing by 15 days (November 30) and harvesting at physiological maturity). The lowest number of tillers m^{-2} was found in S_2 (Normal sowing time (November 15) and harvesting at 7 days after physiological maturity). At 90 DAT, similar trend was observed like that of 60 DAT.At harvest, S_5 (Delay sowing by 30 days (December 15) and harvesting at physiological maturity) shown significantly higher number of tillers m^{-2} and was on par with S_3 (Delay sowing by 15 days (November 30) and harvesting at physiological maturity) and S_6 (Delay sowing by 30 days (December 15) and harvesting at 7 days after physiological maturity),however S_6 was on par with S_4 (Delay sowing by 15 days (November 30) and harvesting at 7 days after physiological maturity). The lowest values of tillers m^{-2} were found in S_2 (Normal sowing time (November 15) and harvesting at 7 days after physiological maturity). This may be due to availability of favorable soil and air temperature during growing cycle of the crop. Similarly, these findings were supported by Sharma [15] and Osman et al. [16]. The interaction effect was found nonsignificant for number of tillers m^{-2} of rice crop among the varieties and different sowing and harvesting dates.

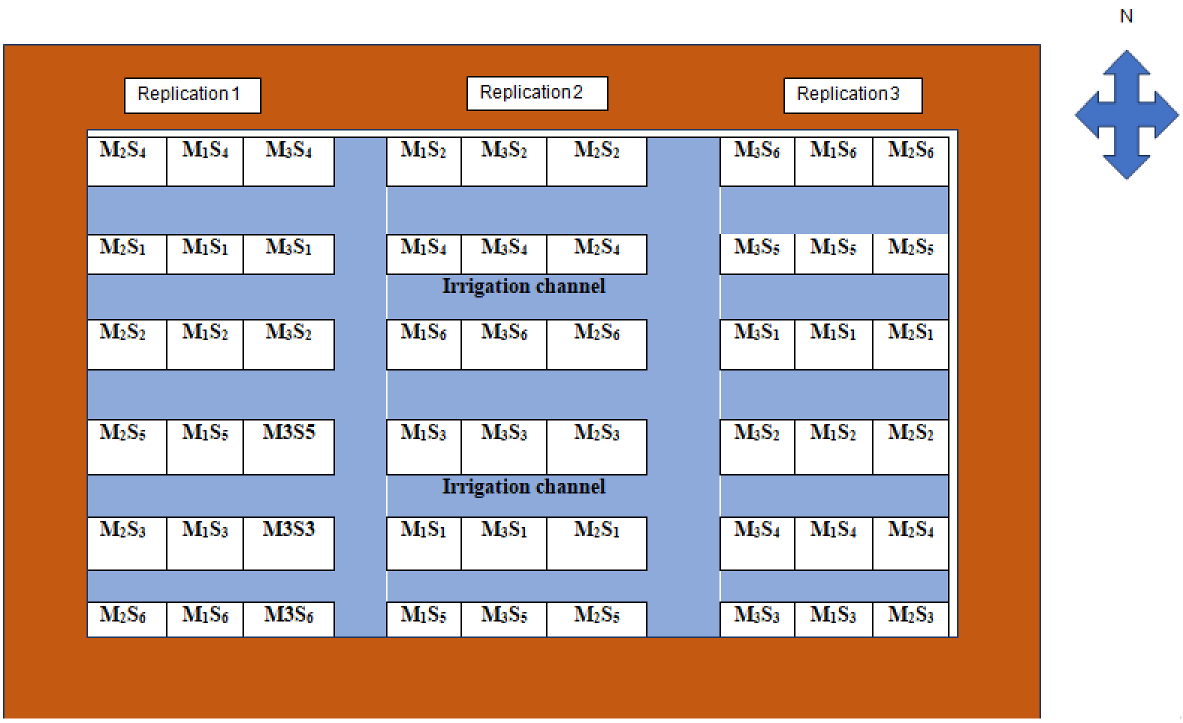

Fig. 1. Strip plot design for the field experiment

Table 1. Plant height (cm) at different growth intervals of rice as influenced by varieties, sowings and harvesting dates

Treatments	30 DAT	60 DAT	90 DAT	Harvest
Main plots : Varieties				
M_1 - Telangana sona	54.0	75.4	82.3	93.8
M_2 - Jagtial rice 1	50.1	67.1	73.4	82.9
M_3 - Chintu	47.8	65.7	71.6	80.1
SE(m)±	1.07	1.17	2.62	2.62
CD (p=0.05)	4.2	4.6	10.3	10.3
Sub plots: Sowing and harvesting dates				
S_1 - Normal sowing time (November 15) and harvesting at physiological maturity	46.8	63.3	71.4	81.7
S_2- Normal sowing time (November 15) and harvesting at 7 days after physiological maturity	43.1	60.8	69.2	78.5
S_3 - Delay sowing by 15 days (November 30) and harvesting at physiological maturity	51.4	70.7	75.7	86.0
S_4 - Delay sowing by 15 days (November 30) and harvesting at 7 days after physiological maturity	51.2	67.5	72.0	81.4
S_5 - Delay sowing by 30 days (December 15) and harvesting at physiological maturity	57.0	78.1	84.1	94.4
S_6 - Delay sowing by 30 days (December 15) and harvesting at 7 days after physiological maturity	54.4	75.8	82.3	91.7
SE(m)±	1.13	1.04	1.76	1.76
CD (p=0.05)	3.6	3.3	5.5	5.5

Treatments	30 DAT	60 DAT	90 DAT	Harvest
Interaction				
M×S				
SE(m)±	1.59	2.22	3.48	3.48
CD (p=0.05)	NS	NS	NS	NS
S×M				
SE(m)±	1.58	2.06	2.78	2.78
CD (p=0.05)	NS	NS	NS	NS

Table 2. Number of tillers m^{-2} at different growth intervals of rice as influenced by varieties, sowing and harvesting dates

Treatments	30 DAT	60 DAT	90 DAT	Harvest
Main plots : Varieties				
M_1 - Telangana sona	297	397	383	359
M_2 - Jagtial rice 1	305	376	359	353
M_3 - Chintu	482	590	579	566
SE(m)±	7.07	12.58	12.65	15.50
CD (p=0.05)	28	49	50	61
Sub plots: Sowing and harvesting dates				
S_1 - Normal sowing time (November 15) and harvesting at physiological maturity	330	430	416	403
S_2- Normal sowing time (November 15) and harvesting at 7 days after physiological maturity	312	404	398	389
S_3 - Delay sowing by 15 days (November 30) and harvesting at physiological maturity	369	457	446	436
S_4 - Delay sowing by 15 days (November 30) and harvesting at 7 days after physiological maturity	352	443	429	419
S_5 - Delay sowing by 30 days (December 15) and harvesting at physiological maturity	418	512	490	462
S_6 - Delay sowing by 30 days (December 15) and harvesting at 7 days after physiological maturity	389	479	463	446
SE(m)±	9.00	10.96	8.48	8.51
CD (p=0.05)	28	35	27	27
Interaction				
M×S				
SE(m)±	16.66	21.55	21.96	23.19
CD (p=0.05)	NS	NS	NS	NS
S×M				
SE(m)±	16.83	19.81	18.93	18.36
CD (p=0.05)	NS	NS	NS	NS

Table 3. Plant dry matter accumulation (kg ha^{-1}) at different growth intervals and grain yield (kg ha^{-1}) as influenced by varieties, sowing and harvesting dates

Treatments	30 DAT	60 DAT	90 DAT	Harvest	Grain yield (kg ha^{-1})
Main plots : Varieties					
M_1 - Telangana sona	4366	9120	13115	14263	6127
M_2 - Jagtial rice 1	4117	8880	12863	14005	6000
M_3 - Chintu	3679	7592	10858	11979	4927
SE(m)±	236.41	189.33	187.81	195.13	92.99
CD (p=0.05)	NS	743	737	766	365

Treatments	30 DAT	60 DAT	90 DAT	Harvest	Grain yield (kg ha^{-1})
Sub plots: Dates of sowings and harvestings					
S_1 - Normal sowing time (November 15) and harvesting at physiological maturity	3585	7916	11688	12832	5665
S_2- Normal sowing time (November 15) and harvesting at 7 days after physiological maturity	3243	7573	11310	12475	5316
S_3 - Delay sowing by 15 days (November 30) and harvesting at physiological maturity	4168	8741	12436	13517	5663
S_4 - Delay sowing by 15 days (November 30) and harvesting at 7 days after physiological maturity	3907	8334	12104	13284	5395
S_5 - Delay sowing by 30 days (December 15) and harvesting at physiological maturity	4901	9564	13363	14501	6235
S_6 - Delay sowing by 30 days (December 15) and harvesting at 7 days after physiological maturity	4520	9055	12771	13885	5835
SE(m)±	129.64	204.82	190.71	188.94	74.52
CD (p=0.05)	409	645	601	595	235
Interaction					
M×S					
SE(m)±	359.38	410.38	400.61	401.03	223.48
CD (p=0.05)	NS	NS	NS	NS	NS
S×M					
SE(m)±	286.23	399.73	384.29	380.53	205.57
CD (p=0.05)	NS	NS	NS	NS	NS

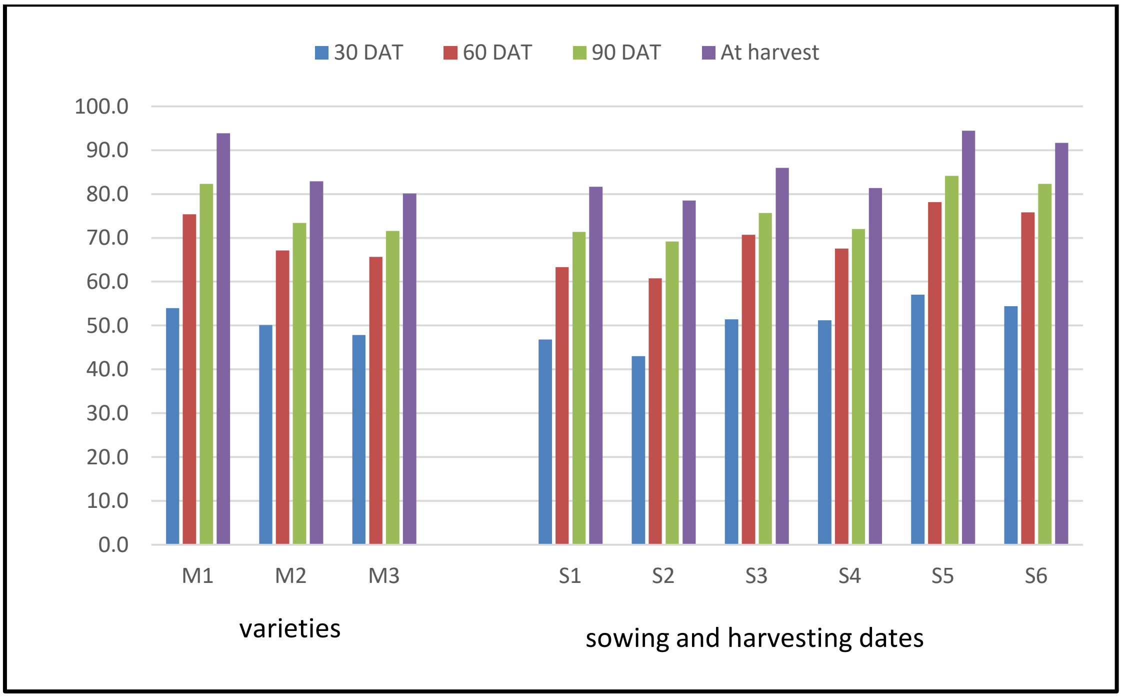

Fig. 2. Plant height (cm) at different growth intervals of rice as influenced by varieties, sowing and harvesting dates

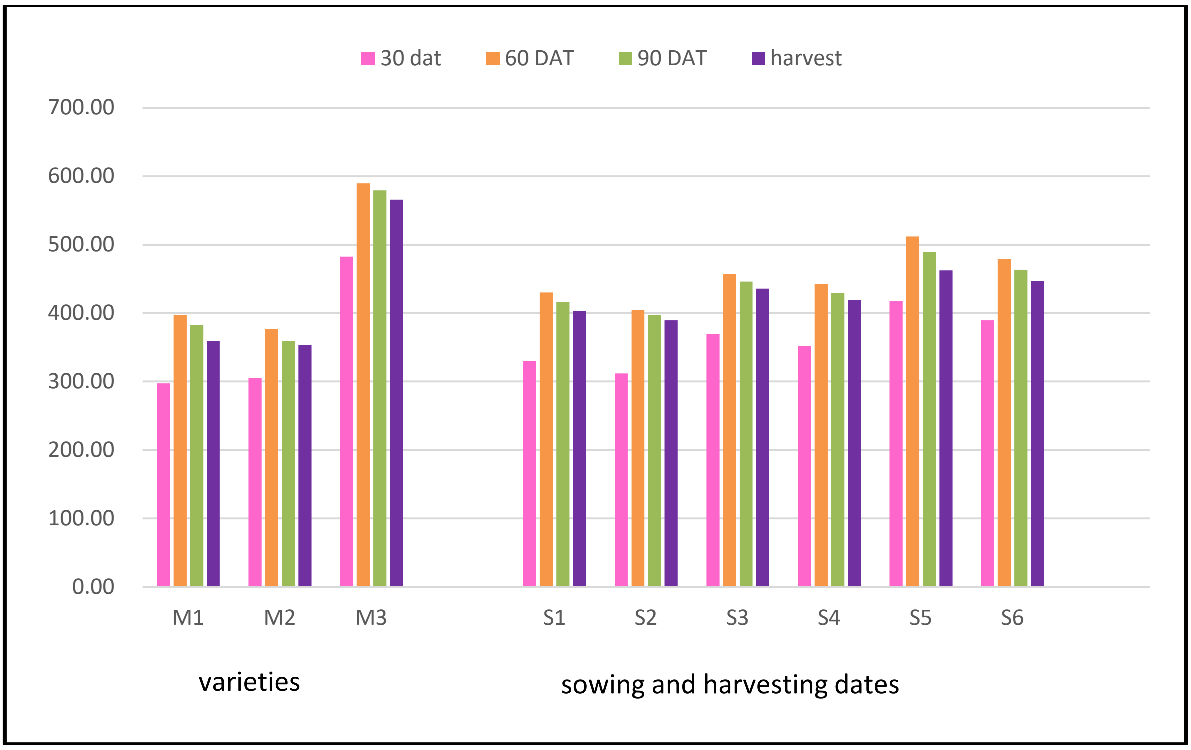

Fig. 3. Number of tillers m^{-2} at different growth intervals of rice as influenced by varieties, sowing and harvesting dates

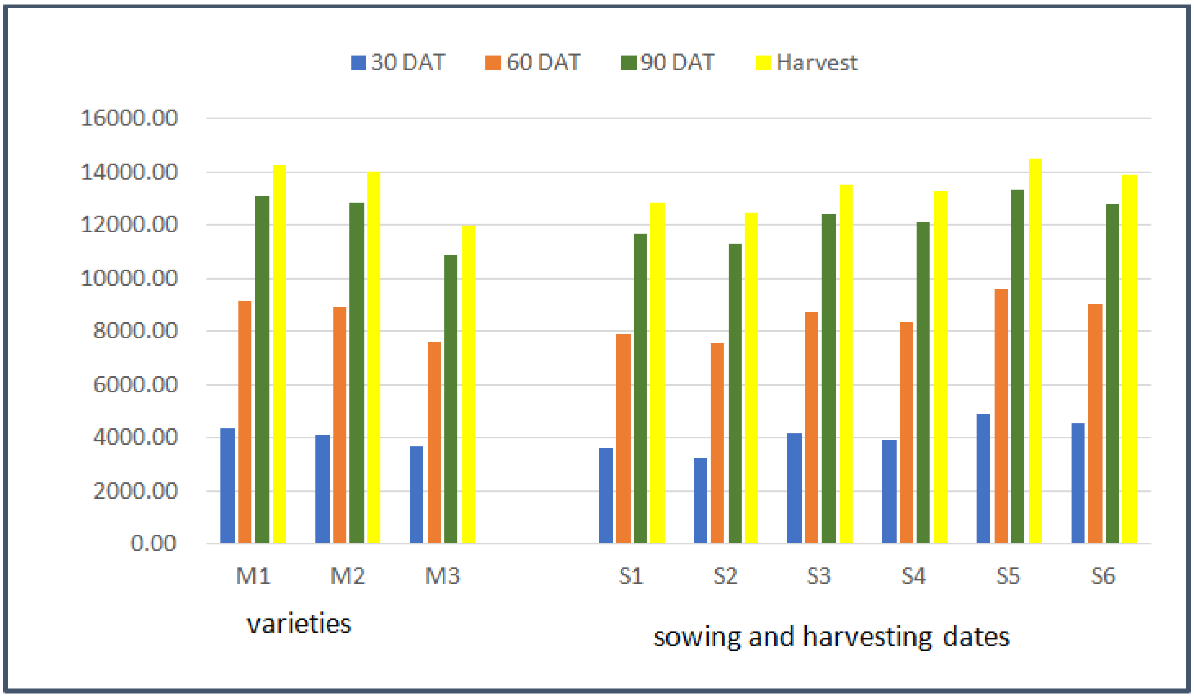

Fig. 4 Dry matter accumulation (kg ha^{-1}) at different growth intervals of rice as influenced by varieties, sowing and harvesting dates

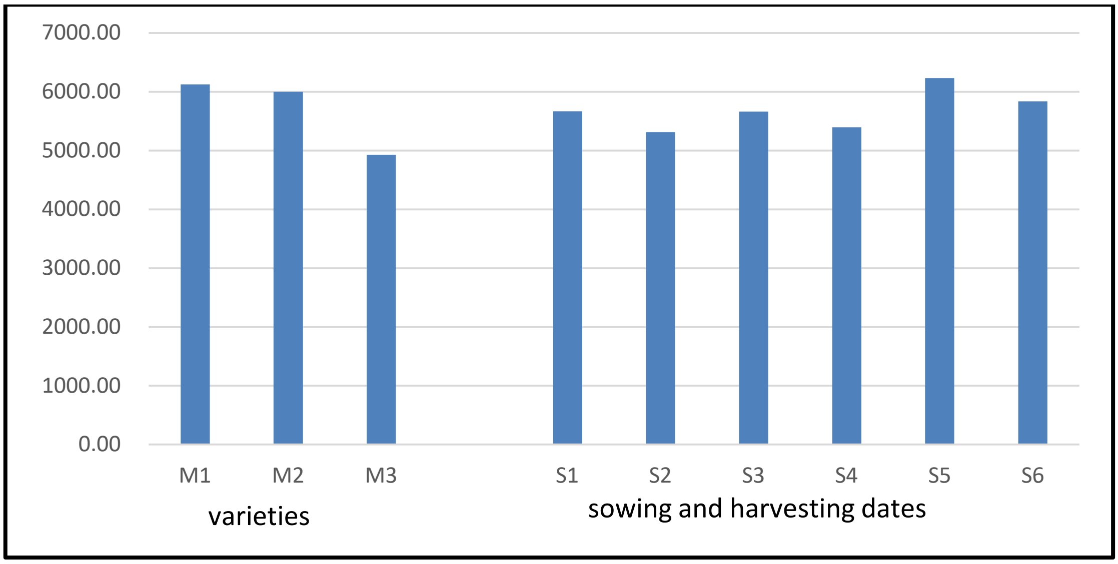

Fig. 5. Grain yield (kg ha^{-1}) of rice as influenced by varieties, sowing and harvesting dates.

3.1.3 Dry matter accumulation

The data presented in Table 3 shows that at 30 DAT, there was no significant difference in dry matter accumulation among varieties. At 60, 90 DAT and at harvest, significantly higher dry matter accumulation was observed in M_1 (Telangana sona) and was on par with M_2 (Jagtial rice 1). The lowest dry matter accumulation was observed in M_3 (Chintu). The difference in dry matter accumulation among the genotypes might be due to their genetic potential and differential plant height. Similar results were obtained by Dileep et al. [17]. At 30, 60 and 90 DAT, significantly higher dry matter accumulation was found in S_5 (Delay sowing by 30 days (December 15) and harvesting at physiological maturity) and was on par with S_6 (Delay sowing by 30 days (December 15) and harvesting at 7 days after physiological maturity), which was again on par with S_3 (Delay sowing by 15 days (November 30) and harvesting at physiological maturity). The lowest values of dry matter accumulation was found in S_2 (Normal sowing time (November 15) and harvesting at 7 days after physiological maturity).At harvest, significantly higher dry matter accumulation was found in S_5 (Delay sowing by 30 days (December 15) and harvesting at physiological maturity)and was on par with S_6 followed by S_3 (Delay sowing by 15 days (November 30) and harvesting at physiological maturity), which was again on par with S_4 (Delay sowing by 15 days (November 30) and harvesting at 7 days after physiological maturity). The lowest values of dry matter accumulation were found in S_2 (Normal sowing time (November 15) and harvesting at 7 days after physiological maturity). Increase in plant height, tillers hill^{-1} resulted in better interception of sunlight and efficient photosynthesis thus provided favourable condition for enhancement of dry matter production during sowing of rice in mid of December.These findings are in accordance with Duvvada et al [18].Interaction effect was found nonsignificant for dry matter accumulation of rice crop among the varieties and different sowing and harvesting dates.

3.2 Grain Yield

The data presented in Table 3 shows among different varieties tested, M_1 (Telangana sona) shown significantly higher grain yield and was on par with M_2 (Jagtial rice 1). Lower values of grain yield were found in M_3 (Chintu).The superiority of Telangana sona and Jagtial rice 1 might resulted from its better growth character *i.e.,* dry matter accumulation.These results are in accordance with Bindu [19]. Among different sowing and harvesting dates, S_5 (Delay sowing by 30 days (December 15) and harvesting at physiological maturity) shown significantly higher grain yield over all other treatments followed by S_6 (Delay sowing by 30 days (December 15) and harvesting at 7 days after physiological maturity), which was on par with S_1 (Normal sowing time (November 15) and harvesting at physiological maturity)and S_3 (Delay sowing by 15 days (November 30) and harvesting at physiological maturity).The lower values of grain yield were found in S_2 (Normal sowing time (November 15) and harvesting at 7 days after physiological maturity).The increased yield might be due to higher dry matter accumulation associated with favorable temperature in delayed sowing responsible for more growth and development, resulting in more storage of photosynthates in the grain during *rabi* conditions.These findings are similar to Bindu [19].These results are in accordance with Anil and Siddi [9] and Chendge et al*.* [20].The interaction effect was found nonsignificant for grain yield of rice crop among the varieties and different sowing and harvesting dates.

4. CONCLUSION AND RECOMMENDATIONS

Based on the research work, it can be inferred that among the varieties, Telangana sona (M_1) performed better in terms of dry matter accumulation and grain yield. Among different sowing and harvesting times, Delay sowing by 30 days (December 15) and harvesting at physiological maturity (S_5) will be more effective in obtaining better dry matter accumulation resulting in higher grain yield under *rabi* conditions.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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