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Performance of rice cultivars for yield and yield attributes at twelve different dates of sowing

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Abstract

A field investigation was conducted to evaluate the effect of different sowing dates on yield and yield components of six rice cultivars during 2018-2019 at Indian Institute of Rice Research, Rajendranagar, Hyderabad. Experiment constituted of twelve sowing dates i.e. from 20th June 2018 to 01st Feb 2019 with an interval of 20 days between each sowing. Data on morphology, yield attributes and yield of six rice genotypes were recorded and statistically analysed by split plot design (main plot- cultivars, subplot-dates of sowing). Significant interaction studies between cultivars and dates of sowing revealed cv. JGL 3855 to perform best for grain yield over other cultivars. The yield contributing parameters productive tiller number m⁻², panicle weight, grain number per panicle and spikelet fertility attributed for the high yielding feature in cv. JGL 3855. Further, interaction studies indicated that sowing date D₁ (20th Jun'2018) was best suitable for all the cultivars except WGL 24071 to attain maximum grain yield. WGL 24071 performed best (7556 kg ha⁻¹) on D₈ (20th Nov'2018) sowing indicating that this cultivar is well suited for Rabi than Kharif season. D₁ (20th Jun'2018) sowing also recorded maximum plant height, number of productive (panicle bearing) tillers, panicle length, panicle weight, number of grains per panicle, 1000-grain weight, filled grain per m² and spikelet fertility %.

Keywords: sowing dates, yield attributes, yield, split plot design

Introduction

Rice grain (*Oryza sativa* L.) consumed by nearly half the world's population is grown in at least 114 countries around the world (Patel *et al.*, 2019)^[19]. Among the rice growing countries in the world, India has the largest area. Rice considered as essential staple food for more than 65 per cent of the people is also said to play a key role in food security. Globally rice is cultivated in an area of 155 million ha with an annual production of around 600 million tonnes and an average productivity of 4.10 tonnes ha⁻¹. In India, rice is grown in an area of 44.5 million ha with a production 115.60 million tonnes and a productivity of 2800 kg ha⁻¹ (Directorate of economics and statistics, 2019). In Telangana, rice is grown in an area of 2.09 million ha area with a production of 6.62 million tonnes, and productivity of 3295 kg ha⁻¹ (CMIE, 2019)^[2].

Demand for rice is estimated to rise from 676 million tonnes in 2010 to 763 million tonnes by 2020 and to further increase to 852 million tonnes by 2035. This clearly indicates that an overall increase of 176 million tonnes of rice is required, globally in the next 25 years. To safeguard and sustain the food security in India, it is important to increase the productivity of rice under limited resources. The sowing time of the rice crop is important for three major reasons. Firstly, it ensures that vegetative growth occurs during a period of satisfactory temperatures and high levels of solar radiation. Secondly, the optimum sowing time for each cultivar ensures the cold sensitive stage occurs when the minimum night temperatures are historically the warmest. Thirdly, sowing on time guarantees that grain filling occurs when milder autumn temperatures are more likely, hence good grain quality is achieved (Farrell, *et al.* 2003)^[5]. Rice seeded before the window of optimum dates usually has slow germination and emergence, poor stand establishment, increased damages from soil borne, seedling diseases under cold conditions and seeds lose by birds or mice (Linscombe, *et al.* 1999)^[13]. Planting rice after the optimum dates can result in low yield due to higher disease and insect incidence, tropical storm-related lodging and possible heat or cold damage during heading and the grain filling period (Groth and Lee, 2003 and Reza, *et al.* 2011)^[12, 9, 22].

Tashiro *et al.*, (1999)^[26] stated that sowing date also has a direct impact on the rate of establishment of rice seedling.

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Vange and Obi (2006) [27] investigated the effect of planting dates on grain yield and some agronomic characters by early seeding (June 15 and June 30) and late seeding (July 15 and July 30). These indicated that planting date affected the performance of these traits significantly. Grain yield (t ha⁻¹) were found to be highest on the July 30th. Recently Khalifa (2009) [11] in Egypt carried out field experiment for physiological evaluation of four hybrid rice varieties under six different sowing dates. Results indicated that early date of sowing is the best time of sowing for important properties such as maximum tillering, panicle initiation, heading date, number of tillers m⁻², plant height and root length at panicle initiation and heading stage, chlorophyll content, number of days to panicle initiation and heading date, leaf area index, sink capacity, spikelets/leaf area ratio, Number of grains per panicle, Panicle length (cm), 1000 grain weight (g), number of panicles m⁻², panicle weight (g) and grain yield (T ha⁻¹). The optimal date of transplanting of any field crop depends on the environmental conditions required for good growth and development. The optimum sowing time is of importance for three major reasons. Firstly, it ensures that the vegetative period occurs during a period of satisfactory temperatures and total sunshine hours which provide congenial conditions for more effective tillers. Secondly, it ensures the avoidance of cold temperatures coinciding with sensitive growth stages. Thirdly the sowing on time ensures proper grain filling that is reflected on yield potential (Patel *et al.*, 2019) [19]. To evaluate the effect of environmental variables like temperature and photoperiod on performance of yield attributing characters the following study was taken up.

Material and Methods

An experiment was conducted at IIRR, Rajendranagar, Hyderabad during the period 2018 to 2019. The plot was laid in split plot design with six cultivars as main plot and twelve dates of sowing as sub plot. The crop was grown on fertile black sandy loam soils with a pH of 7.7. The sowings were taken up from 20th June 2018 to 01st Feb 2019 with an interval of 20 days between each sowing. Cultivars considered for the study were RNR 15048, WGL 24071, IR-64, JGL 3844, JGL 3855 and JGL 11470. Seedlings of 30 days old were transplanted on puddled soils. All the agronomic practices were followed according to standard method. Plant protection measures were taken as necessary. Harvesting was done as and when crop was mature. Data on yield parameters i.e. plant height (cm), number of productive tillers (m⁻²), panicle length, panicle weight, number of grains per panicle, filled grain number per m², test weight (g), spikelet fertility %, and grain yield (kg ha⁻¹) were recorded.

Results and Discussion

Plant Height

Significant difference was observed for plant height at physiological maturity stage. Mean range for plant height among the cultivars was 79 to 87cm. RNR 15048 recorded the mean maximum plant height and was significantly superior (87cm) to the other cultivars (table 1.1). Mean minimum plant height observed was for the cv. IR-64 and JGL 3844 (79.0 cm). Sowing date 20th Jun'2018 (D₁) has recorded the maximum height (96.7cm) and was comparable to 10th Jul'2018 (D₂) (94.7cm). Mean minimum plant height (70.8cm) was recorded for 20th Dec'2018 (D₁₀) sowing and was on par (71.9 & 73.4cm respectively) with 10th Jan 2019 (D₁₁) and 1st Oct 2018 (D₆). Similar to PI and heading stage, a decrease in plant height was observed at the physiological maturity with every delay in sowing to the normal sowing

dates of Kharif and Rabi season (D₁ to D₅- Kharif; D₆ to D₁₂- Rabi season).

Interaction study for cultivars with different dates of sowing revealed a plant height to range from 66.6 to 107.2cm. Similar to the PI and HD stage, the cultivar RNR 15048 and sowing date D₁ (20th Jun'2018) recorded the maximum plant height of 107.2cm. Except for D₆ (1st Oct 2018), remaining sowing dates (D₁ to D₅ and D₇ to D₁₂) have shown maximum height for RNR 15048 cultivar. Further, interaction of cultivars with different dates of sowing showed that sowing date D₂ (10th Jul'2018) was suitable for WGL 24071 and IR-64. To attain maximum height, sowing date, D₁ (20th Jun'2018) was suitable for JGL 11470, JGL 3855, JGL 3844 and RNR 15048. From the above studies it has been observed that, plant height among the cultivars showed variation at PM stage. Two distinct peaks were recorded at D₁ and D₈ sowings (Fig 1.1). Early sowings recorded more plant height than the succeeding sowings (Fig 1.1). Farmers who practice early or late sowing than the recommended dates also reported similar trends in plant height. RNR 15048 has attained maximum height with two peaks as compared to all other cultivars at all crop growth stages (PI, HD and PM stages) and when sown at dates 20th June 2018 (D₁), 10th July 2018 (D₂) and 20th Nov'2018 (D₈) (Fig 4.2). It is obvious that the reduction in plant height was attributed to the reason that late planting had shorter growing period due to photoperiodic response. Longer growing season of May planted crop produced taller plants and higher dry matter production as compared to the rest planting dates. These results are in line with Khakwani *et al.* (2006) [10] who reported that plant height is significantly affected by sowing dates. These results are also in line with Saikia *et al.* (1989) [24] and Gravois and Helms (1998) [8] who reported that early sowing of rice produced taller plants than delayed sowing.

Productive tillers m⁻²

Number of productive tillers per unit area is an important character for attaining potential yields. It accounts for 89% of the variation of grain yield (Miller *et al.*, 1991) [14]. The productivity of rice plant is generally calculated based on the number of productive tillers rather than the total tiller number. Productive tiller number (per m²) was significantly influenced by different dates of sowing among the cultivars. The mean range for productive tiller number was between 299 and 413. IR-64 (413) recorded the mean higher effective tillers m⁻² and was significantly on par with WGL 24071 (401). Mean lower productive tillers was observed for the cv. JGL 3855 (299) and was not comparable to other cultivars which might be attributed to low tiller ability of the cultivar. Gill *et al.* (2006) [7] reported that, the more number of effective tillers in short and medium duration cultivars were due to more relative growth rate of these cultivars.

Significantly more productive tillers m⁻² was recorded with crop sown on 20th Jun'2018 (D₁) (518.9) and was highly superior over the other sowing dates. This increase of fertile tillers m⁻² at 20th June sowing can be attributed to favorable environmental conditions which enabled the plant to improve its growth and development as compared to other sowing dates. The higher number of effective tillers in early sown aerobic rice was also reported by Dawadi and Chaudhary (2013) [3]. Crop sown on 10th Jul'2018 (D₂), 01st Aug'2018 (D₃), 10th Oct'2018 (D₆) and 20th Nov'2018 (D₈) were found to be on par with each other. Significantly less effective tillers m⁻² was recorded for crop sown on 20th Dec'2018 (D₁₀) and was on par with 10th Jan'2019 (D₁₁) sowing. The delay in sowing caused the crop to experience low minimum

temperatures at flowering and ripening phase, which might have resulted in the reduction of effective tillers m^{-2} .

Interaction studies between cultivars and different dates of sowing revealed the effective tiller number to range from 77 to 596. The cultivar JGL 3855 (596) and sowing date D₁ (20th Jun'2018) recorded the highest effective tiller number m^{-2} . Similarly, the cultivar IR-64 recorded high effective tillers for sowing dates D₂, D₃, D₆, D₇, D₈, D₁₀ and D₁₂. Comparison of cultivars with different dates of sowing showed that sowing date D₁ (20th Jun'2018) was suitable to attain maximum effective tillers m^{-2} for JGL 3844, JGL 3855, JGL 11470 and RNR 15048. The more number of effective tillers m^{-2} in early sown crop was due to the fact that the cultivars had longer duration for their vegetative growth, compared to those sown late in the season (for respective seasons Kharif-D1 to D5 and Rabi-D6 to D12). However, the cultivars WGL 24071 and IR-64 showed maximum productive tillers (561.6) on D₄ (01st Sep'2018) sowings, but the panicle length observed was comparatively less, leading to low yields. Tillering in rice is a major determinant for panicle production and as a result affects total grain yield (Gallagher and Biscoe, 1978)^[6].

From the above statistical analysis it has been observed that, the effective tiller number m^{-2} among the cultivars showed significant variation across the dates of sowing. Early or late planting of crop reduced the productive tiller number and yield significantly. It can eventually be inferred that cv. IR-64 and WGL 24071 produce more productive tillers than other cultivars under study and sowing date D₁ (20th Jun'2018) is best time for sowing to attain maximum productive tillers m^{-2} .

Panicle length

Panicle length (PL) is an important trait for improving panicle architecture and grain yield in rice (Liu *et al.*, 2016)^[4]. Significant variation was observed for panicle length across different dates of sowing for all the cultivars. Panicle length ranged between 20.9 to 22 cm. RNR 15048 (22cm) recorded the mean maximum panicle length and was on par with JGL 11470 (21.7cm), and JGL 3844 (21.6cm). Mean minimum panicle length was noted by cv. JGL 3855 and was on par with WGL 24071 (21.4 cm) and IR-64 (21.2 cm). Panicle length is considered to be a genetic feature, but it would be affected by the environmental conditions that prevail during the crop growth period. Similar varietal difference for panicle length was observed by several researchers (Dawadi and Chaudhary (2013)^[3].

Significantly highest panicle length was recorded with crop sown on 20th Jun'2018 (D₁) (23.3 cm) and was on par with 10th Jul'2018 (D₂) and 01st Feb'2019 (D₁₂) sowings. These results were in accordance with the findings of Dawadi and Chaudhary (2013)^[3] who reported that, 28th Jun sown crop had significantly longer panicle length than 13 Jul sown crop, but it was statistically similar with 13 Jun sown crop. Crop sown on 10th Jul'2018 (D₂) recorded lowest panicle length (19.8 cm) and was comparable to 01st Sep'2018 (D₄), 10th Sep'2018 (D₅) and 10th Oct'2018 (D₆) sowing dates. Early sown crop had the benefit of favorable environment for its growth and development. Further, the higher drymatter accumulation in early sown crop might have led to longer panicles, than the late sown crop. Muhammad *et al.* (2010)^[16] made similar observation wherein late sown aerobic rice have reduced growth period which in turn reduced biomass accumulation and length of the panicle to early sown crop.

Interaction studies between sowing dates and cultivars revealed a significant variation for panicle length. The range for panicle length was 18.1 to 25 cm. RNR 15048 at sowing

date D₁ (20th Jun'2018) recorded the maximum panicle length. The sowing date D₁ (20th Jun'2018) was found to be suitable to attain maximum panicle length for cultivars IR-64, JGL 3844, JGL 3855, JGL 11470 and RNR 15048 as revealed from the comparison studies between cultivars and the dates of sowing. However, sowing date D₈ (20th Nov'2018) was suitable for WGL 24071. From the above observation it can be inferred that cv. RNR 15048 possess longer panicle length than the other cultivars and the sowing date D₁ and D₂ are suitable to attain maximum length of panicle as the exertion is completely visible unlike the delayed sowings.

Panicle weight (g)

Panicle length, together with spikelet number and density, seed setting rate and grain plumpiness, determines the grain weight per panicle; hence, yield increase in rice (Liu *et al.*, 2016)^[4]. Variation in panicle weight was observed among the cultivars. Significantly more panicle weight was recorded by JGL 3844 (2.81) and was on par with JGL 3855 (2.68), and RNR 15048 (2.56). Further, significant lower panicle weight was recorded by WGL 24071 (2.04) and was not comparable with other cultivars. This difference in panicle weight among the cultivars was attributed to the dry matter accumulation. High dry matter accumulated due to high rate of photosynthesis is translocated efficiently into the seed (grain) resulting in heavier panicles. Difference in panicle weight among the varieties was also reported by Saad *et al.* (2014)^[23] who stated that, the promising line GZ 9057 had the highest panicle weight, panicle density and number of grains panicle⁻¹ as compared with SK 105 and GZ 7112.

Among the dates of sowing, the D₁ (20th Jun'2018) sowing recorded more panicle weight (3.84) and was on par (3.63) with D₂ (10th Jul'2018), which was due to the maximum dry matter accumulated at early sowing dates (2876 and 2768 g m^{-2}). Lower panicle weight (1.01) was recorded on D₅ (10th Sep'2018) and was not comparable with other dates of sowing. Further, the trend observed for panicle weight showed a decrease with delay in succeeding sowings, in Kharif and Rabi seasons (D₁ to D₅- Kharif season; D₆ to D₁₂- Rabi season).

Interaction between panicle weight and dates of sowing implied a significant variation among the cultivars. The observed range for panicle weight was 0.47 to 4.58 g. The cv. JGL3855 and sowing date D₂ (10th Jul'2018) recorded the maximum panicle weight (4.58). Similar to panicle length, the panicle weight also decreased with every successive 20 days delay in sowing as the accumulated GDD decreased with the advancement of the season. This result were in line with Balaji (2015)^[1] who also reported decrease in panicle length and weight with every successive 15 days delay in sowing due to decrease in accumulated GDD.

Cultivars at different dates of sowing on comparison showed that sowing date D₁ (20th Jun'2018) was suitable for cv., IR-64, JGL 3844, JGL 11470 and RNR 15048. Sowing date D₂ (10th Jul'2018) was suitable for cv. WGL 24071 and JGL 3855 to attain maximum panicle weights. Panicle weight along with other yield attributes determines the yield potential of the crop. Eventually it can be summarized that the cv. JGL 3855 produced heavier panicles over other cultivars under study and sowing date D₁ (20th Jun'2018) and D₂ (10th Jul'2018) are well suited to attain the maximum panicle length and weights.

Grain no. panicle⁻¹

The number of spikelets panicle⁻¹ is basically a genetic feature of a cultivar. Significant variation was observed for grain

number per panicle among the cultivars. Significantly higher grain number per panicle was recorded by RNR 15048 (276) and was on par with JGL 3855 (268). Cv. IR-64 (120) recorded the lowest grain number panicle⁻¹. Grain number per panicle is generally governed by the genetic makeup of the cultivar at PI stage, provided the environmental factors also come into play in deciding the number of filled grains per panicle. The above variation observed for grain number among the cultivars can be attributed to the genotypic variation. Further the length of the panicle is also positively correlated to the grain number (per panicle).

Among the dates of sowing, the D₁ (20th Jun'2018) sowing recorded highest grain number per panicle (283.8) and was on par (278.6) with D₂ (10th Jul'2018). Lower grain number (160.6) was recorded with D₁₀ (20th Dec'2018) and was on par with D₆ (10th Oct'2018) sowing. In earlier sown crop, more number of spikelets panicle⁻¹ might be due to favourable environmental conditions *viz.*, mean minimum temperatures, rainfall and relative humidity. Late sowings, shortened the growth period which in turn reduced the drymatter, length of panicle and number of grains panicle⁻¹ (Muhammad *et al.*, 2010) [16].

Interaction studies revealed that, the grain number ranged from 71.7 to 395.7 per panicle. The cultivar JGL 3855 and sowing date D₁ (20th Jun'2018) recorded the highest grain number. Sowing dates D₃, D₄, D₅, D₇, D₉ and D₁₂ recorded maximum grain number for the cultivar RNR 15048 and sowing dates D₁, D₂, D₆ and D₈ recorded highest grain number for cultivar JGL 3855. Further, interaction studies has shown that, the sowing date D₁ (20th Jun'2018) was suitable to attain maximum grain number per panicle in cultivars JGL 3855, JGL 11470 and RNR 15048. Similarly, the sowing date D₂ (10th Jul'2018) was suitable for the cultivars WGL 24071 and JGL 3844. D₃ (1st Aug'2018) sowings has shown maximum grain number for the cv. IR-64.

The trend for grain number per panicle was in decreasing order with every delay in succeeding sowings for Kharif and Rabi seasons (D₁ to D₅- Kharif season; D₆ to D₁₂- Rabi season). The Fig 1.1 depicts two maximum peaks at D₁ (20th Jun'2018) and D₈ (20th Nov'2018) while, two minimum peaks at D₆ (10th Oct'2018) and D₁₀ (20th Oct'2018). More grain number per panicle during D₁, D₂ and D₈ for the cultivars could be attributed to the increased panicle length which was favoured by environmental conditions like temperature, humidity, rainfall, daylength etc. Further, the cv. RNR 15048 dominated over other cultivars for grain number panicle⁻¹.

Filled grain no. m⁻²

The cultivars showed significant variation for filled grain no. m⁻² with different dates of sowing. Mean highest filled grain number was recorded by the cv. RNR 15048 (73143) was significantly superior over other cultivars. The genotypic variation along with high dry matter, panicle length and grain number per panicle resulted in maximum filled grain number in cv. RNR 15048. However, JGL 3855, JGL 3844 and JGL 11470 were found to be on par with each other. The lowest filled grain number (per m²) was noted for the cv. WGL 24071 (37649) and was comparable to IR-64 (41032). The reduced number of filled grains in WGL 24071 and IR-64 could be attributed to the long and bold nature (physical appearance) of the seed respectively. The genotypic variation in terms of number of filled spikelets panicle⁻¹ was well documented by several researchers. Reddy *et al.* (2012) [21] stated that, more number of filled spikelets panicle⁻¹ was

recorded with WGL-32100 which was significantly superior to WGL-14.

The effect of dates of sowing on the filled grain number was significant. Sowing date D₁ (20th Jun'2018) recorded significantly superior filled spikelets number (per m²). The maximum productive tiller number, panicle length, panicle weight, dry matter accumulated and test weight at D₁ (20th Jun'2018) sowing were the probable reasons for obtaining maximum filled grain number m⁻². The sowing dates D₂ (10th Jul'2018) and D₃ (1st Aug'2018) were found to be on par with each other. However, the lowest filled grain number was noted for the sowing dates D₅ (10th Sep'2018) which was not comparable to other sowing dates. This decrease in filled grain number at D₅ sowing can be attributed to low temperatures that existed in the month of November and December, which coincided with the reproductive stage of crop resulting in poor grain formation.

Significant variation was observed in the interaction study of cultivars with dates of sowing. RNR 15048 and sowing date D₁ (20th Jun'2018) recorded the maximum filled grain number per m² (139018) which can be attributed to maximum plant height and panicle length. The filled grain number m⁻² also showed the decreasing trend with delay in sowing, due to reduced panicle length and panicle weight. The decrease in the filled grain number is attributed to the change in temperatures at flowering and grain filling stage. The dates of sowing when studied in comparison with the cultivars revealed that, D₁ (20th Jun'2018) sowing was suitable for attaining highest filled grain number in cultivars WGL 24071, JGL 3844, JGL 3855 and RNR 15048. Further, for the cultivars IR-64 and JGL 11470 sowing dates D₂ (10th Jul'2018) and D₃ (1st Aug'2018) were found to be suitable, respectively. Ultimately, from the above statistical analysis it can be deduced that cultivar RNR 15048 dominated over the other cultivars for filled grain number and sowing date D₁ (20th Jun'2018) has to be followed to produce maximum filled spikelets per m².

Spikelet fertility (%)

Reduction in grain yield is considerably because of a decrease in the percentage of filled spikelets (Yoshida, 1981) [28]. Significant variation was observed among the cultivars for spikelet fertility. Cultivar IR-64 (81.2) recorded significantly the highest spikelet fertility percentage and was superior over other cultivars. Lowest percentage of spikelet fertility was observed in cultivar WGL 24071. The cause for such varietal differences can be accredited to the ability of the plant to translocate all the photosynthates efficiently to the economic part of the plant.

Sowing date D₁ (20th Jun'2018) recorded the highest percentage of spikelet fertility and was on par with D₂ (10th Jul'2018). Favorable weather parameters like mean maximum temperature, minimum temperature, relative humidity, etc. might have played a vital role in translocation of assimilates to sink organs which was indicated by the longer panicle length (23.3 and 22.9cm), panicle weights (3.84 and 3.63g), filled grain number m⁻² (104573 and 96257) and test weights (16.3 and 15.3g). Lowest spikelet fertility percentage (19.4) was observed for the crop sown on D₅ (10th Sep'2018) and this might be attributed to less number of filled grains, lower panicle weight (1.01g) and test weight (9.5g).

Study on interaction between the cultivars and dates of sowing have shown the spikelet fertility percentage to range from 0 to 97.3. The cultivar IR-64 and sowing date D₁ (20th Jun'2018) recorded the highest percentage for spikelet

fertility. Further studies indicated that the sowing date D₁ (20th Jun'2018) was best to attain maximum spikelet fertility in cultivars WGL 24071, IR-64, JGL 3844, JGL 11470 and RNR 15048. However, JGL 3855 recorded maximum spikelet fertility percentage when sown on D₃ (1st Aug'2018).

A decreasing trend was observed for spikelet fertility percentage from D₁ to D₁₂ sowings. Distinct lower peaks were observed during the D₄ (01st Sep'2018) and D₅ (10th Sep'2018) sowings. However, IR-64 has performed superior over other cultivars. Thus, to obtain maximum spikelet fertility % the crop should be preferably sown on D₁ (20th Jun'2018) and D₂ (10th Jul'2018).

Test weight (g)

Test weight is a measure of grain bulk density and is used as an indicator of general grain quality. Test weight was significantly affected by different sowing dates. IR-64 recorded the mean maximum test weight (21g) and was significantly superior over other cultivars. The mean lowest test weight (10.1) was recorded with JGL 11470 cultivar. These results clearly indicated that, the test weight is a varietal feature which might be affected least with the environmental conditions. In a study by the Praveen *et al.* (2013) [20], genotypic difference in 1000 grain weight among the varieties grown under aerobic culture was reported with the maximum test weight (31 g) recorded by Mahamaya followed by MTU 1010 (26.8 g) and lowest was with Karma Mahsuri (18.5 g). Reddy *et al.* (2012) [21] also reported that, significantly higher test weight was recorded with MTU 1001 compared to WGL 32100 and WGL 14 but at par with Keshava variety.

Crop sown on D₁ (20th Jun'2018) produced heavier grains (16.3) and was significantly superior over other dates of sowing. The maximum plant height, tiller number, panicle length, and panicle weight for the crop sown on D₁ (20th Jun'2018) might have attributed to higher test weight. The least test weight was observed for the sowing date D₅ (10th Sep'2018) which probably might be due to reduced panicle length and weight resulting in lower grain yields and maximum straw yields. A decreasing trend was observed for test weight across the staggered sowings. This indicated that the environmental conditions like temperature, humidity was most favorable for grain development during earlier dates of sowing as compared to delayed sowings.

Significant difference was observed among rice cultivars and their interaction with various dates of sowing in case of test weight. The highest test weight (25.3) was recorded by cv. IR-64 and D₁ (20th Jun'2018) sowing and the lowest test weight was recorded with cv. JGL 11470 on D₄ (1st Sep'2018) and D₅ (10th Sep'2018) sowings. Similar such observation was noticed in study done by Mrudula and Rama Rao (2020) [15]. The comparison studies revealed, that for all cultivars under study, sowing date D₁ (20th Jun'2018) was suitable to attain maximum test weight. Among the cultivars IR-64 can be considered superior over other cultivars. Higher test weight obtained might be attributed to well distributed rainfall, sufficient soil moisture and optimum photoperiod available for crop growth and development. These results are in line with the findings of Muhammad *et al.* (2010) [16], who noticed that, the rice crop sown on 20 Jun (D₁) produced heavier grains. Further, Shah and Bhurer (2005) [25] reported that, early sowing (15 Jun) had the highest 1000-grain weight and decreased with late sowings.

The panicle length, weight, number of spikelets panicle⁻¹ and test weight are basically genetic characters of a cultivar (Naik

et al., 2015). However, the environments under which they grow play a significant role in deciding these parameters. When the crop was sown in time, the genetic potential of the cultivar play a major role whereas under unfavourable environment, biotic and abiotic factors play dominant role in deciding the yield attributes and yield of a cultivar. Under delayed sowings all the cultivars exhibited poor performance in terms of panicle length, weight and number of spikelets panicle⁻¹.

Grain yield (Kg⁻¹)

Grain yield is a function of interplay of various yield components such as number of grains per panicle, productive tillers and test weight. Among the varieties tested, the cultivar JGL 3844 produced more grain yield (5136 kg ha⁻¹) and was significantly superior over other cultivars. The cultivar JGL 11470 produced significantly least grain yield of 3898 kg ha⁻¹ and was on par with WGL 24071 (3955 kg ha⁻¹). The higher yield in JGL 3844 was attributed to minimum tiller number which reduced the competition for assimilates resulting in heavier panicles (3.84g) that reflected in grain yield.

Significantly more grain yield (7636 kg ha⁻¹) was realized from the crop sown on 20th Jun'2018 (D₁) and was not comparable to the other dates of sowing. Thereafter reduction in grain yield was noticed with every successive 20 days delay in sowing from 10th Jul'2018 (D₂) to 01st Feb'2019 (D₁₂) respectively. Early sown crop might have utilized all the growth resources more efficiently than the late sown crop. The prolonged vegetative stage for the early sown crop provided opportunity to accumulate more drymatter and there by higher grain yield and yield attributes to succeeding sown crop in respective seasons (D₁ to D₅- Kharif and D₆ to D₁₂- Rabi). The lowest grain yield (1656 kg ha⁻¹) was recorded with 10th Oct'2018 (D₅) sown crop and was significantly lower than its succeeding and preceding dates of sowing.

The interaction between the cultivars and dates of sowing were significant with JGL 3855 and sowing date D₁ (20th Jun'2018) recorded significantly more grain yield (8428 kg ha⁻¹). The productive tiller number, panicle weight, grain number per panicle and spikelet fertility contributed for higher grain yield in cv. JGL 3855. Too early or too late transplanting causes yield reduction due to crop sterility and lower number of productive tillers, respectively (Nazir, 1994) [18]. Further, interaction studies between cultivars and dates of sowing indicated that sowing date D₁ (20th Jun'2018) was best suitable for all the cultivars except WGL 24071 to attain maximum grain yield. WGL 24071 performed best (7556 kg ha⁻¹) on D₈ (20th Nov'2018) sowing indicating that this cultivar is well suited for Rabi than Kharif season.

From the above studies it can be stated that early sown crop acquired more grain yield than the successive delayed sowings. Two distinct peaks were observed at D₁ (20th Jun'2018) and D₈ (20th Nov'2018) sowings. This indicated that, as the minimum temperature decreases, the grain yield also decreases. These results were in line with Nayak *et al.* (2003) [17] who stated that, late planting exposes rice crop to relatively adverse conditions, in terms of low temperature at reproductive phase, which in turn might have reduced the rice yields compared to the earlier sowings. Further the reduced solar radiation during vegetative and reproductive stages for delayed sowings of Kharif (D₁ to D₅) and Rabi seasons (D₆ to D₁₂) inhibited panicles at heading, particularly during September month in China (Lee-Tiann Feng and Lee, 1977) [12].

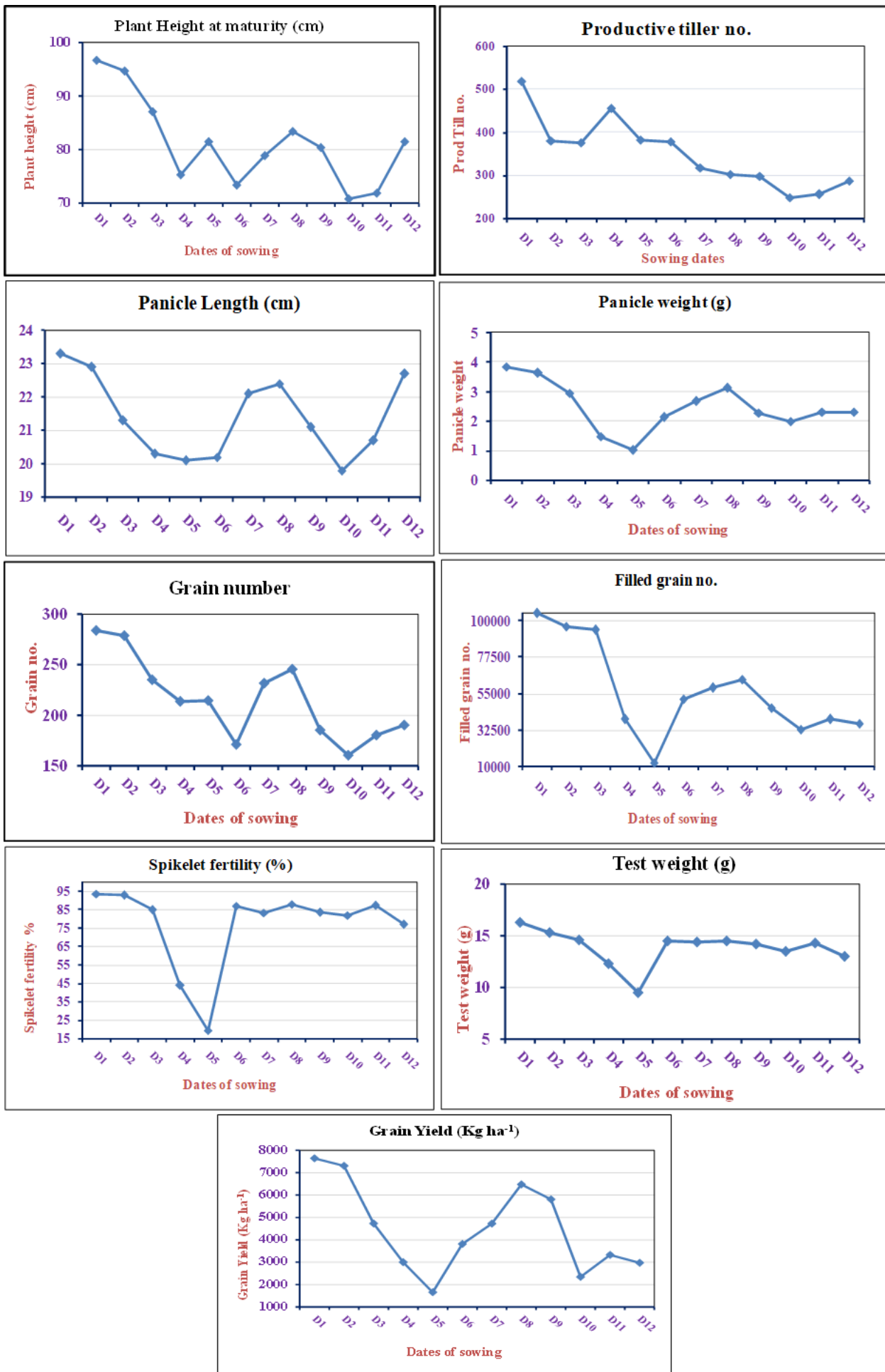


Fig 1: Trend observed for plant height, productive tiller number, panicle length, panicle weight, grain number per panicle, filled grain number, spikelet fertility, test weight and grain yield across the twelve dates of sowing.

Table 1: Split plot analysis showing effect of cultivars and different sowing dates on yield and yield components in rice

Cultivars	PLH (cm)	PRO-TILL	PL (cm)	PW	GNo./P	TW	SF%	FGNo.m ⁻²	Grain yield (Kg ha ⁻¹)
WGL 24071	81	401	21.4	2.04	143	15.9	70.7	37649	3955
IR-64	79	413	21.2	2.36	120	21.0	81.2	41032	4859
JGL 3844	79	330	21.6	2.81	240	13.4	78.0	62681	5136
JGL 3855	80	299	20.9	2.68	268	11.6	76.1	64211	4381
JGL 11470	82	324	21.7	2.40	247	10.1	76.1	59197	3898
RNR 15048	87	332	22.0	2.56	276	11.2	78.9	73143	4659
CD (p=0.05)	Main	4.46	11.6	0.52	0.15	14.44	0.11	1.31	4294.06
Dates of sowing	PLH (cm)	PRO-TILL	PL (cm)	PW	GNo./P	TW	SF%	FGNo.m ⁻²	Grain yield (Kg ha ⁻¹)
D1 (Jun'2018)	96.7	518.9	23.3	3.84	283.8	16.3	95.2	104573	7636
D2 (Jul'2018)	94.7	380.7	22.9	3.63	278.6	15.3	92.7	96257	7304
D3 (Aug'2018)	87.1	375.6	21.3	2.95	235.1	14.6	84.8	94266	4730
D4 (Sep'2018)	75.3	455.8	20.3	1.48	213.7	12.3	43.8	39279	2997
D5 (Sep'2018)	81.5	382.4	20.1	1.01	214.6	9.5	19.4	12250	1656
D6 (Oct'2018)	73.4	378.2	20.2	2.13	171.2	14.5	86.9	51836	3812
D7 (Oct'2018)	78.9	317.6	22.1	2.67	231.7	14.4	83.1	58713	4722
D8 (Nov'2018)	83.4	302.4	22.4	3.12	245.6	14.5	87.9	63604	6473
D9 (Dec'2018)	80.4	297.6	21.1	2.27	185.4	14.2	83.5	46120	5806
D10 (Dec'2018)	70.8	248.3	19.8	1.99	160.6	13.5	81.8	32997	2342
D11 (Jan'2019)	71.9	255.8	20.7	2.31	180.5	14.3	87.2	39276	3325
D12 (Feb'2019)	81.5	286.7	22.7	2.30	190.4	13.0	76.9	36658	2974
CD (p=0.05)	Sub	3.14	15.1	0.64	0.25	13.1	0.15	2.5	5235.04

Table 2: Mean range of values and interaction effect of cultivar with different sowing dates. for yield and yield components in rice

Parameter	Range	Cultivar mean range	Dates mean range	CD (p=0.05)	
				Main (V) at same or different sub (D)	Sub (D) at same main (V)
PLH (cm)	67.4-107.2	79-87	70.8-96.7	8.61	7.70
PRO-TILL	77.3- 596.0	299-401	255.8-518.9	37.3	37.0
PL (cm)	18.1-25.0	20.9-22.0	19.8-23.3	1.60	1.57
PW	0.47-4.58	2.04-2.81	1.01-3.84	0.61	0.63
GNo./P	72-396	120-276	160.6-283.8	33.92	32.10
TW	10.4-25.3	10.1-21.0	9.5-16.3	0.37	0.36
SF%	0.0-97.3	76.1-81.2	19.4-93.6	6.02	6.13
FGNo.m ⁻²	0-13,9018	37649-73143	12250-104573	12998.4	12823.2
Grain yield (Kg ha ⁻¹)	581-8428	3898-5136	1656-7636	777.56	770.02

Note: PLH – Plant height PRO –TILL – Productive tiller number PL – Panicle length PW – Panicle weight

GNo./P -- Grain number per panicle TW – Test weight SF% -- Spikelet fertility % FGNo. m-2 – Filled grain number per m2

Table 3: ANOVA results showing level of significance for the genotype x sowing date interaction for yield-yield attributing traits measured during course of field trials conducted at IIRR (2018-2019).

Source	Df	Sum Square	Mean Square	F value
Plant height				
Genotype (G)	5	1661.4	332.3	4.60*
Date (D)	11	13604.8	1236.8	54.29***
GXD	55	1762.1	32.03	1.42
Productive tillers				
Genotype (G)	5	383858.8	76771.7	156.6***
Date (D)	11	1304371.6	118579.2	225.19***
GXD	55	640862.9	11652.05	22.13***
Panicle length				
Genotype (G)	5	27.21	5.44	5.35*
Date (D)	11	296.48	26.95	28.20***
GXD	55	125.09	2.27	2.38***
Panicle weight				
Genotype (G)	5	13.19	2.63	32.88***
Date (D)	11	134.26	12.20	81.05***
GXD	55	31.23	0.56	3.77***
Filled Grain Number m ²				
Genotype (G)	5	35149080038	14095833.8	105.1***
Date (D)	11	61995773269	66852781.0	233.6***
GXD	55	41607730373	756504188.6	12.00***
Grain number per panicle				
Genotype (G)	5	806839	161367.9	213.3***
Date (D)	11	322733	29339.3	74.3***
GXD	55	174955	3180.99	8.05***
Test weight				

Genotype (G)	5	2960.6	592.11	13794.0***
Date (D)	11	590.22	53.65	1044.4***
GXD	55	1201.9	21.85	425.4***
Grain Yield				
Genotype (G)	5	44232347	8846469.4	39.49***
Date (D)	11	766450563	69677323.9	306.54***
GXD	55	119123335	2165878.8	9.53***

Note: *** significance level, df- degrees of freedom

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