Effect of differential nutrient management on growth and yield components in late sown rice

*Oryza sativa L.*

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Abstract

Sowing time and fertilization for rice cultivation is very important for growth and optimum yield. Due to some or the other factors like poor weather condition, delayed monsoon, late harvest of previous crop, farmers have to go for late sown condition which has negative impact on growth and yield of rice resulting in yield reductions. Optimizing the dose and an understanding of the nutrient utilization capacity under late sown condition will help to improve the productivity of rice. Keeping in view the aforesaid facts, a field study was conducted in rainy season of 2017 and 2018 at GBPUA&T, Pantnagar, India to assess effect of differential nutrient management on the growth and yield of six rice genotypes viz. PR-113, PD-22, HKR-47, PD-24, NDR-359 and PD-19 under late sown conditions. The treatments included 50% RDF (60:30:20 kg NPK ha⁻¹), 100% RDF (120:60:40 kg NPK ha⁻¹), 150% RDF (180:90:60 kg NPK ha⁻¹) and 50% RDF + FYM (5 t ha⁻¹). Incremental doses of N, P and K (150% RDF) significantly improved the growth parameters such as height, number of tillers, number of panicles per square meter, 1000-grain weight as well as grain and biological yield. When the dose was reduced to 50% RDF the growth and yield parameters decreased significantly. Application of FYM along with 50% RDF could not result in yield levels comparable to 100% RDF.

Keywords: Components, late sown rice, *Oryza sativa* L.

1. Introduction

Rice is the second most important cereal crop with global rice production averaging around 759.6 Million tonnes in 2018 (FAO, 2018). In general, South, South-east and east Asia contribute towards more than 90% of rice production and consumption. In particular, in India rice is the major staple food crop and is cultivated round the year in, in diverse ecologies spread over 43.86 M ha with a production of 106.5 million tonnes of rice and average productivity of 23.90 q ha⁻¹ which is quite low as compared to the global average (Anonymous, 2015) [15]. In addition, role of delayed monsoon as well as scanty rainfall in shrinking rice production has become more visible over the past few years. Farmers are forced to delay the transplanting of paddy in view of the dry weather available during the optimum time of transplanting. Delayed transplanting coupled with excessive use of unbalanced fertilizers have become the two main determinants in reducing the yield as well as compromising the partial factor productivity that can be derived per kg of nutrient.

The sowing time of the rice crop is important for synchronization of three major phenophases. Firstly, it ensures that vegetative growth occurs during a period of satisfactory temperatures and total sunshine hours. 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 (Patel et al., 2019) [14]. Sowing date is pivotal for optimum rate of establishment and subsequent phenology for growth and development. A delay in sowing reduces the time for maximum tillering i.e. the vegetative period and thus the number of productive tillers. This in turn reduces the panicle number per square meter. An altered phenology leads to lesser time for spikelet maturity and majority of the spikelets remain as primordial in case of late sowing. Further, late sowing causes coincidence of lower than optimum temperatures at anthesis leading to reduced grain filling. Accordingly, it has been reported that the decreasing trend in grain yield with delayed sowing date might be associated with the reported significant lower number of filled grains per panicle, lower number of panicles m⁻², and lower test weight (Khalifa, 2009; Patel et al., 2019) [19, 1]. Thus it can be acknowledged that, a delay in sowing time reduces the optimum growth...
window both for the vegetative as well as the reproductive phases leading to reduced yield. However, it has been reported that supraoptimal doses of nutrients lead to superior growth, development and yield in case of rice plants. High balanced doses of fertilizers can significantly affect the nutrient uptake and assimilation which translates into better yields (Sampath et al., 2017) [39].

Different nutrients have their own specific roles and in combination lead to superior growth and development of plant. Nitrogen is involved in many plant compounds such as proteins, chlorophyll, enzymes, hormones, alkaloids and vitamins, but its excess delays maturity and unnecessarily prolongs vegetative growth duration (Brady and Weil 2008) [8]. Potassium is the most abundant ionic element in plants and directly affects the crop metabolism. Potassium has an additive influence on number of filled grains per panicle (Banhmany and Mashaee, 2010) [6]. Phosphorus stimulates root development and is required for cell division. This may lead to efficient establishment of seedlings even in late planted condition. It has been shown that addition of phosphorus increased numbers of active tillers per hill and thus yield (Khan and Imtiaz, 2013) [20].

In addition to the above the uptake and availability of nutrients is also complex and is affected by the input levels of other nutrients. More often the uptake of major nutrients is coupled together. Such as both P and K improve the efficiency of N uptake by plants and provide resistance to plants against disease and drought stress. Potassium is involved in regulating the translocation of nitrate. Nutrient availability is also affected by soil physical qualities which in turn are a function of soil organic carbon. Organic manures with high estimated mineralizable C can facilitate availability of N for a greater period. Thus, an optimum level of nutrient input in right combinations only can enhance the nutrient use efficiency (Marschner, 2012) [33]. The input of mineral nutrients must take into account the effect of genotype as well. The response of a genotype depends on environment while rhizospheric environment depends on soil nature and nutrient addition. (Kamal et al., 2015) [17].

2. Material and Methods

A field experiments was conducted on rice (Oryza sativa L.) during two consecutive rainy seasons of 2017 and 2018 at the Norman. E. Borlaug Crop Research Centre, G. B. Pant University of Agriculture and Technology, Pantnagar, India. The site is situated at 29° N latitude, 79° 29’E longitude and at an altitude of 243.8 meter above sea mean level. The experiment was laid out in a split plot design with fertilizer doses in the main plots and the six rice genotypes in the sub-plot. All the main plot treatments were replicated thrice. Twenty-one-day old seedlings were transplanted with a spacing of 20cm x 20cm on 18th July during both the years. Gross plot size was 15m² and net plot size was 8.8 m². The treatments included 50% RDF (60:30:20 kg NPK ha⁻¹) (T1), 100% RDF (120:60:40 kg NPK ha⁻¹) (T2), 150% RDF (180:90:60 kg NPK ha⁻¹) (T3) and 50% RDF+ FYM (5 t ha⁻¹) (T40). The six rice genotypes were PR-113, PD-22, HKR-47, PD-24, NDR-359 and PD-19. Nutrients were applied as per the treatment primarily through NPK, Urea and Muriate of potash (MOP). Entire phosphorus and potassium and one-third of nitrogen in each treatment were applied as basal. Remaining N was applied in two splits at active tillering and panicle initiation stages. The crop was grown under standard cultural practices and plant protection measures. Data on growth, yield attributes and yield were collected at different growth stages such as maximum tillering, flowering and maturity. The data collected in both the years was subjected to pooled analysis. All statistical analysis was performed using STPR1 software and the treatments were compared using Fisher’s least significant difference method at 5% level of significance.

3. Results

3.1 Plant Height: Plant height of the rice genotypes at various growth stages viz., tillering, flowering and maturity is presented in Fig 1 (a-c). In general, plant height significantly increased with increase in dose of fertilizers at all the stages of growth. At 100% RDF, plant height ranged between 55.7 cm to 72.2 cm at tillering; 97.7 cm to 130.5 cm at flowering and 104.4 cm to 129.8 cm at maturity across the six genotypes under study. When fertilizer application was reduced to 50% of RDF, plant height decreased significantly by about 8.6, 7.8 and 9.8% at tillering, flowering and maturity stages respectively, while the magnitude of decrease in plant height when 50% RDF supplemented with FYM supplemented dose was less. When 150% RDF was applied, significant increase in plant height was observed. It was observed that FYM application increased plant height by about 3.9, 5.3 and 6% at tillering, flowering and maturity stages respectively, when compared with that at 50% RDF only. It is evident that in all the treatments the magnitude of increase in plant height was higher between tillering to flowering stages as compared to that between flowering and maturity stages except in HKR 47 where plant height continued to increase between flowering and maturity stages at recommended and 150% fertilizer doses.

3.2 Number of tillers: Data in Fig 2 represents the tiller number per metre square at active tillering, while Fig 3 represents the number of productive tillers at maturity for all the six varieties under study. Since number of tillers is a direct function of nutrition and spacing, the genotype effect was statistically insignificant. With recommended dose of fertilizer 176 to 195/m² tillers were reported at maximum tillering and 220-340/m² productive tillers at maturity. With 50% RDF average tiller number decreased significantly by 12% at maximum tillering, and 22% at maturity in terms of number of active tillers, while the decrease in tiller number was less when FYM is supplemented with 50% RDF. At 150% RDF the tiller number was significantly increased on an average by 18% at tillering, and by 20% in terms of number of productive tillers as compared to that with 100% RDF.
**Fig 1:** Effect of differential nutrient management on plant height of six rice genotypes at tillering (a), flowering (b) and maturity (c).
3.3 Yield and yield components

3.3.1 Number of panicles/m²: The number of panicles/m² of rice increased with increase in the amount of fertilizers applied and the difference was highly significant for treatment effect only (Fig 3.3). At 100% RDF the number of panicles ranged between 226/m² to 336/m² in different genotype. A significant increase (between 8-23%) was recorded with 150% RDF treatment. When the dose was reduced by half, the number of panicles decreased significantly by 22%. As compared to 50% RDF treatment, application of FYM along with 50% RDF increased the panicle number by 4-8% for all the varieties except for HKR47 in which a 14% increase was recorded. However, genotype and interaction effect were non-significant.
3.3.2 Filled grain percentage: The filled grain% was significantly affected only by incremental fertilizer dosage whereas the effect of genotype was statistically insignificant. At 100% RDF, the filled grain% ranged from 71-85%, while reducing the nutrient dose to half, filled grain% significantly decreased by 12%. The value increased significantly by 5% at 150% RDF. Application of FYM, increased the filled grain% by an average of 8-10% in rice genotypes when compared with that to 50% RDF alone. The interaction effect was non-significant (Fig 4).

3.3.3 Grain Yield and Biological Yield (Kg ha⁻¹): Grain yield and biological yield of the rice genotypes under study is presented in Fig 5a & b. At 100% RDF, the grain yield and biological yield ranged between 3080 kg ha⁻¹ to 5247 kg ha⁻¹ and 8521 kg ha⁻¹ to 11481 kg ha⁻¹ respectively, while reducing the nutrient dose to half, resulted in 47% and 46% significant reduction in grain yield and biological yield respectively. For both the parameters, the yield increased significantly by 30-60% at 150% RDF for all genotypes except HKR47 in which yield is increased by 18% only. Application of FYM enhanced grain and biological yield between 21-44% and 20-44% of the rice genotypes when compared with that to 50% RDF alone. The interaction effect was non-significant for both the parameters.

3.3.4 1000-grain weight and harvest index (HI): 1000-grain weight and harvest index (HI) of the rice genotypes under study is presented in Fig 6a & b. 1000-grain weight ranged from 21-23g at 100% RDF, the value reduced by 5.2% which is insignificant, when dose is reduced by 50%. At 150% RDF 1000-grain weight significantly increased by 3-7% of the rice genotypes under study. Application of organic manure (50% RDF+FYM) had only a slight effect on 1000-grain weight and it was increased by only 2% when compared with 50% RDF alone. Unlike 1000 grain weight the harvest index is largely governed by genotype only and effect of treatments was statistically insignificant. At 100% RDF the value ranged from 36-38%, while on reducing the nutrient dose to half, value did not reduce significantly. At 150% RDF the harvest index is increased by only 0.2%, which is non-significant. The interaction effect was non-significant for both the parameters.
Fig 5: Effect of differential nutrient management of six rice genotype on grain yield (a) and biological yield (b).

Fig 6: Effect of differential nutrient management of six rice genotype on 1000-grain weight (a) and Harvest index (b).

Discussion
Among the many factors that govern rice yield and productivity, time of sowing has the most significant influence, followed by fertilization levels and weather-based aberrations like intermittent dry spell at the time of sowing or delayed monsoon. There is unequivocal scientific proof that time of sowing and nitrogen fertilization are the two most important agronomic factors for obtaining optimum rice
yields and their importance is further underlined in the current climatic scenario where, the incidences of late monsoons are increasing year after year. Delayed transplanting of rice in view of dry weather conditions at the time of sowing coupled with unbalanced or inadequate fertilizer use lead to reduced yield as well as partial factor productivity in rice. A delay in sowing affects the rate of establishment and hence alters the phenological synchronization between and climatic conditions and various growth stages. An altered phenology reduces the optimal growth window for vegetative and reproductive phases resulting in reduced number of productive tillers as well as less time for grain filling thus leading to an overall decrease in yield and productivity. Applying supraoptimal fertilizer doses under late sown conditions significantly affects rice yield and productivity. Chemical fertilizers offer readily soluble nutrients to plants that lead to quick establishment and uptake. A high balanced dose of nutrients gears up the vegetative growth positively affecting the tiller number and canopy establishment. Based on the above background, the present study was conducted in an attempt to understand the effect of differential nutrient management on growth, yield and nutrient use efficiency of six rice genotypes under late sown conditions. It has been reported that a delay in sowing time results in reduced plant height and number of productive tillers (Shah and Bhuver, 2005) [41]. Soomro et al. (2000) reported that a delay in sowing reduced plant height by 12-15%. A two-month delay in transplanting of rice reduced plant height from 107cm to 83cm. Experiments with hybrid rice indicate that timely sowing results into optimal number of total as well as effective tillers per hill, and that a delayed sowing results in a decrease of 30-38% (Nayak et al., 2003; Wani et al., 2016) [37, 52]. Results of the present study indicate that incremental fertilizer dose of 150% RDF resulted in maximum plant height at all the growth stages as well as maximum number of total and productive tillers. The increased plant height and tiller number observed under incremental nutrient supply are in corroboration with the related previous studies. Gala et al. (2011) reported that there is supplemental effect of nitrogen fertilization on vegetative growth. Similar results have been obtained when level of N ranged from 0-150Kg/ha, with maximum plant height reported at N150 for variety SSRC91216 (Somasundaram et al., 2002) [46]. In a similar study maximum number of tillers was observed under 150Kg/ha N fertilizer and minimum tiller number was obtained for 50Kg/ha N fertilizer Hukum et al. 2014 also reported increase in plant height and tiller number of different rice genotypes with increase in fertilizer dose from N0 to N100. The increase in plant height with increase in fertilizer dose is due to the enhanced uptake by roots as well as translocation of N from culm to leaves leading to the production of sufficient photosynthates required for growth of developing panicle. Easy solubility of inorganic nutrients leads to greater availability in the soil solution, thus leading to quick establishment of seedling as faster uptake leads to greater availability in the soil solution, thus leading to quick establishment and uptake. A high balanced dose of nutrients gears up the vegetative growth positively affecting the tiller number and canopy establishment. Based on the above background, the present study was conducted in an attempt to understand the effect of differential nutrient management on growth, yield and nutrient use efficiency of six rice genotypes under late sown conditions. It has been reported that a delay in sowing time results in reduced plant height and number of productive tillers (Shah and Bhuver, 2005) [41]. Soomro et al. (2000) reported that a delay in sowing reduced plant height by 12-15%. A two-month delay in transplanting of rice reduced plant height from 107cm to 83cm. Experiments with hybrid rice indicate that timely sowing results into optimal number of total as well as effective tillers per hill, and that a delayed sowing results in a decrease of 30-38% (Nayak et al., 2003; Wani et al., 2016) [37, 52]. Results of the present study indicate that incremental fertilizer dose of 150% RDF resulted in maximum plant height at all the growth stages as well as maximum number of total and productive tillers. The increased plant height and tiller number observed under incremental nutrient supply are in corroboration with the related previous studies. Gala et al. 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Easy solubility of inorganic nutrients leads to greater availability in the soil solution, thus leading to quick establishment of seedling as faster uptake (Awan et al., 2011) [5]. The development of the tiller primordium depends on the N, P, and K contents in leaves and sheaths (Yoshida, 1981) [53]. Tiller number increases linearly with sheath N content. A high sheath N and P content increases the cytokinin content within tiller nodes and enhances the germination of the tiller primordium (Hasanuzzaman et al., 2010; Liu et al., 2011) [15, 27]. Similar findings where increase in fertility levels lead to increase in plant height and number of tillers of rice have been reported by Sovmyalatha et al. (2012) [49] and Songyikhangsauthor et al. (2014) [47]. Yield in any given environment is the result of yield components developed in different development phases and growth stages. Yield potential is determined by the number of tillers formed during the vegetative growth phase, the number of panicles induced at the end of the vegetative stage, the number of spikelets formed in each panicle during panicle development, the number of fertile spikelets determined during the booting and flowering stage and the final individual grain weight determined during the grain filling phase (Dingkuhn and Kropff, 1996) [11].

It has been reported by Baloch, et al. 2006 that a one-month delay in sowing decreases the grain yield by 24.3%. Similar reduction in total dry matter accumulation and grain yield in view of delayed sowing has been reported by Salfar, et al. (2008). Khalifa (2009) [19], reported that the decreasing trend in grain yield with delayed sowing date might be associated with the significant decrease in number of filled grains per panicle, lower number of panicles m−2, and lower test weight of grains. Moreover Patel et al. (2019) [1], conclude that an altered phenology in view of delayed sowing leads to lesser time for spikelet maturity and majority of the spikelets remain as primordial. Delayed sowing also causes coincidence of lower than optimum temperatures at anthesis leading to reduced grain filling and an overall decrease in grain yield. From the results of the present study it follows that total dry matter, yield and yield attributes significantly increased with increase in fertilizer dose under late sown condition. While grain and biological yield increased from 30 to 60%, increase in panicle number per square meter was around 20%. 1000 grain weight showed minimal increment, while differences in harvest index values were negligible. Similar findings were reported in previous studies regarding increase in rice yield with high balanced dose of fertilizers by Mahajan et al. (2012) [31], Mallaredyyet et al. (2013) [32] and Uddin et al. (2013) [50]. Dekhane et al. (2014) [10], concluded that increasing the rate of nitrate fertilizer considerably improves yield parameters such as: number of panicles per plant, the number of panicle m−2 and the weight of 1000 grains. However, it has been reported by Yadnar et al. (2018) that, even though nitrogen contributes to sink size by decreasing the number of degenerate spikelets and increasing the hull size, this effect of nitrogen is not visible if it not supplemented by equivalent dose of potassium fertilizer. In addition to this, high dose of phosphorus fertilizer reduces spikelet sterility and ensures maximum grain filling leading to increased yield. Ability of a cultivar to partition dry matter towards seeds is largely affected by the nutrient status as well as genotype. It has been reported by Ndaeyo et al. (2008) [38] that one basis of increased yield attributes is the affinity of the genotype to produce a greater number of tillers m−2 in early growing period followed by its differential ability to assimilate as well as partitioning of photo assimilates. On the basis of related studies by Onaga et al. (2012) [40] and Vanitha and Mohandass (2014) [51] it can be concluded that source size and activity as well as sink potential is affected not only by incremental fertilizer dose but by genotype as well. Moreover, rice varieties with greater sink capacity and source activity per plant could produce heavier grain weight. High nitrogen levels not only increase total dry matter on a whole plant basis, but the increment is stage specific. High nitrogen influenced dry matter accumulation after heading stage and its synchronization with grain filling might be the key reason for increase in yield. High nitrogen levels delay senescence and maintains the capacity of functional leaves after heading. This
promotes greater photosynthetic transfer towards grain and thus the increase in yield (Zhou et al., 2017).

1000 grain weight and harvest index did not show much variation with the increased nutrient status. 1000 grain weight is a stable varietal trait and the size of grain is limited by hull, which in turn is loosely genetically regulated, hence the variation observed is minimal. Similarly, harvest index is a property that is mostly genetically determined and hence difference in harvest index was found to differ non-significantly with fertility levels showing only a slight improvement with incremental fertilizer dose. The results are in congruence with those obtained by Murthy et al. (2015) and Abbas et al. (2016b) (18).

Conclusion

The results indicate that late sown rice responds to a higher dose of fertilizers (150%RDF) which significantly improved the plant height (6-10%) and tiller numbers at active tilling (18-22%) and also number of productive tillers at maturity (15-20%). The number of panicles per square meter (16-20%), 1000 grain weight (3-7%) and grain yield (25-40%) also increased at 150% RDF. Response to nutrient doses varied among genotypes under study. When supplied with half the recommended dose along with organic manure (50% RDF+5 t ha⁻¹ FYM), the performance of genotypes was still below that at 100% RDF.

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