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Influence of Different Establishment Methods and Nutrient Management Practices on Growth Attributes of Rice (*Oryza sativa* L.)

Rakesh Kumar[1], D.K. Singh[1], V.K. Singh[1], Amit Bhatnagar[1], Navneet Pareek[2], Gangadhar Nanda[3], Anupama Rawat[1]

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ABSTRACT

Background: Rice is most important staple meal for more than half of the world's population. The conventional method of rice production uses a lot of water, requires a lot of labor and has a negative impact on soil and environmental health. Besides, unbalanced nutrient supply leads to low growth and development of plant, soil deterioration and poor environmental health.

Methods: The field experiment was conducted with rice variety PR-121 using 4 establishment methods (transplanting, system of rice intensification, direct seeded rice and wet-direct seeded rice) and 5 nutrient management practices (100% RDF, 75% RDF+FYM (equiv. to 25% N), 150% RDF, RDF (LCC based N application) and RDF+5 t FYM) in split plot design with three replication.

Result: Results revealed that the highest value of plant height was recorded under transplanting method while the maximum value of number of tillers m^{-2}, dry matter accumulation crop and relative growth rate was found under direct seeded method of rice establishment over other establishment methods at all the stages of crop growth during both the years of study. Application of 150% RDF recorded the highest value of plant height, number of tillers m^{-2}, dry matter accumulation, crop growth rate and relative growth rate on most of the crop growth stages during both the years of study compared to remaining nutrient management practices but found statistically on par with application of RDF+5 t FYM.

Key words: Establishment method, Growth attributes, Nutrient management practices, Rice.

INTRODUCTION

Rice is recognized as the world's most valuable commodity since it provides life, culture, tradition and a source of income for millions of people. It is a significant staple meal for more than half of the world's population (Singh *et al*., 2017). The current situation indicates that research on rice crop establishment methods and management techniques are getting more emphasis. This is mostly due to differences in crop establishment methods in terms of energy requirements, resource use and potential to operate as a climate change mitigation technique, which may have far-reaching ramifications in terms of yield and revenue for farmers, as well as environmental health. Furthermore, novel crop establishment methods and management strategies are becoming increasingly important to address concerns such as natural resource degradation and the rising cost of chemical and agronomic treatments or resources (Shahane *et al*., 2020).

In India, majority farmers prefer conventional (transplanting) system of rice production because they don't want any type of risk with new technology. However, we know that conventional rice production uses a lot of water, requires a lot of labor and has a negative impact on soil and environmental health. As a result, in order to maintain long-term rice production, we need more efficient alternative rice producing methods (Saharawat *et al*., 2010) like system of rice intensification which saves 22 to 38% of water compared to conventional rice-growing methods (Singh *et al*., 2015). Another method of crop establishment that may assure improves plant population and staggered labor usage is direct sowing of rice seeds or presprouted seeds (Mankotia *et al*., 2009). Dry seeding (sowing dry seeds into dry soil), wet seeding (sowing pre-germinated seeds over wet puddle soils) and water seeding are the three main ways for establishing direct seeded rice (DSR) (seeds sown into standing water). However, as water scarcity worsens, the motivation to develop and implement dry-DSR has increased. In irrigated regions, dry-DSR output is minimal,

[1]Department of Agronomy, College of Agriculture, Govind Ballabh Pant University of Agriculture and Technology, Pantnagar-263 145, Uttarakhand, India.
[2]Department of Soil Science, College of Agriculture, Govind Ballabh Pant University of Agriculture and Technology, Pantnagar-263 145, Uttarakhand, India.
[3]Department of Agronomy, PG College of Agriculture, Dr. Rajendra Prasad Central Agricultural University, Pusa-848 125, Bihar, India.

Corresponding Author: Rakesh Kumar, Department of Agronomy, College of Agriculture, Govind Ballabh Pant University of Agriculture and Technology, Pantnagar-263 145, Uttarakhand, India.
Email: rakeshsarswat58@gmail.com

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but it is done in rainfed upland ecosystems in most Asian nations (Joshi *et al.,* 2013).

Nutrient management strategies have a significant impact on rice crop growth and development. Different nutrients have their own specific roles in growth and development of plant. The nutrients from the organic and inorganic sources differ in their relative availability for crop. Chemical fertilizers are plentiful in nutrients and are a rapid source of nutrient delivery and readily available to plant because most fertilizers are water soluble. Furthermore, the continued use of chemical fertilizers results in a considerable decrease in cereal crop production after only a few years of cropping (Singh *et al*., 2019). On the other hand, farmyard manure, is an easy and complete source of most nutrients (Nanda *et al*., 2016) and become available for crop uptake for a longer period of time due to their low nutrient content, bulky nature, slow decomposition and gradual release of nutrients into the labile pool. Furthermore, organic nutrition sources enhance soil physical qualities by reducing bulk density, increasing water holding capacity and enhancing penetration rates (Joshi *et al*., 2019). As a result, an integrated approach involving the use of organic and inorganic fertilizers is necessary to ensure that crops receive all of the needed nutrients in appropriate levels and that the nutrients are easily available during crop growth (Das *et al*., 2014).

Therefore, the present investigation was undertaken with the objective to assess growth performance of rice under different establishment methods and nutrient management practices.

MATERIALS AND METHODS

A field experiment on rice was conducted in the Rice Agronomy A_2 Block at the N.E. Borlaug Crop Research Centre, G.B. Pant university of Agriculture and Technology, Pantnagar, Uttarakhand during *Kharif* 2018 and 2019. The geographical reference of the study area is 290′N latitude and 79.290′E longitude, with a height of 243.84 meters above mean sea level. The climate is humid subtropical and the mean annual rainfall of this region is 1450 mm. Soil of experimental area was silty loam having pH value of 7.6; organic carbon (0.87%), available nitrogen (227 kg ha^{-1}), available phosphorus (19.6 kg ha^{-1}) and potassium (202 kg ha^{-1}). The experiment was laid out with rice variety PR-121 in a split plot design (SPD) with three replications and 20 treatments comprising four establishment methods (transplanted rice (TPR), system of rice intensification (SRI), direct seeded rice (DSR) and wet-direct seeded rice (WDSR) and five nutrient management practices (120:60:40 NPK (100% RDF), 75% inorganic+FYM (equiv. to 25% N), 180:90:60 NPK (150% RDF), LCC based nitrogen application (having 3 shade as crucial for N application of 20-25 kg ha^{-1}) and 100% RDF+5 tonns FYM (Farmer's practice). Prior to sowing, a full dose of phosphorus and potassium, as well as 50% nitrogen was applied as a basal in all rice-established plots using urea (46% N), NPK fertilizer (12:32:16) and murate of potash (60% K_2O), respectively and incorporated into the soil as needed in each treatment. The remaining nitrogen was administered in two split doses, one at tillering (50% in direct seeded and moist direct seeded plots and 25% in transplanted rice plots) and the other at panicle initiation (25% N was applied in all plots as per the treatment). Prior to sowing or transplanting, FYM was applied as per treatment on required sub-plots and thoroughly incorporated into the top 15 cm soil with the help of spade manually. Gap filling and thinning were done wherever necessary to maintain optimum plant population. Plant protection measures were taken to prevent infestation of insects, weeds and diseases.

Plant height (cm), number of tillers m^{-2}, dry matter accumulation (m^{-2}), crop growth rate and relative growth rate were measured at 30, 60, 90 DAS/DAT and at harvest during both the years of experimentation. On both sides of the direct seeded plot, one meter row length of crop in the third row was marked from north to south for recording observations on plant height, number of tillers and dry matter accumulation, leaving the two rows as borders. Also, in the wet-direct seeded plot, a 0.5 m×0.5 m area in each corner was demarcated for recording the aforementioned observations after leaving a 0.5 m boundary on both sides of the plot. In SRI and transplanted rice plots total 16 hills, 4 from each corner in third and fourth row were marked for observations on growth attributes of rice.

Data on growth attributes of rice were analyzed following standard statistical analysis of variance procedure as suggested by Gomez and Gomez (1984). Wherever the interaction between establishment methods and nutrient management practices found significant were presented in separate two way tables.

RESULTS AND DISCUSSION

Plant height

Establishment method

The height of rice plant was increased progressively as the age of crop advanced (Table 1). Significantly higher plant height was recorded under TPR followed by SRI and WDSR during both the years of study at 30 and 60 DAS/DAT stages. At 90 DAS/DAT, the maximum plant height was found under TPR which is statistically at par with SRI followed by DSR during both the years of study. The highest plant height at harvest was recorded with TPR and SRI for 2018 and 2019, respectively but both were comparable. Greater plant height in TPR was because of less competition for nutrients, between the crop and weed for space and sunlight compared to direct seeded and wet direct seeded method of rice cultivation. In addition, the rice seedlings were transplanted at a specific distance in the transplanting method, which allowed the rice crop to take advantage of maximum solar radiation and more area for better root growth and penetration, resulting in efficient use of uptaken nutrients, whereas in the direct seeded rice and wet-direct seeded

rice methods, the appropriate plant to plant distance was not maintained because seeds were either drilled or sown directly. These findings are consistent with those of Kumhar *et al.* (2016); Ali *et al.* (2012) and Yadav *et al.* (2009).

Nutrient management practices

The maximum plant height was observed under 150% RDF at all the crop growth stage of rice during 2018 and 2019 (Table 1). The increase in plant height with application of 150% RDF might be due to additional supply of nutrients which might have increased nutrient uptake and better translocation which would have increased the cell division, elongation and photosynthesis. The results confirm the findings of Manzoor *et al.* (2006); Mirza *et al.* (2010) and Sowmyalatha *et al.* (2012).

Number of tillers

Establishment method

At 30 DAS/DAT, DSR recorded 12.3 and 6.4% more tillers m^{-2} during 2018 and 2019, respectively over TPR. At 60 and 90 DAS/DAT stage, DSR gave significantly higher number of tillers m^{-2} which was significantly superior over other methods of rice cultivation in year 2018 and 2019 (Table 2). Tillers were much higher in DSR compared to other rice establishment methods at all the phases of crop growth. This might be attributed to the direct seeded method's

Table 1: Effect of establishment methods and nutrient management practices on plant heightat different stages of rice.

	Plant height (cm)							
	30 DAS/DAT		60 DAS/DAT		90 DAS/DAT		At harvest	
	2018	2019	2018	2019	2018	2019	2018	2019
Establishment method								
TPR	49.7	53.0	73.6	76.7	90.2	96.0	101.3	103.9
SRI	41.2	44.1	68.9	73.3	88.5	94.0	98.3	106.0
DSR	30.3	38.9	51.6	57.9	81.4	81.4	94.9	99.4
WDSR	32.7	39.4	52.1	59.9	81.2	79.8	93.7	97.2
SEm±	1.6	1.1	1.1	1.3	1.4	2.0	1.5	1.5
CD(P=0.05)	5.4	3.6	3.6	4.6	2.4	6.9	5.3	5.2
Nutrtient management practices								
100% RDF	37.6	43.8	60.5	63.1	80.6	85.3	95.4	101.1
75% RDF+FYM (equiv. to 25% N)	39.3	43.7	60.7	68.3	84.8	86.9	96.7	101.6
150% RDF	39.6	44.1	63.6	70.0	89.9	91.0	99.2	102.8
RDF(LCC based N)	37.4	43.3	59.6	66.1	83.6	86.4	95.4	100.5
RDF+5 t FYM	38.3	44.5	63.4	67.4	87.5	89.3	98.5	102.2
SEm±	0.7	0.7	1.0	1.2	1.0	1.4	0.9	0.9
CD(P=0.05)	1.9	NS	3.0	3.4	2.8	3.9	2.5	NS

Table 2: Effect of establishment methods and nutrient management practices on number of tillers m^{-2} at different stages of rice.

	Number of tillers (m^{-2})					
	30 DAS/DAT		60 DAS/DAT		90 DAS/DAT	
	2018	2019	2018	2019	2018	2019
Establishment method						
TPR	154	172	286	302	234	250
SRI	139	147	249	275	211	232
DSR	173	183	410	432	379	394
WDSR	159	167	329	358	320	327
SEm±	7	6	9	8	8	6
CD (P=0.05)	NS	22	29	28	26	22
Nutrient management practices						
100% RDF	133	135	246	302	238	274
75% RDF+FYM (equiv. to 25% N)	161	169	319	322	287	293
150% RDF	167	185	361	377	312	325
RDF (LCC based N)	158	163	315	348	291	299
RDF+5 t FYM	162	183	353	361	302	313
SEm±	6	7	9	5	8	5
CD(P=0.05)	19	20	26	15	23	15

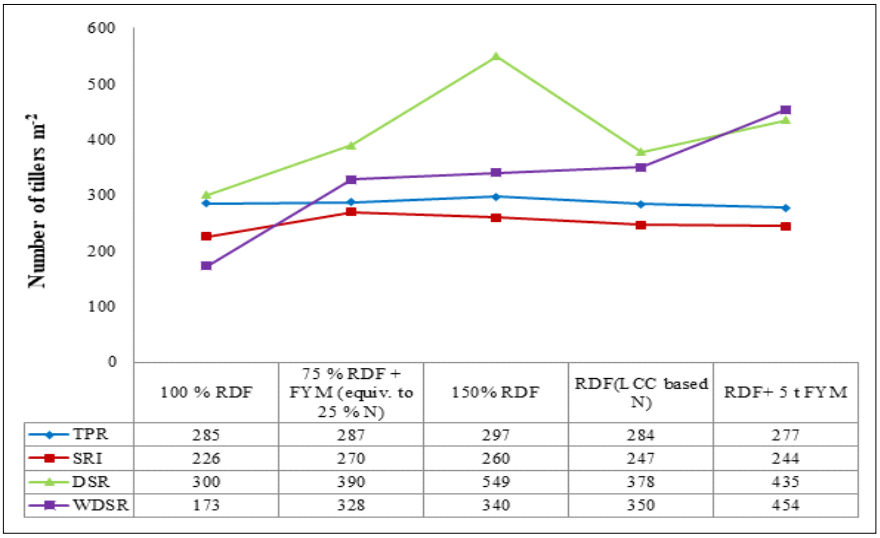
slighter plant to plant distance as compared to the transplanted and system of rice intensification methods, which caused higher number of tillers. These findings are consistent with those of Thakur *et al.* (2004) and Rashid *et al.* (2009). Conversely, in transplanted method root damage due to nursery uprooting and transplanting trauma reduced early growth and vigour in transplanted method (Ishfaq *et al.*, 2020).

Nutrient management practices

The highest number of tillers m^{-2} was noted under 150% RDF as compared to remaining nutrient management practices at 30, 60 and 90 DAS/DAT stages of 2018 and 2019. Higher number of tillers with application of 150% RDF might be due to the fact that the inorganic fertilization has quick, adequate and easy nutrient supplying capacity to the crop which cop up with the demand of crop resulting improved number of tillers and dry matter accumulation. Similar results were reported by Songyikhangsuthor *et al.* (2014) and Joshi *et al.* (2019).

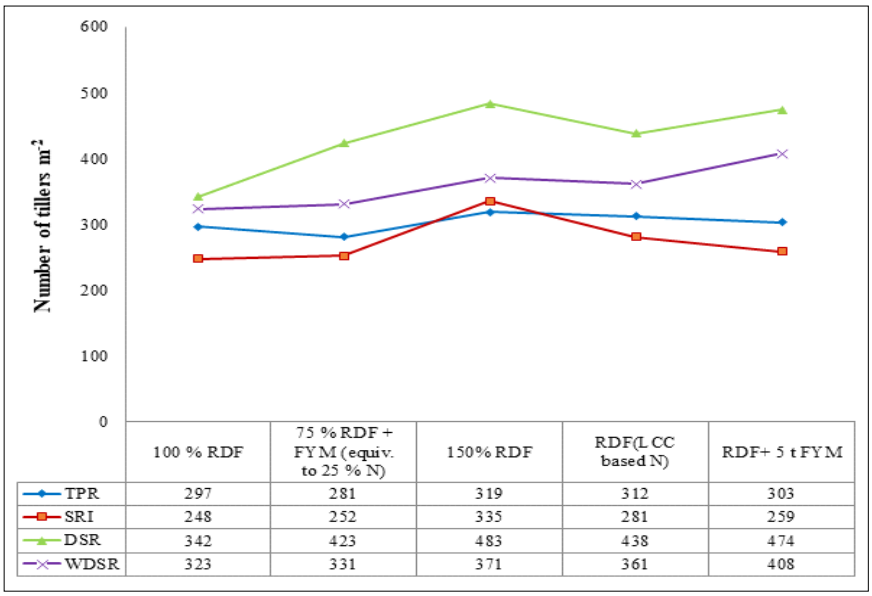
Interaction effect

The interaction effect of different establishment method and nutrient management practices found to be significant at 60 DAS/DAT stage of rice crop during both the years. DSR with application of 150% RDF gave the highest number of tllers m^{-2} during 2018 (Fig 1) and 2019 which is significantly superior over all other treatment combination during 2018 and 2019 except DSR with application of RDF+5 t FYM (Fig 2).



	100 % RDF	75 % RDF + FYM (equiv. to 25 % N)	150% RDF	RDF(LCC based N)	RDF+ 5 t FYM
TPR	285	287	297	284	277
SRI	226	270	260	247	244
DSR	300	390	549	378	435
WDSR	173	328	340	350	454

Fig 1: Interaction effect of different establishment methods and nutrient management practices on plant height of rice at 60 DAS/DAT during 2018.



	100 % RDF	75 % RDF + FYM (equiv. to 25 % N)	150% RDF	RDF(LCC based N)	RDF+ 5 t FYM
TPR	297	281	319	312	303
SRI	248	252	335	281	259
DSR	342	423	483	438	474
WDSR	323	331	371	361	408

Fig 2: Interaction effect of different establishment methods and nutrient management practices on plant height of rice at 60 DAS/DAT during 2019.

Dry matter accumulation

Establishment method

Data presented in Table 3 showed that dry matter accumulation (DMA) increased with increasing crop age till maturity under various rice growing methods. At 30 DAS/DAT stage, the highest dry matter was recorded under TPR which is superior over all the other rice establishment methods. At 60, 90 DAS/DAT and at harvest stages, DSR gave the highest DMA which was significantly superior over other establishment methods followed by TPR during both the year of study. Higher DMA with DSR as compared to other establishment methods was due to higher number of effective tillers and vigorous vegetative growth. Similar findings have been made by Gill *et al.* (2006 a,b) and Sharma *et al.* (2016).

Nutrient management practices

Maximum DMA was recorded in RDF+5 t FYM at 30 DAS/DAT. However at 60 and 90 DAS/DAT and at harvest stage, 150% RDF recorded the maximum DMA (Table 3). Application of 150% RDF resulted in a larger amount of dry matter buildup might be due to the fact that inorganic fertilization provides a rapid, adequate and easy nutrient-supply capacity for the crop, which enhances crop dry matter accumulation. Furthermore, a larger nitrogen supply may have aided in the maintenance of a better condition for photosynthetic activity in the leaves. In addition, enough

Table 3: Effect of establishment methods and nutrient management practiceson dry matter accumulation m^{-2} at different stages of rice.

	Dry matter accumulation (g m^{-2})							
	30 DAS/DAT		60 DAS/DAT		90 DAS/DAT		At Harvest	
	2018	2019	2018	2019	2018	2019	2018	2019
Establishment method								
TPR	49.5	56.4	504.3	526.4	890.1	898.3	1190.1	1191.2
SRI	41.4	46.0	450.4	483.1	841.6	863.1	1146.6	1160.4
DSR	39.5	42.4	520.1	536.5	942.2	964.5	1242.2	1277.8
WDSR	37.9	40.3	449.7	437.9	862.7	887.1	1162.7	1180.3
SEm±	1.9	1.6	13.1	9.7	13.7	18.4	16.7	16.5
CD(*P*=0.05)	6.9	5.6	45.3	33.5	47.6	39.1	57.8	57.2
Nutrient management practices								
100% RDF	40.2	42.2	441.6	452.5	843.2	863.2	1145.7	1156.5
75% RDF+FYM (equiv. to 25% N)	44.3	47.7	471.3	496.0	891.7	904.0	1191.7	1212.2
150% RDF	43.5	51.0	518.5	532.4	913.9	939.3	1218.0	1230.1
RDF(LCC based N)	37.9	39.3	475.8	486.8	875.0	888.4	1175.0	1194.5
RDF+5t FYM	44.8	51.1	498.3	512.3	896.8	921.3	1196.8	1218.9
SEm±	1.7	1.7	13.5	8.3	10.8	13.6	12.3	15.9
CD (P=0.05)	4.8	5.0	38.9	23.9	31.1	39.1	35.5	45.7

Table 4: Effect of establishment methods and nutrient management on crop growth rate at different stages of rice.

	CGR (g m^{-2} day^{-1})					
	30-60 DAS/DAT		60-90 DAS/DAT		90 DAS/DAT- At harvest	
	2018	2019	2018	2019	2018	2019
Establishment method						
TPR	15.16	15.67	12.86	12.40	10.00	9.76
SRI	13.63	14.57	13.03	12.67	10.18	9.92
DSR	16.02	16.47	14.07	14.27	10.00	10.45
WDSR	13.73	13.25	13.77	14.97	10.91	9.77
SEm±	0.47	0.35	0.56	0.45	0.29	0.90
CD (*P*=0.05)	1.62	1.19	NS	1.56	NS	NS
Nutrient management practices						
100% RDF	13.38	13.67	13.39	13.69	10.08	9.78
75% RDF+FYM (equiv. to 25% N)	14.24	14.94	14.01	13.60	10.00	10.27
150% RDF	15.84	16.05	13.18	13.56	10.14	9.69
RDF (LCC based N)	14.60	14.92	13.31	13.39	10.00	10.20
RDF+5 t FYM	15.11	15.37	13.28	13.64	10.00	9.92
SEm±	0.45	0.29	0.47	0.52	0.38	0.58
CD (P=0.05)	1.31	0.85	NS	NS	NS	NS

Table 5: Effect of establishment methods and nutrient management on relative growth rate at different stages of rice.

	RGR (g g^{-1} day^{-1})					
	30-60 DAS/DAT		60-90 DAS/DAT		90 DAS/DAT- At harvest	
	2018	2019	2018	2019	2018	2019
Establishment method						
TPR	2.64	2.66	2.86	2.86	2.98	2.98
SRI	2.60	2.63	2.84	2.85	2.96	2.97
DSR	2.66	2.67	2.88	2.89	2.99	3.01
WDSR	2.60	2.58	2.85	2.86	2.97	2.97
SEm±	0.01	0.01	0.01	0.01	0.01	0.01
CD (P=0.05)	0.04	0.03	0.02	0.03	0.02	0.02
Nutrient management practices						
100% RDF	2.59	2.59	2.84	2.85	2.96	2.96
75% RDF+FYM (equiv. to 25% N)	2.61	2.64	2.86	2.87	2.98	2.99
150% RDF	2.66	2.67	2.87	2.88	2.99	3.00
RDF (LCC based N)	2.62	2.63	2.85	2.86	2.97	2.98
RDF+ 5 t FYM	2.64	2.65	2.86	2.87	2.98	2.99
SEm±	0.01	0.01	0.01	0.01	0.01	0.01
CD (P=0.05)	0.04	0.02	0.01	0.02	0.01	0.01

nitrogen delivery aids in cell elongation and multiplication, which increased the growth characteristics of rice plants grown under nutrient management practices of 150% RDF. These findings are similar to those of Sowmyalatha *et al.* (2012); Songyikhangsuthor *et al.* (2014) and Joshi *et al.* (2019).

Crop growth rate (g m^{-2} day^{-1})

Establishment method

During both the years, DSR had higher crop growth rate (CGR) than other establishement methods at all the observations except 60-90 DAS/DAT stage during 2019 and 90 DAS/DAT- At harvest stage during 2018 (Table 4). The variable trends in CGR at different observations were due to the variation in accumulated dry matter per day.

Nutrient management practices

Different nutrient management practices had a significant influence on CGR of rice at 30-60 DAS/DAT stage only during both the years of study (Table 4). During both the years of study, greater CGR was seen under 150% RDF over other practices at 30-60 DAS/DAT stage. However, the nutrient management practices had no significant influence on crop growth rate at 60-90 DAS/DAT and 90 DAS/DAT to harvest stage of rice during both the year of study.

Relative growth rate (g g^{-1} day^{-1})

Establishment method

Data pertaining to relative growth rate (RGR) of rice at 30-60, 60-90 DAS/DAT and 90 DAS/DAT to harvest varied significantly due to differennt establishment methods during both the year of study (Table 5). The maximum RGR was noted under DSR at all the stages of rice growth which was due to higher dry matter accumulation in this treatment except 30 DAS/DAT. Ishfaq *et al.* (2020) also reported that DSR achieved higher relative growth rate than TPR, as observed in our study.

Nutrient management practices

The highest RGR was recorded in 150% RDF over other nutrient management practices but statistically at par with RDF+5 t FYM at all the crop growth stages during both the years (Table 5). The lowest value of relative growth rate was observed under 100% RDF at all the stage of crop growth stages during both the years of study. As dry matter production was the highest with 150% RDF, so RGR was higher with this treament. The results are supported by the findings of Dissanayke *et al.* (2014) and Jeyajothi and Durairaj (2015).

CONCLUSION

On the basis of present investigation it may concluded that the direct seeded method of rice establishment and RDF+5 t FYM nutrient management was found most effective for enhancing the growth attributes of rice over remaining treatments.

Conflict of interest: None.

REFERENCES

Ali, R.A., Iqbal, N., Saleem, M.U. and Akhtar, M. (2012). Effect of different planting methods on economic, yield and grain quality of rice. Inter. J. Agri. App. Sci. 4(1): 28-34.

Das, A., Patel, D.P., Munda, G.C., Ramkrushna, G.I., Kumar, M. and Ngachan, S.V. (2014). Improving productivity, water and energy use efficiency in lowland rice (*Oryza sativa* L.) through appropriate establishment methods and nutrient management practices in the mid altitudes of north east India. Exp. Agri. 50(3): 353-375.

Dissanayake, D.M.D., Premaratne, K.P. and Sangakkara U.R. (2014). Integrated nutrient management for lowland rice (*Oryza sativa* L.) in the Anuradhapura District of Sri Lanka. Tropical Agricultural Research. 25(2): 266-271.

Gill, M.S., Kumar, A. and Kumar, P. (2006a). Growth and yield of rice (*Oryza sativa* L.) under various method and times of sowing. Indian J. Agron. 51(1): 23-27.

Gill, M.S., Kumar, Pradeep and Kumar, Ashwani. (2006b). Growth and yield of direct-seeded rice (*Oryza sativa*) as influenced by seedling techniques and seed rate under irrigated conditions. Indian J. Agron. 51(4): 283-287.

Gomez, K.A. and Gomez, A.A. (1984). Statistical Procedures in Agricultural Research, Wiley 2nd edn., Paperback, New York.

Ishfaq, M., Akbar, N., Anjum, S.A. and Anwar-Ul-haq, M. (2020). Growth, yield and water productivity of dry direct seeded rice and transplanted aromatic rice under different irrigation management regimes. J. Int. Agric. 19(11): 2656-2673.

Jeyajothi, R. and Durairaj, S. (2015). Influence of integrated nutrient management practices on yield and yield attributes and economics of transplanted rice (*Oryza sativa*) in South Zone of Tamil Nadu. Inter. J. Inn. Res. Sci. Tech. 1(11): 462-466.

Joshi, B., Mishra, S., Prinsa, Singh, D.K. and Guru, S.K. (2019). Effect of differential nutrient management on growth and yield components in late sown rice (*Oryza sativa* L.). J. Pharmac. Phytochem. 8(5): 1891-1899.

Joshi, E., Kumar, D., Lal, B., Nepalia, V., Gautam, P. and Vyas, A.K. (2013). Management of direct seeded rice for enhanced resource-use efficiency. Plant Know. J. 2(3): 119-134.

Kumhar, B.L., Chavan, V.G., Rajemahadik, V.A., Kanade, V.M., Dhopavkar, R.V., Ameta, H.K. and Tileka, R.N. (2016). Effect of different rice establishment methods on growth, yield and different varieties during *kharif* season. Inter. J. Plant, Ani. Environ. Sci. 6(2): 127-131.

Mankotia, B.S., Shekhar, J. and Negi, S.C. (2009). Effect of crop establishment techniques on productivity of rice-wheat cropping system. Oryza. 46(3): 205-208.

Manzoor, Z., Awan, T.H., Zahid, M.A. and Faiz, F.A. (2006). Response of rice cropsto different nitrogen levels. J. Animal Plant Sci. 16: 1-2.

Mirza, H., Ahamed, K.U., Rahmatullah, N.M., Akhter, K.N. and Rahman, M.L. (2010). Plant growth characters and productivity of wetland rice (*Oryza sativa* L.) as affected by application of different manures. Emir. J. Food Agric. 22(1): 46-58.

Nanda, G., Sravan, U.S., Singh, A. and Singh, S.P. (2016). Effect of NPK levels and bio-organics on growth, yield and economics of basmati rice (*Oryza sativa* L.) cv. HUBR 10-9. Environment and Ecology. 34(3C): 1530-1534.

Rashid, M.H., Alam, M., Khan, M. and Ladha, J.K. (2009). Productivity and resource use of direct seeded and transplanted rice in puddled soils in rice-rice and ricewheat ecosystems. Field Crop Res. 113: 274-281.

Saharawat, Y.S., Singh, B., Malik, R.K., Ladha, J.K., Gathala, M., Jat, M.L. and Kumar, V. (2010). Evaluation of alternative tillage and crop establishment methods in rice-wheat rotation in North Western IGP. Field Crops Res. 116: 260-267.

Shahane, A.A., Shivay, Y.S., Prasanna, R. and Kumar, D. (2020). Nutrient removal by rice-wheat cropping system as influenced by crop establishment techniques and fertilization options in conjunction with microbial inoculation. Nature Res. 10: 21944. https://doi.org/10.1038/s41598-020-78729-w.

Sharma, V., Bali, A.S. and Kachroo, D. (2016). Effect of different establishment methods and sowing schedules on growth and yield of hybrid rice (*Oryza sativa*) and their after effects on succeeding wheat (*Triticum aestivum*) in rice-wheat cropping system. Eco. Affairs. 61(3): 487-493.

Singh, C.S., Singh, S.M., Singh, K., Singh, A.K. and Ashok, K.R. Singh (2015). Growth and yield response of rice cultivars under system of rice intensification and conventional method of rice production system. Int. J. Environ. Res. 9(3 and 4): 1077-1081.

Singh, D.K., Pandey, P.C., Nanda, G. and Gupta, S. (2019). Long-term effect of inorganic fertilizer and farmyard manure application on productivity, sustainability and profitability of rice-wheat system in Mollisols. Archives of Agronomy and Soil Science. 65(2): 139-151.

Singh, D.K., Pandey, P.C., Thapliyal, S.D. and Nanda, G. (2017). Yield and economics of rice (*Oryza sativa* L.) as influenced by establishment methods and varieties under mollisols of Pantnagar. Int. J. Curr. Microbiol. App. Sci. 6(6): 297-306.

Songyikhangsuthor, K., Sybounheuang, S. and Samson, B.K. (2014). Response of rice landraces and promising cultivars to nitrogen fertilizer on sloping uplands. Inter. J. Agri. Sci. Res. 3(9): 181-186.

Sowmyalatha, B.S., Ramachandra, C., Shivakumar, N. and Manjunatha, K.B. (2012). Effect of methods of cultivation and fertility levels on growth and yield of rice hybrids. Mysore J. Agri. Sci. 46(1): 171-173.

Thakur, A.K., Roychowdhury, S., Kundo, D.K. and Singh, R. (2004). Evaluation of planting methods in irrigated rice. Arch. Agron. Soil Sci. 50: 631-640.

Yadav, D.B., Yadav, A. and Punia, S.S. (2009). Evaluation of bispyribac-sodium for weed control in transplanted rice. Indian J. Weed Sci. 41(1 and 2): 23-27.