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Performance and Profitability of Rice using the Site Specific Nutrient Management Approaches under Different Crop Establishment Options in Puranchaur, Kaski, Nepal

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Key words: SSNM, rice, DSR, transplanting, performance

Abstract: Rice cultivation in Asia including Nepal is becoming most challenging due to excessive tillage and unscientific use of resources like labor, fertilizers and water. To address this problem and to observe performance and profitability of rice over various SSNM and crop establishment approaches, an experiment was conducted on the silty loam soil with slightly acidic pH in the research fields of CNRM, Puranchaur, Kaski. The experiment was laid in Strip plot design consisting three crop establishment methods (ZT-DSR, RT-DSR and TPR) and four Site-Specific Nutrient Management (SSNM) options (NE Model, LCC, CCM-200 and FFP) with three replications in the fields where the initial crops were mustard, potato and garlic, respectively. Khumal-4 variety of rice, among the various SSNM options CCM-200 individually and its interaction with TPR, showed higher LAI, above ground dry matter accumulation and growth rate in many stages. The analysis of variance showed the significantly highest grain per panicle (222.9) under TPR but grain yield under ZT-DSR (4.11 t ha^{-1}) remained non-significant with TPR (4.67 t ha^{-1}). CCM-200 performed superior with significantly maximum effective tillers per square meter (288.2), longest panicle (26.89 cm), maximum number of grains per panicle (214), least sterility (4.19%), comparatively higher grain (5.11 t ha^{-1}) and straw yield (6.73 t ha^{-1}) and maximum economic return with highest B:C ratio (2.24) which was statistically at par with NE Model. Despite of the non-significant interaction effect of crop establishment and nutrient management on growth, yield and profitability of rice, the combination of ZT-DSR and CCM-200 could be more resource conserving and profitable.

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INTRODUCTION

On the basis of volume of production (495.9 million tons in 2016), rice is the world's third crop after wheat and maize[1]. In Nepal, rice occupies 56.42% of cultivated land with the productivity of 3.51 t ha^{-1}[2], constitutes about 20% of agricultural gross domestic product and 7% of gross domestic product[3]. The research station at Khumaltar, Nepal has reported maximum yield of rice grain to be 8 t ha^{-1}[4] but the statistical data of MoALD in 2018/19 shows the average yield of rice grain in farmer's fields as 3.51 metric t ha^{-1}. In the scenario of timely unavailability of the required fertilizers in Nepal, there exists the large gap between crop yield potential and farmer's yields. The gaps between the potential yield and farmers' field yield (yield gap 3) of rice, maize and wheat are at 2.76, 2.58 and 3.15 t ha^{-1}, respectively[5]. The farmers ignorance about proper and timely fertilization as well as governments blanket fertilizer recommendation for rice are either creating the overutilization or underutilization of nutrients. Previous research has also found the fertilizer utilization is still below the optimum level for achieving the potential yield in Nepal[6].

Nitrogen in rice is the most crucial nutrient for better yield attributes and economic yield. Nitrogen (N), among the major nutrient elements, is the most limiting nutrient for rice crop growth and yield which is required in higher amounts compared to other essential nutrients[7]. Site Specific Nutrient Management (SSNM) is an innovative approach for "feeding" crops with nutrients according to their need which can improve nutrient use efficiency, crop yield and farmers' income. Thus, use of SSNM practices like NE Model, LCC and CCM-200could increase proper utilization of fertilizers applied, decrease the yield gaps and increase the production and profitability in rice cultivation.

Likewise, rice cultivation in Nepal is predominantly puddling transplantation method that requires large amount of water, energy and labor which are becoming increasingly scarce and expensive. Transplanting involves more human drudgery and consumes approximately 25% of the total labor requirement of the crop[8]. Gathala *et al.*[9] reported that higher labor cost resulted in significantly higher cost of production and lower gross return, net return and B:C ratio. They have also reported that the CA based technologies which includes zero, strip, reduced tillage or permanent raised beds facilitates improved crop establishment and timely sowing, reduced irrigation water requirements, lower production cost and hence increased income. Hence, the major objective of this experiment has been to assess the growth performance, yield and profitability of rice under various SSNM and crop establishment practices in the condition of Puranchaur, Kaski, Nepal.

MATERIALS AND METHODS

The experiment was conducted at research blocks of College of Natural Resource Management, Puranchaur, Kaski (Latitude: 25°17'23.4" North and Longitude: 83°56'51.8" East with an elevation of 1200 masl) during rainy season (May to October) of 2019. The soil type is silty loam and climatically sub-temperate with average annual rainfall of 3400 mm (mainly during July to September) (Fig. 1).

The experiment was layed out in strip plot design with three column factors for crop establishment viz. Zero tillage with Direct Seeded Rice (ZT-DSR), Reduced tillage with Direct Seeded Rice (RT-DSR) and Transplanted Rice (TPR) and four row factors for site specific nutrient management (SSNM) viz. Nutrient Expert Model (NE Model), Leaf Color Chart (LCC), Chlorophyll Content Meter-200 (CCM-200) and Farmers Fertilization Practice (FFP) replicated thrice in the plots preceded with mustard, potato and garlic respectively. The plot size of 12 m^2 (4×3 m) and net plot size of 7 m^2 was maintained. Khumal-4 which is one of the recommended rice varieties for mid-hills of Nepal was selected. Spacing of 20 cm between the lines and continuous sowing within the line for DSR and for TPR, 20×20 cm was maintained.

The recommended dose of FYM @ 10 ton/ha was applied 20 days before land preparation for direct seeding in RT and two primary tillage in TPR plots. Full dose of phosphorous and potassium fertilizers (20 and 26 kg ha^{-1}, respectively) were applied as basal dose at the time of seed sowing under ZT-DSR and RT-DSR and puddling under TPR based on NE Model. The time of N fertilizer applied from different SSNM options is scheduled as shown in Table 1.

Nitrogen at the rate of 23 kg ha^{-1} was applied when 6 leaves out of 10 recordings showed the LCC reading below critical value 4. Similarly, for CCM-200 reading, average Chlorophyll Content Index (CCI) of each plot below 35 was subjected to fertilization with nitrogen at the rate 35 kg ha^{-1}. Two hand weeding operations were done for TPR and four hand-weeding for ZT-DSR and RT-DSR. Irrigating was provided at the crop stages like heading, flowering and grain filling. The phenological, biometrical, yield and yield attributing observations were taken timely.

The Leaf Area Index which is the index measuring the amount of leaf material in canopy was calculated using the formula:

$$\text{LAI} = \frac{\text{Leaf area}}{\text{Ground area}}$$

Similarly, Crop Growth Rate (CGR) which measures the rate of growth in weight of plant with time was calculated by using formula:

Table 1: Amount and timing of Nitrogen applied (kg ha^{-1}) using different nutrient management practices in ZT, RT (DAS) and TPR (DAT) at Puranchaur, Kaski, 2019

Fertilization method	Basal (for all)	21 DAS and 14 DAT	31 DAS and 21 DAS	41 DAS and 28 DAT	51 DAS and 35 DAT	Total N applied (kg ha^{-1})
Replication I						
NE-Model	54.5	28	26.5	-	-	109
LCC	-	23	23	23	23	92
CCM-200	-	35	35	35	35	140
FFP	16	-	-	-	-	16
Replication II and III						
NE-Model	59	28	26.5	-	-	118
LCC	-	23	23	23	23	92
CCM-200	-	35	35	35	35	140
FFP	16	-	-	-	-	16

NE Model represents application of N, P and K applied according to model output; LCC represents application of N from LCC and P, K from NE Model; CCM-200 represents application of N from CCM-200 reading and P, K from NE Model

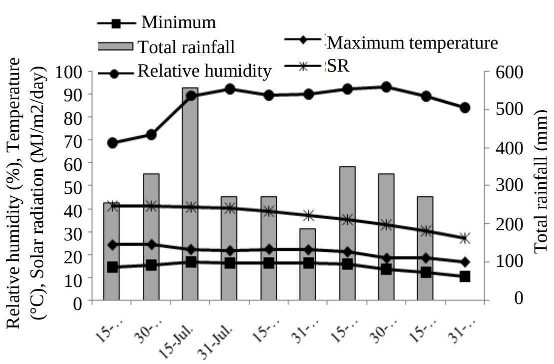

Fig. 1: Weather data of experimental site for crop growing period at Puranchaur, Kaski, Nepal, 2019 (OHM, Pokhara)

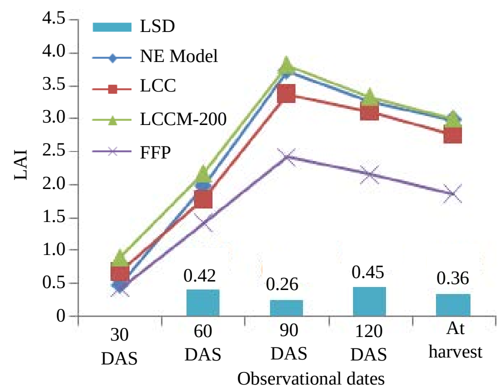

Fig. 2: Effect of SSNM practices on LAI of rice at Puranchaur, Kaski, 2019

$$CGR = \frac{w_2 - w_1}{t_2 - t_1}$$

where, w_1 and w_2 are dry matter at times t_1 and t_2 respectively. Analyses of Variance (ANOVA) was performed using MS-Excel and R-Studio computer-based package and later computed with Least Significant Difference (LSD) and Duncan's Multiple Range Test (DMRT) for mean comparison whenever necessary[10].

RESULTS AND DISCUSSION

Effects on growth index

Leaf area index: The ANOVA of observational data of LAI showed that CCM-200 has increasing trend from 30 DAS up to 90 DAS and decreasing after 90 DAS up to harvest (Fig. 2). The highest LAI under CCM-200 was followed by NE Model, LCC and FFP respectively with the similar trend. The experiment elucidated more LAI under higher N application using CCM-200 and NE Model, respectively. Anzoua *et al.*[11], Azarpour *et al.*[12], Esfahani *et al.*[13] and Lampayan *et al.*[14] have also reported raised LAI with increasing nitrogen fertilizer in rice. Besides, the promising crop response due to timely and need based application of nitrogen from CCM-200 and NE Model resulted higher LAI in rice. Critical role of timely application of fertilizer on optimizing crop response was also found by Pagani *et al.*[15].

Comparatively higher LAI (4.67) was recorded under TPR+NE at 90 DAS, followed by TPR+CCM-200 (4.44) and TPR+LCC (4.23). The lowest LAI was recorded under RT+FFP at all observational dates (Fig. 3). The N applied before flowering could have been utilized for vegetative growth of crops and the additional N applied after flowering is primarily utilized in grain filling[16] (Fig. 3).

Dry matter accumulation and Crop Growth Rate (CGR): The above ground dry matter (AGDM) differed non-significantly due to crop establishment, except at 60 DAS. However, AGDM was significantly affected due to SSNM practices from 60 DAS and after (Fig. 4). CCM-200 recorded significantly highest at 60 DAS (172.6 g m^{-2}), 90 DAS (725g m^{-2}), 120 DAS (876 g m^{-2}) and at harvest (986 g m^{-2}) which was statistically at par with NE Model at respective observational dates (156.7 g m^{-2}, 733 g m^{-2}, 829 g m^{-2} and 926 g m^{-2}). The

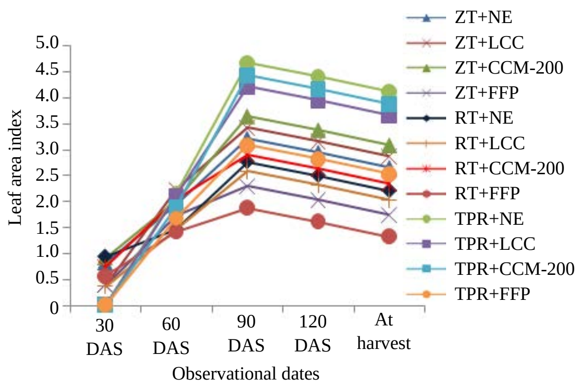

Fig. 3: Effects of interaction of crop establishment and SSNM on LAI of rice at Puranchaur, Kaski, 2019

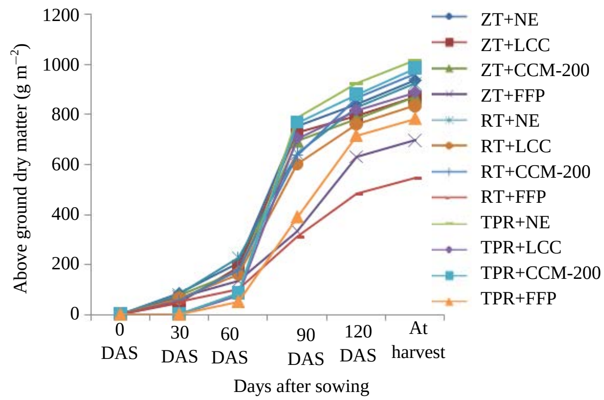

Fig. 5: Effect of interaction of crop establishment and SSNM on above ground dry matter of rice at Puranchaur, Kaski, 2019

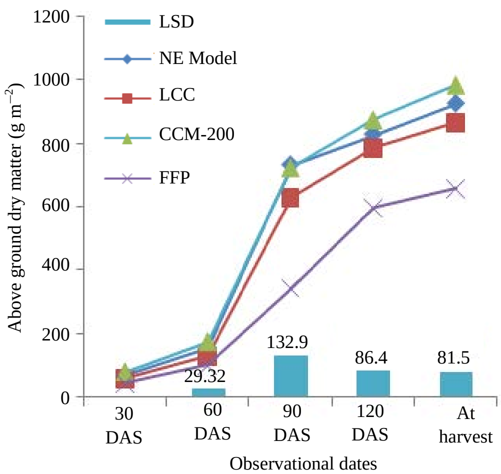

Fig. 4: Effect of SSNM on above ground dry matter of rice at Puranchaur, Kaski, 2019

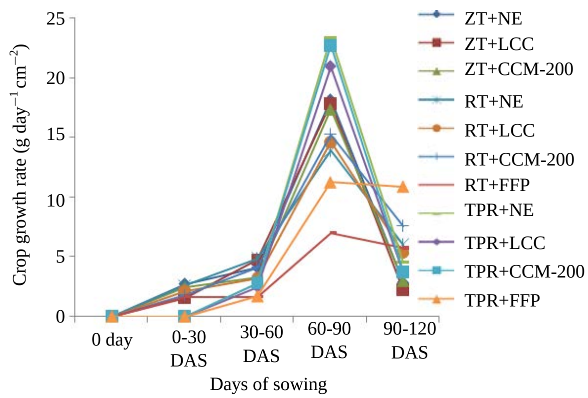

Fig. 6: Effect of crop establishment and SSNM practices on CGR of rice at Puranchaur, Kaski, 2019

minimum AGDM was recorded under FFP in each stage of rice growth. Singh *et al.*[17] found significantly higher dry matter accumulation at maturity stage under 120 kg ha^{-1} N (624.1 g m^{-2}) than under no application of N (343.3 g m^{-2}). The CCM-200 also used higher N at the rate of 140 kg N ha^{-1} resulting the higher dry matter accumulation.

AGDM was comparatively higher under TPR when interacted with NE Model and CCM-200 from 90 DAS and after (Fig. 5). The dry matter accumulation was seen increasing at increasing rate from 60 DAS up to 90 DAS and it was increasing at decreasing rate after 90 DAS.

However, CGR was comparatively higher under TPR interacted with NE, CCM-200 and LCC, respectively. The CGR was higher from 60-90 DAS and the later was in diminishing rate (Fig. 6).

Effects on phenological performance: The experiment showed an average of 93.53 days required for 75% heading (Table 2). Statistically non-significant but early heading was observed in ZT at 92.75 DAS and in CCM-200 at 92.33 DAS. Similarly, earlier heading under ZT-DSR and RT-DSR was found in comparison to TPR which might have triggered for significantly earlier maturity under ZT-DSR (133 DAS) and RT-DSR (134 DAS) by 11 and 10 days respectively to TPR (144 DAS). Sharma *et al.*[18] and Gill[19] also found earlier maturity in direct seeding as compared to TPR.

Dendup and Chhogyel[20] explained the difference could have been due to environmental shock imposed from uprooting of the seedlings until crop establishment for the transplanted rice. Gill *et al.*[21] reported that direct seeding of rice results in early heading and maturity and shorter crop duration in comparison to transplanted rice.

Similarly, the Farmers Fertilization Practice (FFP) was observed with early maturity (136.22 DAS) which was followed by LCC (137.33 DAS) and NE-Model (137.89 DAS). The early maturity in FFP could have been due to the nitrogen deficiency which directs in stunted

Table 2: Influence of crop establishment and nutrient management practices on phenology of rice during monsoon season at Puranchaur, Kaski, 2019

Treatments	75% emergence (DAS)	75% heading (DAS)	75% maturity (DAS
Crop establishment options			
ZT-DSR	10.25	92.75	133.25[a]
RT-DSR	10	93.67	134.83[a]
TPR	94.17	144.67[b]	
SEm (±)	0.152	0.44	0.766
LSD(0.05)	ns	ns	3.008
Nutrient management options			
NE Model	9.89	94.11	137.89[ab]
LCC	10.44	93.56	137.33[ab]
CCM-200	10.11	92.33	138.89[b]
FFP	10.11	94.11	136.22[a]
SEm (±)	0.319	0.52	0.481
LSD(0.05)	ns	ns	1.665
Interaction			
SEm (±)	0.458	0.782	1.141
LSD (0.05)	ns	ns	ns
CV (%)	7.7	1.1	1.4
Grand mean	10.14	93.5	137.58

Treatments means followed by common letter (s) in column are not significantly different among each other based on DMRT at 5% level of significance

Table 3: Influence of crop establishment and nutrient management practices on yield attributing characters of rice during monsoon season at Puranchaur, Kaski, 2019

Treatments	ET m^{-2}	Panicle length (cm)	Grain per panicle	Sterility (%)	Test wt. (g)
Crop establishment					
ZT-DSR	284.9	25.63	168.5[b]	8.66[a]	18.15
RT-DSR	230.2	25.54	183.5[b]	4.84[ab]	18.11
TPR	203.3	25.45	222.9[a]	3.39[b]	19.44
SEm (±)	18.7	0.355	9.56	1.06	0.315
LSD(0.05)	ns	ns	37.54	4.162	ns
Nutrient management					
NE Model	235.5[b]	25.88[a]	197.9[a]	5.77[b]	17.98
LCC	246.5[ab]	25.63[a]	195.1[a]	5.08b[c]	18.82
CCM-200	288.2[a]	26.89[a]	214.0[a]	4.19[c]	18.45
FFP	187.7[c]	23.76[b]	159.5[b]	7.47a	19.02
SEm (±)	13.28	0.428	6.87	0.358	0.278
LSD(0.05)	45.96	1.481	23.79	1.24	ns
Interaction					
SEm (±)	25.23	0.643	12.66	1.191	0.508
LSD (0.05)	ns	ns	39.74	4.078	ns
CV (%)	11.8	3.4	6.5	19.5	4.1
Grand mean	293.5	25.54	191.6	5.63	18.57

Treatments means followed by common letter (s) in column are not significantly different among each other based on DMRT at 5% level of significance

growth and yellow leaves, cause poor assimilate formation and results premature flowering and early maturation of crops[22].

Effects on yield attributes and yield performance: Effective tillers per square meter were comparatively higher under ZT-DSR (Table 3) which may have been resulted due to close spacing with higher plant population which eventually increases the number of mother plant. Similar results of higher ET m^{-2} under DSR in comparison to TPR corroborate with Patil *et al.*[23] and Gathala *et al.*[24], panicle length statistically similar for DSR and puddled TPR[25].

Grains per panicle was significantly highest under TPR (222.9) and lowest under ZT-DSR (168.5). Similarly, the sterility percentage was significantly lowest under TPR (3.39 %) and highest under ZT-DSR (8.66 %). Gathala *et al.*[24] also reported that higher number of sterile spikes; lower grain per panicle and lower thousands grain weight under direct seeded rice.

Meanwhile, CCM-200 was superior with significantly highest ET m^{-2} (288.2), panicle length (26.89 cm), grain per panicle (214) and lowest sterility (4.19%) which was statistically at par with NE Model (235.5, 25.88 cm and 197.9, respectively) followed by LCC (246.5, 25.63 cm and 195.1, respectively) (Table 3). Higher ET m^{-2} and grain per panicle under CCM-200 could be due to the application of nitrogen fertilizer in the need based crop growth stages like tillering and panicle initiation. The result partially corroborates with Singh *et al.*[17] who found maximum panicle length and fertility percentage under SSNM in comparison to FFP. Swain and Sandip[16] reported that nitrogen contributes in grains during the grain filling stage.

Table 4: Influence of crop establishment and nutrient management options on yield of rice during monsoon season at Puranchaur, Kaski, 2019

Treatments	Grain yield (t ha-1)	Straw yield (t ha^{-1})	HI
Crop establishment options			
ZT-DSR	4.11	5.80	0.42
RT-DSR	4.13	5.45	0.43
TPR	4.67	5.70	0.45
SEm (±)	0.1296	0.238	0.008
LSD (0.05)	ns	ns	ns
Nutrient management			
NE Model	4.82^{a}	6.26^{ab}	0.44
LCC	4.47^{b}	5.73^{b}	0.44
CCM-200	5.11^{a}	6.73^{a}	0.43
FFP	2.81^{c}	3.89^{c}	0.42
SEm (±)	0.0944	0.224	0.0072
LSD (0.05)	0.3268	0.775	ns
Interaction			
SEm (±)	0.1934	0.416	0.0147
LSD (0.05)	Ns	ns	ns
CV (%)	6.7	12.2	6.2
Grand mean	4.30	5.65	0.43

Treatments means followed by common letter (s) in column are not significantly different among each other based on DMRT at 5% level of significance

Table 5: Influence of crop establishment and nutrient management practices on economic analysis of rice at different growth stages during monsoon season at Puranchaur, Kaski, 2019

Treatments	Total cost of production (x1000 ha^{-1})	Gross return (x1000 ha^{-1})	Net return (x1000 ha^{-1})	B:C ratio
Crop establishment options				
ZT-DSR	69.06	144.61	75.56	2.08
RT-DSR	69.31	137.47	68.16	1.096
TPR	85.71	157.11	71.40	1.82
SEm (±)		4621.9	4621.9	0.0539
LSD(0.05)		ns	Ns	ns
Nutrient management options				
NE Model	77.14	163.49^{ab}	86.35^{ab}	2.11^{ab}
LCC	76.36	151.390^{b}	75.03^{b}	2.00^{b}
CCM-200	77.53	173.39^{a}	95.87^{a}	2.24^{a}
FFP	67.73	97.31^{c}	29.58^{c}	1.65^{c}
SEm (±)		3153.1	2955.6	0.0675
LSD (0.05)		10911.3	10227.5	0.2335
Interaction				
SEm (±)		6602.3	6510.3	0.1002
LSD (0.05)		ns	Ns	ns
CV (%)		6.4	13.1	6.8
Grand mean	146.40	71.71	1.95	

Treatments means followed by common letter (s) in column are not significantly different among each other based on DMRT at 5% level of significance

Grain yield of rice, straw yield and Harvest Index (HI) were found with non-significant influence due to the crop establishment options (Table 4) which was similar with Sah *et al.*[26] and Bastola *et al.*[27]. DSR recorded 13.63% lesser yield as compared to TPR which is similar to the finding of Xu *et al.*[28] where they found 13% lesser yield under DSR. TPR comparatively reported higher grain yield (4.67 t ha^{-1}) whereas, the straw yield was comparatively higher under ZT-DSR (5.8 t ha^{-1}).

The grain and straw yield was statistically promising under CCM-200 (5.11 and 6.73 t ha^{-1}, respectively), statistically at par with NE Model (4.82 and 6.26 t ha^{-1}, respectively) and followed by LCC (4.47 and 5.73 t ha^{-1}). Higher nitrogen application rate of 140 kg N ha^{-1} under CCM-200 and average of 112 kg N ha^{-1} under NE Model found significantly higher grain yield as compared to LCC (4.47 t ha^{-1}) and FFP (2.81 t ha^{-1}) which applied 92 kg N ha^{-1} and 16 kg N ha^{-1}, respectively.

Effects on economics and profitability: The ANOVA shows that the cost of input in TPR is more than cost input in ZT-DSR by 24.11% (Table 5). DSR are more cost saving in land preparation, seedling raising, uprooting and transplanting. TPR requires manual operation in tillage, sowing and irrigation cost[29] and DSR is more economical than transplanting[30]. Ho and Romli[31] and Younas *et al.*[32] found that the cost of production of transplanted rice was higher than DSR by 29 and 20.4%, respectively. In nutrient management methods, the total cost of production was higher in CCM-200 (77.53 thousand NRs. ha^{-1}) followed by NE Model (77.14

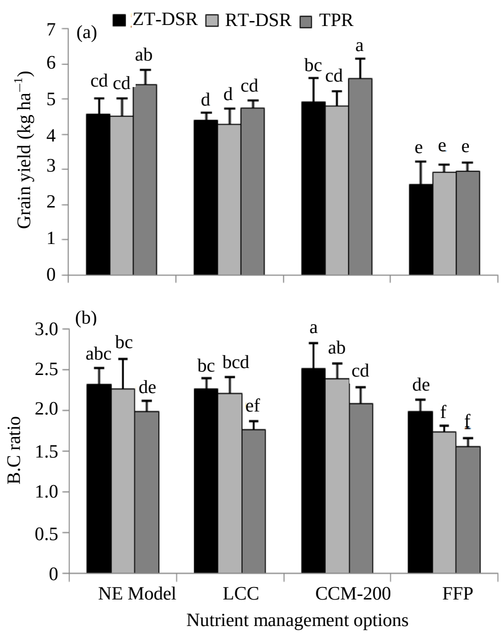

Fig. 7a, b: Comparative interaction effect of crop establishment and SSNM on grain yield and B:C ratio of rice at Puranchaur, Kaski, 2019

thousand NRs. ha^{-1}) and LCC (76.53 thousand NRs. ha^{-1}). CCM-200 has 14.47% more input cost than FFP. The requirement of more amounts of N fertilizer and labors charge is the major reason for higher cost of production under CCM-200 which was followed by NE Model and LCC.

Net return and B:C ratio was higher in ZT-DSR by 5.8 and 14.29%, respectively in comparison to TPR. These cost reductions and increased income were largely due to either reduced labor cost or tillage cost or both under DSR systems. Kumar and Ladha[33] from 77 published literatures of rice establishment methods concluded that ZT-DSR reduces US $ 9-125 ha^{-1} on the cost of production compared with puddled-TPR.

CCM-200 resulted significantly highest gross return, net return and B:C ratio (173.39 thousand NRs. ha^{-1}, 95.87 thousand NRs. ha^{-1} and 2.24, respectively) which was statistically at par with NE Model (163.49 thousand NRs. ha^{-1}, 86.35 thousand NRs. ha^{-1} and 2.11) and then followed by LCC (151.30 thousand NRs. ha^{-1}, 75.03 thousand NRs. ha^{-1} and 2.00 respectively). Although, CCM-200 requires highest input cost for production, the gross return, net return and B:C ratio are also highest under it because of highest biological and economical yields.

Comparative interaction effect on yield and profitability of rice: The analysis of variance elucidated comparatively higher yield under TPR+CCM-200 (5.59 t ha^{-1}) which was statistically followed by TPR+NE Model (5.40 t ha^{-1}). The grain yield was comparatively lowest under FFP combined with all the crop establishment options. Similarly, the ZT-DSR+CCM-200 showed comparatively highest B:C ratio (2.52) which was followed by RT-DSR+CCM-200 (2.39) and ZT-DSR+NE Model (2.32), respectively. DSR in combination with NE Model, LCC and CCM-200 showed the B:C ratio >2.0. The TPR clearly has the value of B:C ratio >2 only when combined with CCM-200. The B:C ratio in ZT-DSR with CCM-200 is 61.54% higher than the B:C ratio of TPR+FFP. The lowest B:C ratio was recorded in TPR+FFP (1.56) and RT-DSR with FFP (1.73), respectively (Fig. 7a, b).

CONCLUSION

The experiment shows that growth rate of rice is found higher in TPR than in ZT-DSR and RT-DSR. In comparison to FFP, SSNM approaches have positive and promising effects on growth, yield and profitability in which fertilizer application is timely, based on the crop demand. Higher the N used higher will be the cost incurred for production which results in higher growth rate, yield and economical outputs of rice. Despite of the non-significant interaction effect of crop establishment and nutrient management on growth, yield and profitability of rice, the combination of ZT-DSR and CCM-200 could be more resource conserving and profitable in the scenario of increasing labour and fuel cost and their scarcity.

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