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An Optimistic Effects of Resource Conservation Technologies on Growth Characteristics of Rice in Rice-Wheat Cropping System

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ABSTRACT
An alarming rate of groundwater exhaustion and soil resources depletion are major threats to rice cultivation in north India. Conservation strategies that reduce the irrigation amount and increasing productivity while maintaining natural balance are urgently required. Resource conserving techniques such as dry seeded rice (DSR), mulching and optimum nutrient management have been likely as one means of accomplishing these objectives, but little is known about combined adoption of all these practices in rice-wheat system. Therefore, a field study was conducted on a sandy loam soil in Pantnagar, India in 2011-12 and 2012-13, to investigate the effects of resource conservation technologies (RCTs) on the performance of rice crop growth characters. The treatment consists of two different tillage practices i.e., direct seeded rice (DSR) and transplanted rice (TPR); two levels of mulching i.e., paddy straw mulch and no mulch; and two fertility levels i.e., 100% recommended dose fertilizer (RDF) and 75% RDF. The experiment was laid out in factorial split plot design with three replication. The results revealed that DSR showed higher shoot growth and no. of shoots than TPR. The shoot height of rice in the DSR method was increased by 15 and 34% over TPR in 2011-12 and 2012-13, respectively. Mulching plots and 100% RDF also produced higher no. of shoots. Similarly, DSR, mulching and 100% RDF had produced higher DMA, CGR and LAI than TPR, no mulch and 75% RDF. In contrast, chlorophyll content (SPAD value) of rice was higher in TPR method along with mulched and 100% RDF. Practices such as DSR as well as mulched and 75% RDF registered a lesser number of days taken to 75% flowering and maturity as compared to conventional practices. Hence, a combined application of different RCTs practices could improve the growth characteristics of rice in rice-wheat system in northern India.
Keywords: *Direct seeding, Fertility, Growth, Mulching, Transplanted rice*

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INTRODUCTION

The rice-wheat cropping system (RWCS) is, being as a well-known food production system, providing food security for majority of the population in Asia, engaging roughly 24 m ha area in Asian sub-tropical territory i.e. India, China, Pakistan, Bangladesh and Nepal [1]. RWCS accounted for about 32 and 42% of the entire rice and wheat area in these Asian countries, respectively [2]. In India, Rice and wheat are accounting for approximately 58 and 77% of the total area and food grain production, respectively. The mainstream of the Indian populace lives in villages and the combined share of these two crops products reported more than 90% of total cereal usage in rural India. However, the sustainability of RWCS is under menace due to monotonous husbandry of RWCS in the same area of the field. Repetitive practices of RWCS causes excess soil nutrient mining and productivity fatigue. Hence, productivity enhancement of RWCS must be a prime concern to feed the rapidly increasing population of India, which is predicted to increase to 1.35 billion by 2025 [3]. Capital and energy-intensive conventional farmer's management practices for rice cultivation puts this life supporting production system on a ventilator.

The traditional method of rice cultivation in Indo-Gangetic Plains (IGP) requires a large amount of labor, water, and energy. Water and labor, however, are becoming increasingly scarce in this region, raising questions about the sustainability of rice production and the overall environment. In IGP, the increasing use of groundwater for rice cultivation has led to a decline in the water table by 0.1–1.0 m yr^{-1}, resulting in water scarcity and increased cost for pumping water [4]. Conventional flooding practice of transplanting rice requires a large amount of water (approximately 150 cm), of which 10 cm is used only for puddling (soil cultivation in ponded water called puddling) and further maintenance of standing-water conditions for the first 15 days for weed control in puddled-transplanted rice (PTR) increases the water requirement [5]. These concerns suggest that alternatives to transplanted rice are required to save water and increase crop, water, and labor productivity. Resource conserving techniques have been explored for eliminating the above issues; simultaneously, improving soil water supply during the cropping period and stabilizing or increasing crop production.

One approach to reducing water and labor demand is that grow rice with reduced tillage such dry-seeded rice (DSR) with alternate wetting and drying instead of flooded transplanted rice [6]. Dry seeding of rice with subsequent aerobic soil conditions eliminates the need for ponding water, thus reducing the overall water demand and providing opportunities for water and labor savings [7]. DSR is now considered to be an emerging production system in IGP and other parts of India and Asia [8]. Direct seeding helps reduce water consumption by about 30% as it eliminates the need for nursery raising, seedling uprooting, puddling, manual transplanting and 10–12 cm of water at the base of the crop for the first 15 days after seedling transplanting. Farmers also save about US$100 ha^{-1} in cultivation cost that is to be used during transplanting operations. In Asia, with the increasing shortage of water for irrigation, more research and extension efforts are being made toward the adoption and fine tuning of DSR production technologies to make DSR more sustainable.

Reduced tillage followed by mulching to subsequent crops by using previous rice crop residue offers a viable opportunity to increase crop productivity in a long term sustainable manner [9]. The soil water, growth and yield in rice benefits derived from using reduced tillage under semi-arid conditions can be enhanced by using mulch cover in the cropping system. Resource conservation practices have a direct influence on the growth of rice crop. A positive effect of this resource conserving techniques leads to improve growth characters such as growth, number of tillers, duration of crops. Further, fertilizer application over large conventional rice producing areas in IGP leads to inefficient utilization of applied nutrients and other production inputs [10]. Hence, the field-specific nutrient needs of crops should be tailored with other resource conserving techniques for harnessing the optimum nutrients use efficiency of applied nutrients. In recent years, interest of farmers in DSR has increased because of improving growth and yield of rice. In view of the above, the present investigation was aimed to determine the effect of resource conserving technique systems on the growth of rice crop.

MATERIAL AND METHODS

Location, Climate and Soil

The field experiment was conducted at Pantnagar, Uttarakhand, India in 2011-12 and 2012-13. The experimental site is located at latitude of 29°N and longitude of 79.3°E and 243.8 m above mean sea level. The site is characterized by a humid sub tropical climate. During the experimental period, the average rainfall in 2011-12 and 2012-13 was 2750 and 2518 mm, respectively. The experimental soil was sandy loam in texture with neutral pH and having medium organic carbon.

Experimental design and measurement

The treatments consisted of two tillage (direct seeded rice and transplanted rice) and two levels of mulching (no mulch and paddy straw mulch) in main plots and two levels of fertility (100% RDF and 75% RDF) in sub-plot. The experiment was laid out in factorial-split plot design, replicated thrice with a single plot size of 21.6m^2. Rice (cv. PR 113) was planted in June and harvested in October in each year. The land was prepared using a tractor involving two ploughing with a disc harrow and one planking. After preparation of the field, dry-seeding of rice (60 kg seed ha^{-1}) was done using a tractor-mounted seed-cum-fertilizer drill keeping 20 cm distance from line to line; whereas, field for transplanted rice prepared by tilling the soils until pulverized and puddling operation carried out to create an impervious layer. The seed rate 40 kg seed ha^{-1} was used for seedling establishment in nursery field and later transplanted in main field keeping the spacing of 20 cm between the rows and 10 cm between the plants. The full recommended dose of fertilizer (150-60-40 kg NPK ha^{-1}) was applied to 100% RDF treatment plots; whereas fertilizer dose (112.5-45-30 kg ha^{-1}) applied to 75% RDF treatment plots. The N was applied in three splits, 1/3 each as basal, 42 and 65 DAS. Phosphorus and potash were applied as basal as per the treatments in all plots uniformly before rice sowing. The plant growth parameters i.e. shoot height (cm), number of active tillers and dry matter accumulation (DMA) (g m^{-2}) were recorded at harvesting stage. Mean crop growth rate (CGR) (g m^{-2} d^{-1}) was computed by dry matter accumulation over two different periods. Leaf area index was measured by the ratio of leaf area and spacing. Flowering and physiological maturity of rice crop were observed when reached 75% through visual observation. Chlorophyll content was randomly measured at the top third leaves by using SPAD meter at 60 and 90 DAS. Statistical analyses of all the data were done as per the methodology of Gomez and Gomez (1984). In the table, only those interactions which were found significant have been presented.

RESULTS

Shoot height and No. of tillers

In the present study, shoot height was recorded higher in 2012-13 as compared to that of 2011-12. Tillage method had a considerable effect on shoot height at all the growth stages during both the years. Higher shoot height was recorded under DSR at all the succeeding stages. DSR crop attained highest shoot height of 91.9 and 100.5 cm as compared to TPR (i.e., 88.5 and 91.5 cm) in 2011-12 and 2012-13, respectively (Table 1). However, there was no significant difference existed between DSR and TPR in the first year. The mulching effect of the preceding crop did not cause significant variation at any stage in shoot height during both the years of experimentation. Straw mulch treated plots recorded more shoot height (93.5 and 97.2 cm) over no- mulch plot (86.9 and 95.0 cm) in 2011-12 and 2012-13, respectively. The fertility level had influenced significantly at all the growth stages during both the years. The 100% RDF had significantly registered maximum shoot height than 75% RDF treatment.

Different methods of tillage system, mulching and fertility level had also significantly influenced the number of shoots per square meter (Table 1). Generally, the number of shoots increased up to panicle initiation stage in DSR and up to flowering in the case of TPR during both the years. The greatest number of shoots per square meter (350.5 and 384.2 in 2011-12 and 2012-13, respectively) was recorded in DSR than TPR (305.8 and 287.3 in 2011-12 and 2012-13, respectively). Between mulching treatments, straw mulch treatment was significantly produced the maximum number of shoots per square meter at all the growth stages during both the years. At an end of the plant growth, a higher number of shoots per square meter was recorded in mulch treatment (355.8 and 352.4) which was significantly superior over no-mulch treatment (300.5 and 319.2) in 2011-12 and 2012-13, respectively. Similarly, significantly higher number of shoots per square meter were observed with 100% RDF; whereas, lower shoots in 75% RDF.

Table 1 Shoot height (cm) and number of shoots (m^{-2}) of rice as influenced by different RCT, s practices in rice-wheat cropping system during the study period

Treatments		Shoot height		No. of shoots	
		2011-12	2012-13	2011-12	2012-13
Tillage system (T)					
Direct seeded rice (DSR)		91.9	100.5	350.5	384.2
Transplanted rice (TPR)		88.5	91.5	305.8	287.3
SEm.±		1.65	1.55	4.84	6.01
LSD (P=0.05)		NS	5.35	16.71	20.74
Mulch (M)					
No-mulch		86.9	95.0	300.5	319.2
Straw mulch		93.5	97.2	355.8	352.4
SEm.±		1.65	1.55	4.84	6.01
LSD (P=0.05)		5.70	NS	16.71	20.74
Fertility levels (F)					
100% RDF		92.8	99.3	345.3	347.4
75% RDF		87.6	92.9	311.1	324.1
SEm.±		1.26	1.14	4.83	4.41
LSD (P=0.05)		4.09	3.73	15.72	14.38
Interaction effect between different treatments					
T x M	SEm.±	2.34	2.19	6.85	8.50
	LSD (P=0.05)	NS	NS	23.63	29.34
T x F	SEm.±	1.77	1.62	6.83	6.24
	LSD (P=0.05)	NS	5.27	NS	NS
M x F	SEm.±	1.77	1.62	6.83	6.24
	LSD (P=0.05)	NS	NS	NS	NS
T x M x F	SEm.±	2.51	2.29	9.65	8.83
	LSD (P=0.05)	NS	NS	NS	NS

Dry matter accumulation (DMA) and Crop growth rate (CGR)

Tillage method significantly influenced the total DMA per unit area in both years (Table 2). Total DMA was significantly highest under DSR (86.6 and 86.0 g m^{-2}) as compared to TPR (64.9 and 65.5 g m^{-2}) during both the years, respectively. However, the mulching treatment showed differential behaviour concerning to its statistical effect on dry matter accumulation at all the growth stages during both the years. Total DMA was higher under mulch plots (510.8 and 525.1 g m^{-2}) whereas, less under no-mulch plots (487.9 and 496.0 g m^{-2}) in 2011-12 and 2012-13, respectively. The application of 100% RDF produced significantly higher total dry matter accumulation (78.4 and 77.5 g m^{-2}) than 75% RDF (73.2 and 74.0 g m^{-2}) level in 2011-12 and 2012-13, respectively.

The dry matter accumulation of the crop per unit land area in a unit of time is referred to crop growth rate (CGR) expressed as g m^{-2} d^{-1}. CGR indicates the rate, which the crop is growing. In the present study, it is evident that crop growth rate is significantly influenced by the method of tillage system only not by other mulch and fertility treatments. In the present study, the mean CGR was gradually increased up to flowering then thereafter slightly decreased at harvest stage in both the tillage system but decreasing CGR at harvest stage in TPR was 2.76 and 2.83 g m^{-2} d^{-1} from 6.29 and 6.72 g m^{-2} d^{-1} at the flowering stage as compared to DSR (5.77 and 5.57 g m^{-2} d^{-1} at the harvesting stage from 6.59 and 6.67 g m^{-2} d^{-1} at flowering stage) in 2011-12 and 2012-13, respectively (Table 2). In case of mulching effect, straw mulch had the highest CGR at harvest stage (4.39 and 4.29 g m^{-2} d^{-1} in 2011-12 and 2012-13, respectively); whereas, no-mulch recorded lower CGR value (4.14 and 4.10 g m^{-2} d^{-1} in 2011-12 and 2012-13, respectively). Fertility levels had not significantly influenced CGR in both years of the study. Between the treatments, 100% RDF had registered the highest CGR than 75% RDF. Generally, the increasing CGR gradually up to flowering thereafter it was decreased in all the treatments during both the years.

Table 2 Dry matter accumulation (g m^{-2}) and Mean CGR (g m^{-2} d^{-1}) of rice as influenced by different RCT, s practices in rice-wheat cropping system during the study period

Treatments		Dry matter accumulation		Mean CGR	
		2011-12	2012-13	2011-12	2012-13
Tillage system (T)					
Direct seeded rice (DSR)		567.1	568.5	5.77	5.57
Transplanted rice (TPR)		431.7	452.6	2.76	2.83
SEm.±		7.54	8.71	0.23	0.21
LSD (P=0.05)		26.03	30.07	0.80	0.71
Mulch (M)					
No-mulch		487.9	496.0	4.14	4.10
Straw mulch		510.8	525.1	4.39	4.29
SEm.±		7.54	8.71	0.23	0.21
LSD (P=0.05)		NS	NS	NS	NS
Fertility levels (F)					
100% RDF		515.7	520.8	4.31	4.21
75% RDF		483.0	500.3	4.22	4.19
SEm.±		7.06	5.97	0.31	0.28
LSD (P=0.05)		23.01	19.45	NS	NS
Interaction effect between different treatments					
T x M	SEm.±	10.67	12.32	0.33	0.29
	LSD (P=0.05)	36.81	NS	NS	NS
T x F	SEm.±	9.99	8.44	0.44	0.39
	LSD (P=0.05)	NS	NS	NS	NS
M x F	SEm.±	9.99	8.44	0.44	0.39
	LSD (P=0.05)	NS	NS	NS	NS
T x M x F	SEm.±	14.13	1.94	0.62	0.55
	LSD (P=0.05)	NS	NS	NS	NS

Leaf Area Index (LAI) and Chlorophyll content

The leaves of a plant are normally its main organ of photosynthesis and the total area of leaves per unit ground area, called leaf area index (LAI), has therefore been proposed by Watson (1947) as the best measure of the capacity of a crop producing dry matter and called it as productive capital. The LAI was given here for the stage of flowering. Variation in the LAI due to tillage methods was significant only in the second year of experimentation. At the flowering stage, LAI was significantly higher in DSR during 2012-13 and reached a maximum (4.72 and 4.79 in 2011-12 and 2012-13, respectively) and significantly lower leaf area index was observed in TPR (4.61 and 4.39 in 2011-12 and 2012-13, respectively). Likewise, mulch treatment had a significant influence on LAI in second year study (Table 3). The straw mulch recorded maximum LAI at all the growth stages and reached maximum as 4.73 and 4.68 at flowering stage in 2011-12 and 2012-13, respectively. Conversely, fertility levels had not significantly influenced in the both years. The maximum LAI recorded at flowering stage under 100% RDF level was 4.75 and 4.72 in 2011-12 and 2012-13, respectively.

SPAD value is proportional to the amount of chlorophyll present in leaves and a linear relationship exists between SPAD value and leaf nitrogen concentration. Thus, the higher SPAD value indicates a healthier plant. Tillage system, mulching and fertility levels had a significant influence on SPAD reading. SPAD values in general increased up to 50 DAS and decreased thereafter. On 60 and 90 DAS, TPR recorded maximal value than DSR during both the years (Table 3). Mulching level had also significant influence on SPAD reading during both the years. Straw mulch treatment was recorded relatively higher SPAD value at all the stages in 2011-12 and 2012-13 and no- mulch was noticed the lower value. Similarly, between fertility levels, 100% RDF had influenced higher SPAD reading at all the growth stages and lower value observed in 75% RDF in both the years.

Table 3 Leaf area index and chlorophyll content through SPAD at various growth stages of rice as influenced by different RCT, s practices in rice-wheat cropping system during the study period

Treatments		LAI		Chlorophyll content			
				60 DAS		90 DAS	
		2011-12	2012-13	2011-12	2012-13	2011-12	2012-13
Tillage system (T)							
Direct seeded rice (DSR)		4.72	4.79	34.1	35.4	26.6	29.9
Transplanted rice (TPR)		4.61	4.39	39.7	40.5	37.7	34.5
SEm.±		0.08	0.07	0.32	0.15	0.23	0.21
LSD (P=0.05)		NS	0.23	1.09	0.53	0.80	0.71
Mulch (M)							
No-mulch		4.60	4.49	34.5	35.9	30.5	29.3
Straw mulch		4.73	4.68	39.3	40.0	33.8	35.2
SEm.±		0.08	0.07	0.32	0.15	0.23	0.21
LSD (P=0.05)		NS	0.23	1.09	0.53	0.80	0.71
Fertility levels (F)							
100% RDF		4.75	4.72	38.2	39.1	33.8	34.4
75% RDF		4.58	4.45	35.6	36.8	30.5	30.0
SEm.±		0.06	0.07	0.33	0.29	0.31	0.22
LSD (P=0.05)		NS	NS	1.08	0.95	1.00	0.73
Interaction effect between different treatments							
T x M	SEm.±	0.11	0.09	0.45	0.22	0.33	0.29
	LSD (P=0.05)	NS	NS	NS	0.75	NS	1.00
T x F	SEm.±	0.09	0.10	0.47	0.42	0.43	0.32
	LSD (P=0.05)	NS	NS	NS	NS	1.41	NS
M x F	SEm.±	0.09	0.10	0.47	0.41	0.43	0.32
	LSD (P=0.05)	NS	NS	1.53	NS	1.41	NS
T x M x F	SEm.±	0.13	0.14	0.67	0.58	0.61	0.45
	LSD (P=0.05)	NS	NS	2.17	NS	NS	1.46

Days taken to 75% flowering and maturity

In general, a lesser number of days were taken to attain 75% flowering stage in 2011-12 as compared to 2012-13 in DSR and 2012-13 in case of TPR. Tillage methods have a significant effect on the number of days taken to 75% flowering during both the years. A lesser number of days taken to 75% flowering were recorded under DSR plots as compared to TPR in both the years (Table 4). However, mulching treatment had not influenced on 75 % flowering significantly. Straw mulch plots had recorded early flowering than no- mulch treatment. Similarly, between fertility levels, 75% RDF was taken to minimum days of 75% flowering during both the years but it was non-significant with 100% RDF. Similar to 75% flowering, there was a same pattern also observed about days taken to 75% physiological maturity for both years under tillage, mulch and fertility level treatment.

Table 4 Days taken to 75% flowering and Days to 75% physiological maturity of rice as influenced by different RCT, s practices in rice-wheat cropping system during the study period

Treatments		Days taken to 75% flowering		Days to 75% physiological maturity	
		2011-12	2012-13	2011-12	2012-13
Tillage system (T)					
Direct seeded rice (DSR)		73.4	77.0	110.9	110.2
Transplanted rice (TPR)		83.4	81.6	116.1	114.2
SEm.±		0.87	1.12	0.97	1.62
LSD (P=0.05)		3.02	3.85	3.36	NS
Mulch (M)					
No-mulch		79.7	80.6	114.4	114.7
Straw mulch		77.0	77.9	112.5	109.7
SEm.±		0.87	1.12	0.97	1.62
LSD (P=0.05)		NS	NS	NS	NS
Fertility levels (F)					
100% RDF		79.1	79.7	114.6	113.7
75% RDF		77.6	78.8	112.3	110.7
SEm.±		0.89	1.18	1.75	1.64
LSD (P=0.05)		NS	NS	NS	NS
Interaction effect between different treatments					
T x M	SEm.±	0.87	1.58	1.38	2.30
	LSD (P=0.05)	3.02	NS	NS	NS
T x F	SEm.±	0.87	1.67	2.48	2.32
	LSD (P=0.05)	NS	NS	NS	NS
M x F	SEm.±	1.26	1.67	2.48	2.32
	LSD (P=0.05)	NS	5.45	NS	NS
T x M x F	SEm.±	1.78	2.36	3.50	3.29
	LSD (P=0.05)	5.81	NS	NS	NS

DISCUSSION

Results show that rice growing under resource conserving practices greatly advantageous over conventional practices. Resource conserving techniques such as DSR with mulching practices adopted for succeeding arable crops and optimum nutrient management imparted an immense effect on the growth of rice crop. In our study, an interaction between tillage and fertility levels was a significant effect on the growth of rice. DSR resulted in higher shoot height than TPR at both the fertility levels. DSR with even 75% RDF over-performed TPR with 100% RDF and both are showing similar effects as DSR with 100% RDF. Rice grown in DSR showed 10 per cent higher shoot height over TPR; similarly, shoot height was 7 percent more by fertilizer applied with 100% RDF over 75% RDF levels. Qureshi *et al*., [11] observed TPR could produce lower plant growth as compared to DSR. Seedlings during the initial period affected by transplanting shock might be reduced growth. Ros *et al*. [12] found that severe damage of roots during transplanting affected both early seedling vigour and the subsequent growth rate. Rice in DSR used higher seed rate per unit area than TPR; thus, it could be the reason that higher plant height possible in DSR for light competition.

The maximum number of shoots was observed from the treatment of mulch along with 100% RDF under DSR method. The DSR produced 15 and 33 per cent higher number of shoots as compared to TPR. The mulched plot had produced 18 and 10 per cent higher over no- mulch plot in 2011-12 and 2012-13, respectively. Plant density is an important contributor to tiller density and yield of rice. Miller *et al.* [13] found increasing tiller density with increasing plant density from 122 to 458 plants m^{-2}. The present investigation also showed maximum tillers under DSR were attributed due to higher plant density under DSR method than TPR. However, after maximum tillering, the greater tiller mortality was noticed in DSR than TPR. The tiller mortality rate was 36 and 26 per cent in DSR and it was 29 and 23 per cent in TPR in 2011-12 and 2012-13, respectively. This might have been the result of higher intra-specific competition for light, water and nutrients due to the higher plant density, especially in the DSR treatments. Similar results have also been reported with previous findings of Boonjung and Fukai [14]; Hasanuzzaman *et al*., [15]. Higher tiller mortality in these treatments of DSR was also probably due to water deficit stress and iron deficiency. Many authors have reported severe iron deficiency symptoms in DSR [16,17,18]. Similarly, mulch treatment also significantly influenced number of shoots under DSR and TPR methods. The plots which had mulch on previous crops could produce more numbers of tillers than no mulched plots but this has obviously interacted more under DSR. A possible reason for higher number of tillers from mulch in DSR treatment plots that release sufficient amounts of nutrients and buffering them through organic residue. Meyer [19] also reported that mulching under DSR fields creating favourable condition to uptake of nutrients by plants from soil.

In general, high production of total dry matter per unit area is the first prerequisite for high yield. The total yield of dry matter is the total amount of dry matter produced, less the photosynthates used for respiration. The DSR in the present study recorded higher DMA as compared to TPR. Similarly, DMA was more apparent in the mulched plot. The combination of DSR with mulch treatments produced significantly more DMA than any other treatment. The more plant density and better crop growth with mulch under DSR methods could be a reason to accumulate and produced more dry matter of rice. TeKrony and Egli, [20] also confirmed similar results that more dry matter production observed under DSR method. However, the mean CGR and LAI were not found any significant effect as influenced by the treatments in the present investigation.

The functional relationship of leaf chlorophyll content associated with leaf N content. Mamin [21] reported a strong, linear and positive relationship between SPAD values and chlorophyll a and b contents. The higher value of SPAD with mulch under TPR might be due to more available form of N (ammoniacal N) under puddled condition can easily absorb by rice roots and more indigenous source of organic matter content under mulched field that increases the N pool in the soil and crop take up nutrients without any stress condition. Even though mulch has been applied under DSR field, there nutrient availability in available form is much less as compared to TPR and less decomposition of residue under DSR to release the nutrient from straw. Therefore, more value was attributed to mulch under TPR than DSR.

An interaction effect of tillage, mulch and fertility has been shown on 60 and 90 DAS. The higher SPAD values recorded were significant with mulch along with 100% RDF under TPR followed by the same practices with 75% RDF. DSR recoded lower values as compared to TPR in the study. This finding of the study has confirmed the earlier perception that plants at higher density suffer from hidden hunger of nitrogen due to more intra-specific competition causing dilution that was reflected in SPAD values. This finding supports a study with the DSR [22]; where SPAD values at the flowering stage were lower at higher plant populations of DSR. Higher SPAD values in TPR treatment compared with DSR was undoubtedly the consequence of higher inter-specific competition for nitrogen. The highest value under 100% RDF and mulch was associated with SPAD value was linearly correlated with leaf N content. Other researchers noted similar observations, where the SPAD value increased with the N top dressing [23,24].

There was a significant interaction of 75% flowering among tillage, mulch and fertility during first year study but significant interaction found only between mulch and fertility for the second year study. During the investigation period, the difference of average duration of the flowering stage was 9.99 and 6.61 days earlier in DSR than in TPR; 2.63 and 2.72 days earlier in mulch than in no- mulch and 1.45 and 0.94 days earlier in 75% RDF than 100% RDF during 2011-12 and 2012-13, respectively. The combination of mulch with 75% RDF under DSR had significantly lesser duration i.e. 71.7 DAS to achieve a 75% flowering followed by mulch with 100% RDF (72.0 DAS) under DSR method. The combination of no-mulch with 100% RDF under TPR had a greater duration for 75% flowering (85.7 DAS). From this result in the present investigation, TPR method has significantly taken a longer duration for 75% flowering; whereas, it was the shortest in case of DSR method in the experiment. Similar research in Thailand by Sanjeewane *et al*. [25] reported that flowering commenced earlier in DSR than TPR, and phenological stages were earlier in DSR than in continuous flooding method. The differences could have been associated with time required to establish the root system of transplanted seedlings as suggested by McDonald *et al.* [26]. Water stress leads to growth of the elasticity and shortening the time interval between phenological stages [27]. The minimum duration of rice to attain 75% flowering stage in 75% RDF fertility levels attributed because of 25 percent less nutrients, especially nitrogen applied to the crop which hastening the vegetative stage to complete and accelerate the exertion of flowering. Both the fertility level difference of 75% flowering duration was less associated with mulch plot than no- mulch plot under both the established methods of rice.

CONCLUSION

Conventional practices of rice cultivation are major responsible for the deterioration of soil quality leads to poor growth of rice. The RCTs are promising soil management practices that can promote the growth characteristics of rice especially in RWCS, and consequently, increase the accumulation of dry matter as compared to conventional practices. Also, the adoption of RCT practices could significantly reduce the growth period in terms of days taken to 75% flowering and maturity. Hence, this holistic approach of RCT,s practices could be a viable technology towards successful future rice production.

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