



Nutrient and residue management in zero tilled-direct seeded basmati rice (*Oryza sativa*)-wheat (*Triticum aestivum*) system

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ABSTRACT

To assess the effect of nutrient and residue management on the performance of zero till - direct seed rice (DSR) (*Oryza sativa* L.)-wheat (*Triticum aestivum* L.) cropping system in partially reclaimed sodic soils, a three-year field experiment was conducted at ICAR-CSSRI during *kharif* and *rabi* 2016–18. The experiment was conducted in factorial randomized block design with 8 nutrient management options as first factor and two levels of residue management as second factor with three replications. Plant height, number of tillers and effective tillers were not affected significantly both in rice and wheat due to different nutrient and residue management treatments. Under different N management practices, basmati CSR 30 showed higher physiological efficiency in terms of SPAD reading, relative water content (RWC) and photosynthetic traits under treatments with recommended dose of fertilizers (RDF) + CSR bioformulation and RDF + CSR bioformulation + top cut at 75 days after sowing. Grain yield of basmati CSR 30 was the highest under transplanted conditions (36.0 q/ha) which was 20.0-30.6% higher than different nutrient and residue management treatments under DSR. Additional Zn application and foliar Fe sprays did not increase grain yield than RDF under ZT-DSR. Residual effect of nutrient and residue management was non-significant for all the yield attributes of wheat, viz. ear length, grains/ear and 1000-grain weight as well as for grain and straw yield of wheat. This study concludes that ZT-DSR is not suitable option for replacing puddled transplanted rice.

Keywords: Basmati rice, CSR bioformulation, Nutrient management, Residue management, Zero tillage

About 90% of the world's rice is grown and produced in Asia. In Asia, it is commonly grown by transplanting seedlings into puddled soil. Puddling benefits rice by reducing water percolation losses, controlling weeds, facilitating easy seedling establishment, and creating anaerobic conditions to enhance nutrient availability. But repeated puddling adversely affects soil physical properties by destroying soil aggregates and reducing permeability in subsurface layers. Also, transplanting requires large amount of water and labor that makes it expensive and non-profitable (Mahajan *et al.* 2013). These factors demand a major shift from puddled-transplanted rice (TPR) to direct seeding of rice (DSR) in irrigated areas. Limited work has been attempted on DSR especially on zero-till DSR (ZT-DSR). Higher loss of N due to denitrification (N₂O, NO), leaching (NO₃), volatilization; results into higher N requirements; therefore, DSR demands efficient nitrogen management system. The

retention of crop residues has also been advocated in the intensive rice (*Oryza sativa* L.)-wheat (*Triticum aestivum* L.) system because of increasing concern about depleting soil organic matter and environmental pollution with the burning of crop residues (Gupta *et al.* 2006). In Dry-drill-DSR due to aerobic conditions and alternate wetting/drying cycles, the availability of several nutrients including N and micronutrients such as Zn and Fe, is likely to be a constraint. Therefore, N management with micronutrient management is critical in Dry-DSR. Therefore, keeping in mind all these facts, the experiment was planned to standardize the nutrient and residue management strategies for salt-tolerant basmati rice grown under ZT-DSR for higher resource-use efficiency in rice-wheat system in partially reclaimed sodic soils.

MATERIALS AND METHODS

A field experiment was conducted during *kharif* 2016–17 and *rabi* 2016–17 to 2017–18 at ICAR-Central Soil Salinity Research Institute, Karnal. The experimental site was partially reclaimed sodic soil with the following chemical characteristics for top 0-30 cm soil in the beginning of the experiment. Soil pH was in the range of 7.90-9.82 (30-60 cm), 8.33-10.05 (60-90 cm) and 8.60-10.15 for 90-120 cm soil depth. The upper 0-15 cm soil layer was low in organic carbon (0.34-0.43%), low in available nitrogen

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(120 kg/ha), medium in available phosphorus (16-20 kg/ha), high in available potassium (350-420 kg/ha) and not deficient in iron and zinc micronutrients. However 15-30 cm soil layer was low in organic carbon (0.20-0.28%), low in available nitrogen (84-100 kg/ha), low in available phosphorus (9-13 kg/ha), high in available potassium (300-350 kg/ha) and low in zinc.

The experiment was conducted in factorial randomized block design with 8 nutrient management options as first factor, viz. T₁: Recommended dose of fertilizers (RDF) @ 60 kg N+30 kg P₂O₅+30 kg K₂O+25 kg ZnSO₄/ha + 5 q/ha FYM (30 DAS); T₂: RDF+10% higher N; T₃: RDF+20% higher N; T₄: RDF+20% higher N with top cutting (~75 d); T₅: RDF+25 kg/ha ZnSO₄; T₆: RDF + foliar spray of FeSO₄ @ 3% (40 and 60 DAS); T₇: RDF + CSR-Bioformulation (Seed treatment with 3% liquid formulation + soil application @ 25 kg/ha with FYM @ 5 q/ha at 30 DAS); T₈: RDF + CSR bioformulation with top cutting (~75 d) and two levels of residue management as second factor, viz. M₁: Rice straw as mulch (5 t/ha) and M₂: without mulch replicated thrice in the direct-seeded rice (salt-tolerant variety Basmati CSR 30) during *kharif* under zero-tillage (ZT). CSR bioformulation, an upgraded formulation of CSR-BIO that was developed and licensed by ICAR-CSSRI is the consortia of salt-tolerant bacterial isolates CSR-M16 (*Bacillus licheniformis*), CSR-A11 (*Lysinibacillus fusiformis*) and CSR-A16 (*Lysinibacillus sphaericus*) cultured on CSR patent protected media. In *rabi* season, the salt-tolerant wheat variety KRL 210 was grown with recommended package of practices under zero-tillage without imposing any treatment to evaluate the residual effect of treatments given to rice crop during *kharif* season. From *rabi* 2015-16, ZT conditions were maintained both for rice and wheat, therefore, the pooled data taken during *kharif* 2016 and 2017 and *rabi* 2016-17 and 2017-18 is being presented and discussed in this paper.

Sowing of the rice was done by Turbo happy seeder with seed rate 25 kg/ha at 20 cm row spacing on 15 June during both seasons. The rice crop was fertilized as per treatment and the 1/3rd dose of nitrogen and full dose of phosphorus, potassium and zinc sulphate were applied at the time of sowing and remaining 2/3rd nitrogen in two equal splits at 40 and 60 DAS. Rice mulch was applied as per treatment just after sowing of rice crop. In wheat crop recommended crop management practices were followed. Photosynthetic rate (pN), stomatal conductance (gS), transpiration rate (E) was measured with an infrared open gas exchange system (LI-6400, LICOR

Inc., Lincoln, NE, USA), while chlorophyll fluorescence (Fv/Fm) was measured with (Junior PAM fluorescence meter, Germany). The data were analyzed statistically using randomized block design (Version 9.3, SAS Institute Inc., Cary, NC, USA) at 5% probability level to compare the mean differences.

RESULTS AND DISCUSSION

Growth and physiological parameters: In zero-till direct-seeded rice (ZT-DSR) plant height at all the stages of observation (30, 60, 90 and 120 d) were not affected significantly due to different nutrient and residue management treatment. However, plant height was lower in treatment T₄ and T₈ at 90 and 120 days after sowing (DAS) than rest of the nutrient management treatments, where top cutting was done ~75 DAS. The plant height of transplanted rice was markedly higher at all the stages than all treatments under DSR (Fig 1A). Total tillers at 120 DAS and effective tillers/running meter length (rml) in ZT-DSR were statistically same in all nutrient and residue management treatments, but it was appreciably higher than transplanted rice at both the stages (Fig 1B). Residual effect of nutrient and residue management treatments given to ZT-DSR was not significant in salt tolerant wheat cv. KRL 210 for both plant height at 120 d and effective tillers/rml at harvest.

SPAD reading (µg/cm²) and chlorophyll content (mg/g) measures the greenness of the plant and hence, has been known as an index for evaluation of plant growth (Kumar *et al.* 2016, 2017). The treatment (Table 1) RDF + 20%

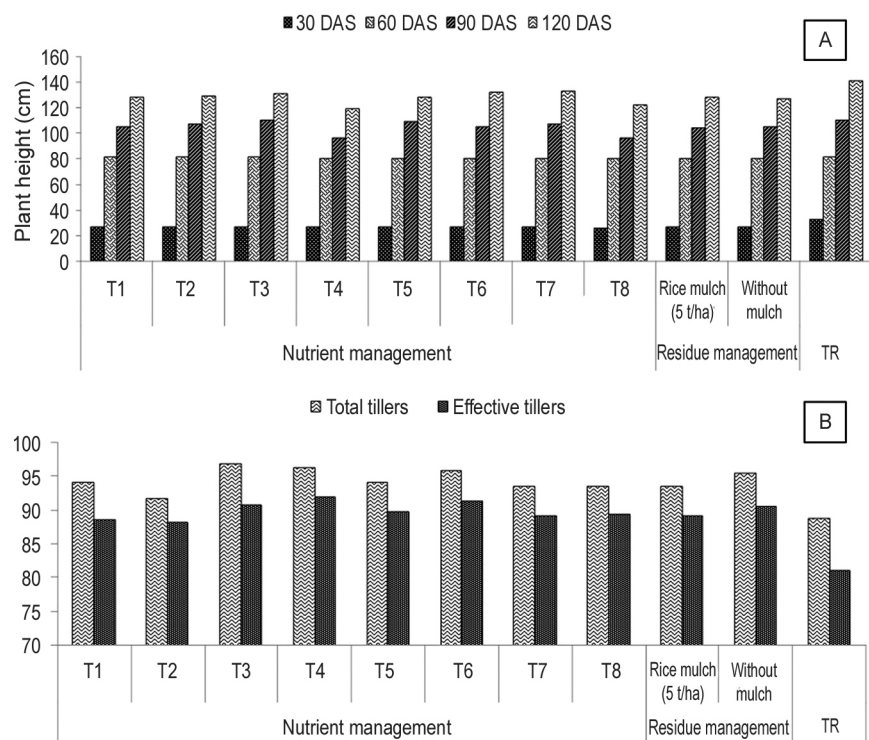


Fig 1 Effect on (A) plant height (cm) and (B) number of tillers of basmati CSR 30 under nutrient and residue management options in partially reclaimed sodic soils. (*TR – Transplanted rice)

N + Top cut showed the maximum value for SPAD and chlorophyll content (39.0 $\mu\text{g}/\text{cm}^2$ and 1.66 mg/g). Relative water content (RWC) indicates the level of cellular and tissues hydration (Kumar *et al.* 2018, Pooja *et al.* 2019). Rice grown under treatment RDF + 20% N + Top cut had maximum RWC statistically at par with RDF + CSR bioformulation + Top cut (Table 1). Additional supply of N helps to maintain water content in the leaves of the crop (Qadeer *et al.* 2019), thus resulting in higher RWC in the higher N application treatment. The presence of phosphate and potash solubilizing bacterial isolate CSR-M-16 *Bacillus licheniformis* affected the nutrients absorption from the soil (Damodaran *et al.* 2018). All the gas exchange attributes showed variability under different N management was found to have higher values under the treatment RDF + 20% N + Top cut (Table 1). This improvement might result from the synthesis of more photosynthetic pigments and increased cell wall rigidity under N treatments (Chen *et al.* 2010). These traits were statistically at par under treatment RDF + 20% N and RDF + CSR bioformulation + Top cut. Top cutting of leaves increases compensatory photosynthetic rate of the leaves thereby increased the chlorophyll and SPAD values of the leaves. Elevated N supply increased the chlorophyll content and photosynthetic rate of rice in present study. Additionally, leaf clipping reduced the leaf surface area and curtailed the transpiration losses and maintained better water status in the plant. Mulching showed significant effect with 3.78% increase in RWC. In addition, transplanted rice had maximum RWC of 87.3%. Residue mulching on soil surface decreases the evaporative water losses, maintains soil moisture for longer time, reduces the weed growth and moderates the soil temperature (Meena *et al.* 2020). All these

beneficial effects might lead to improved water uptake by crop plants which maintained higher RWC in leaves. Fv/Fm ratio showed maximum values of 0.690 under RDF + 20% N + Top cut followed by RDF + 20% N (0.659) and RDF +10% N (0.620). We observed that N stimulates the maximum quantum efficiency of photosystem II and similar results have been reported by Ji-rui *et al.* (2013).

Yield and yield attributes of rice and wheat. Perusal of the data given in Table 2 indicated that all the yield and yield attributes were markedly higher in transplanted rice compared to DSR, mainly due to poor germination/establishment. Among yield attributes only grains/panicle in ZT-DSR was significantly affected due to nutrient management treatments, but adding of rice mulch did not bring any marked effect on yield attributes recorded in this study. Among DSR treatments maximum grains/panicle was observed with RDF+20 % N treatment (78.2) which was statistically at par with all treatments where top cutting was not done, both the treatments (T_4 and T_8) where top cutting was done had statistically lower grains/panicle. Panicle length and 1000-grain weight was highest with transplanted rice but under DSR all the nutrient and residue management treatments were statistically similar. Grain yield of salt-tolerant rice (Basmati CSR 30) was highest under transplanted conditions (36.0 q/ha) which was 20.0-30.6% higher than different nutrient and residue management treatments under DSR. This was due to higher values of yield attributes under transplanted treatment than DSR. Bajjiya *et al.* (2020) also reported that in rice variety Pusa Basmati 1 the yield reduced under aerobic rice (DSR) by 12.4% than transplanted rice under Delhi conditions. On contrary, Balaji *et al.* (2020) documented marginal

Table 1 Effect of nutrient and residue management on physiological traits of ZT-DSR (pooled data of 2 years)

Treatment	SPAD	CC	RWC	pN	gS	E	Fv/Fm
<i>Nutrient management</i>							
T_1 -RDF*	33.3	1.43	79.5	23.5	1.82	19.1	0.575
T_2 -RDF+10% N	36.0	1.56	81.4	25.4	1.97	21.3	0.620
T_3 -RDF+20% N	35.2	1.64	81.4	25.0	2.11	20.5	0.659
T_4 -RDF+20% N+ Top cut**	39.0	1.66	84.2	26.6	2.43	22.7	0.690
T_5 -RDF+25 kg ZnSO_4	36.5	1.66	81.8	22.7	1.90	20.1	0.595
T_6 -RDF+ 3% FeSO_4 (40, 60 d)	33.3	1.59	80.9	22.9	2.03	21.9	0.586
T_7 -RDF+CSR bioformulation	36.2	1.56	81.2	26.7	2.31	21.7	0.601
T_8 -RDF+CSR bioformulation+Top cut**	37.6	1.58	83.3	25.7	2.16	21.5	0.603
LSD _{0.05}	2.11	0.06	3.02	2.44	0.51	2.80	0.033
<i>Residue management</i>							
Rice mulch (5 t/ha)	36.0	1.61	82.0	24.5	2.08	20.6	0.658
Without mulch	34.8	1.55	78.9	22.1	2.10	21.6	0.639
LSD _{0.05}	NS	0.03	NS	NS	NS	NS	NS
Transplanted rice (FP)	42.1	1.70	87.3	28.1	2.54	23.2	0.640

*RDF 60 kg N+30 kg P_2O_5 +30 kg K_2O +25 kg ZnSO_4 /ha + 5q/ha FYM (30 d); **Top cutting was done ~ 75 d, before panicle initiation in rice ; FP= Farmer's practice SPAD ($\mu\text{g}/\text{cm}^2$); CC – Chlorophyll content (mg/g); RWC – Relative water content (%); pN – Photosynthetic rate ($\mu\text{mol CO}_2/\text{m}^2/\text{s}$); gS – Stomatal conductance ($\text{mmol H}_2\text{O}/\text{m}^2/\text{s}$); E – Transpiration rate ($\mu\text{mol H}_2\text{O}/\text{m}^2/\text{s}$); Fv/Fm – Chlorophyll fluorescence

Table 2 Effect of nutrient and residue management on yield and yield attributes of ZT-DSR (pooled data of 2 years)

Treatment	Panicle length (cm)	Grains/panicle	1000-GW (g)	Grain yield (q/ha)	Yield decrease over TPR (%)	Lodging (%)
<i>Nutrient management</i>						
T ₁ -RDF*	22.7	75.4	22.9	25.7	28.6	27.9
T ₂ -RDF+10% N	22.5	74.6	22.6	27.0	25.0	36.7
T ₃ -RDF+20% N	22.9	78.2	22.2	25.6	28.9	45.4
T ₄ -RDF+20% N+ Top cut**	22.0	72.3	22.0	28.8	20.0	10.6
T ₅ -RDF+25 kg ZnSO ₄	22.3	74.6	22.3	25.9	28.1	33.5
T ₆ -RDF+ 3% FeSO ₄ (40, 60 d)	22.0	76.7	22.5	25.0	30.6	39.8
T ₇ -RDF+CSR bioformulation	22.5	75.5	23.1	28.2	21.7	26.0
T ₈ -RDF+CSR bioformulation +Top cut**	22.1	72.9	22.8	28.1	21.9	11.0
LSD _{0.05}	NS	4.51	0.67	2.10		10.3
<i>Residue management</i>						
Rice mulch (5 t/ha)	22.2	74.0	22.5	26.6	26.1	29.9
Without mulch	22.6	76.0	22.6	27.0	25.0	27.8
LSD _{0.05}	NS	NS	NS	NS		NS
Transplanted rice (FP)	25.2	85.0	26.0	36.0		60.0

*RDF 60 kg N+30 kg P₂O₅+30 kg K₂O+25 kg ZnSO₄/ha + 5q/ha FYM (30 d); **Top cutting was done ~ 75 d before panicle initiation in rice; FP= Farmer's practice

improvement in yield of DSR paddy than transplanted rice. Among DSR maximum grain yield was recorded in T₄ (28.8 q/ha) where 20% extra N was given with RDF along with top cutting before panicle initiation to reduce lodging which was statistically at par with treatments T₇ (28.2 q/ha), T₈ (28.1 q/ha) and T₂ (27.0 q/ha). However, yield attributes, viz. panicle length and 1000-grain weight in ZT-DSR did not influence due to top cutting rather grains/panicle reduced with top cutting, but higher yield in top cutting treatments (T₄ and T₈) can be ascribed to reduced lodging which might have reduced the shattering. Additional Zn application (T₅) and foliar Fe sprays (T₆) did not increase grain yield than RDF under ZT-DSR (Table 2).

Residual effect of nutrient and residue management treatments applied to DSR was non-significant for all the yield attributes of wheat.

Nutrient composition of rice grain: N content in direct seeded rice grain responded positively to higher N dose and CSR bioformulation application (Fig 2A). Significantly higher N content in rice grain was recorded with T₇ (1.64%), where CSR bioformulation application was made along with RDF followed by

T₃ (1.59%), T₈ (1.59%) and transplanted rice (1.58%) than T₁ (1.45%). Addition of rice mulch did not influence the

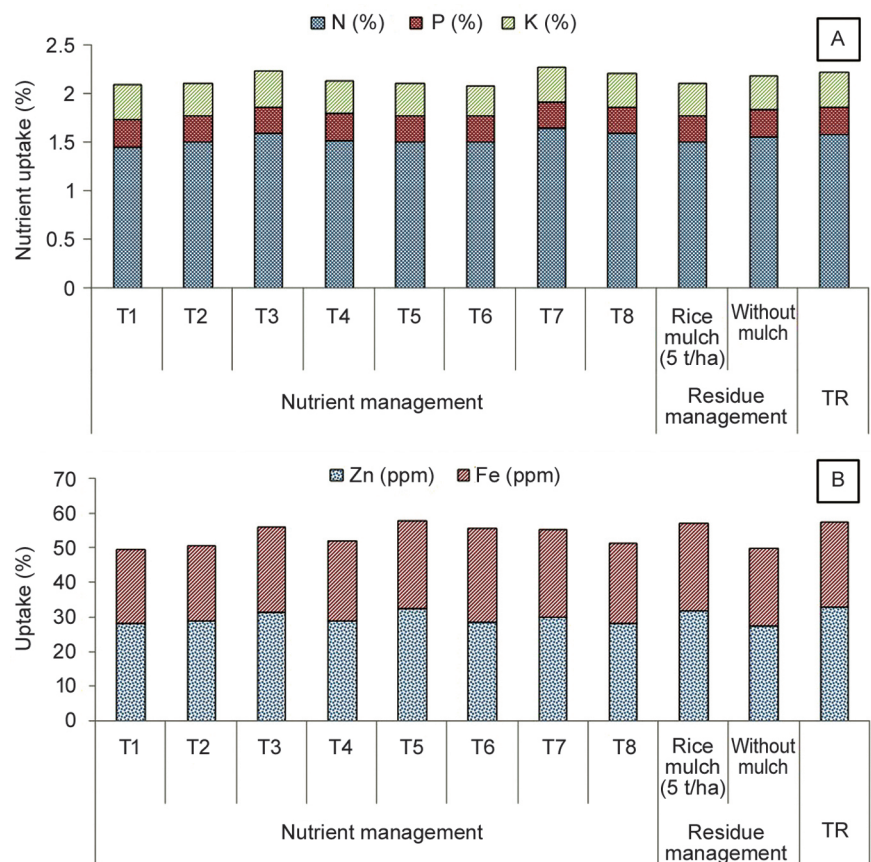


Fig 2 Effect of nutrient and residue management on (A) NPK uptake and (B) Zn and Fe uptake in grain of rice.

N content in paddy grain under DSR conditions. On the other hand, values of P and K content in transplanted rice grain were also almost similar with values recorded under DSR conditions.

Maximum Zn content in rice grain was estimated in transplanted rice (33.0 ppm) followed by T₅ (32.7 ppm) where double dose of ZnSO₄ was applied under DSR (Fig 2B). Addition of rice mulch (31.8 ppm) also increased the Zn content significantly in rice grain under DSR conditions than without mulch (27.6 ppm). Among DSR treatments, over residue management the highest Fe content was found in treatment T₆ (27.0 ppm) where two FeSO₄ sprays were done followed by T₅ (25.1 ppm) and T₇ (25.0 ppm). Addition of mulch (25.3 ppm) also increased the Fe content in rice grain under DSR than without mulch (22.4 ppm). Incorporation of residue could help in better recycling of nutrient and increase the soil organic matter content (Kone *et al.* 2010).

Nitrogen management is an important strategy in regulating the rice growth and photosynthetic efficiency in direct seeded rice. Application of the 20% additional nitrogen or the inoculation of the CSR bioformulation was effective in improving the SPAD value, chlorophyll content and relative water content. The CSR bioformulation application can effectively reduce the need for additional 20% nitrogen required under DSR conditions. The yield and yield attributes were markedly higher in transplanted rice compared to DSR. These findings suggest that ZT-DSR may not be a suitable option to replace transplanted rice in partially reclaimed sodic soils because of poor germination/establishment. However, further research is needed to standardize the seeding technique for ZT-DSR especially in salt-affected soils.

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