1. Institute Project Code : NRMACSSRI SIL201400600864
2. **Project Title: Nutrient and residue management of ZT-DSR basmati rice-ZT wheat cropping system under partially reclaimed sodic soils**
3. Key Words : Nutrient management, residue management, direct seeded rice, zero tillage, wheat, grain yield
4. (a) Name of the Lead Institute : Central Soil Salinity Research Institute, Karnal- 132001
   (b) Name of Division/ Regional Centre: Division of Soil and Crop Management
5. (a) Name of the Collaborating Institute(s) : Nil
   (b) Name of Division/ Regional Centre : Division of Crop Improvement
6. Project Team(Name(s) and designation of PI, CC-PI and all project Co-PIs, with time spent)

S. No.	Name, designation and institute	Status in the project (PI/ Co-PI)	Time to be spent (%)	Work components assigned to individual scientist
1	Dr. Parveen Kumar Principal Scientist CSSRI Karnal	PI	50	• Periodic observations on growth, yield and yield attributes • Collection of soil and plant samples and its analysis. • Statistical analysis of data, tabulation, interpretation and report writing.
2	Dr. R K Yadav Principal Scientist CSSRI Karnal	Co-PI	10	• Help in taking agronomic and physiological observations in rice and wheat. • Help in statistical analysis of data, interpretation and report writing.
3	Dr. A K Rai Principal Scientist CSSRI Karnal	Co-PI	25	• Chemical analysis of soil and plant samples. • Help in statistical analysis of data, interpretation and report writing.
4	Dr. Ashwani Kumar Scientist, CSSRI Karnal	Co-PI	10	• Recording periodic physiological observations in rice and wheat. • Help in statistical analysis of data, interpretation and report writing.

*Man months involved as per old pattern of RPF 1

7. Project Duration: Date of Start – 1 July 2014; Date of Completion – 30 June 2018

a. Objectives

1. 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.
2. To study the response of CSR-BIO Plus on salt tolerant basmati rice grown under ZT-DSR and its residual effect on ZT wheat.

3. To determine the effect of different nutrient and residue management on nutrient use efficiency and soil fertility parameters in rice-wheat system.
4. To study the physiological efficiency of salt tolerant basmati rice grown under ZT-DSR with different nutrient and residue management options and its residual effect on ZT wheat.

b. Practical utility

Results of the present study indicated that DSR under ZT in partially reclaimed soils should not be recommended to farmers since it has problems in germination, hence led to reduction in yield by ~18% compared to transplanted rice. It was also observed that DSR needs ~20% higher N compared to transplanted rice, which can be substituted by adding CSR BIO. Since disposal of rice residue is big concern in the region, study indicated that mulching with rice residue @ 5 t/ha helped in bio-fortification of rice grains besides improving the soil health.

Materials and Methods

Technical programme (Varieties: Rice- Basmati CSR 30; Wheat-KRL 210)

Design: Factorial RBD; Replication: Three

Factor A: Residue management: Two

M_1 = Rice straw as mulch (5 t/ha)

M_2 = Control

Factor B: Nutrient management: Eight

T_1: *RDF (60 kg N+30 kg P_2O_5+30 kg K_2O+25 kg $ZnSO_4$/ha) + 5q/ha FYM (30 d)

T_2: RDF+10% higher N

T_3: RDF+20% higher N

T_4: RDF+20% higher N with top cutting

T_5: RDF+25 kg/ha $ZnSO_4$

T_6: RDF + foliar spray of $FeSO_4$ @ 3% (40 and 60 DAS)

T_7: RDF+ CSR-BIO (Seed treatment with 3% liquid formulation + soil application @ 25 kg/ha with FYM @ 5 q/ha at 30 DAS)

T_8: RDF + CSR-BIO with top cutting

Results

2014-15

Proper levelling is considered to be the entry point of the ZT-rice, therefore, to do the precise levelling in the plots the conventional tillage was done in the beginning to grow direct seeded

rice. Therefore, only preliminary effect of CSR BIO was observed in the first year. All the treatments will be imposed in next 3 crop season. The initial soil pH data and effect of CSR-BIO plus are being presented in the Tables 1to 3.

Table 1: Initial soil pH of the experimental field

Soil depth (cm)	pH value
0-30	7.77-9.20
30-60	7.90-9.82
60-90	8.33-10.05
90-120	8.60-10.15

Table 2: Effect of CSR BIO on growth of conventional tillage-direct seeded rice basmati CSR-30

Treatment	At harvest			P_N (μ mol $CO_2/m^2/sec$)	gS (m mol $CO_2/m^2/sec$)	E (μ mol $CO_2/m^2/sec$)
	Plant height	Total tillers /hill	Effective tillers/hill			
CSR BIO*	126.7	16.0	15.8	24.5	1.44	24.9
Control	122.4	15.5	15.5	23.6	1.38	24.2
$LSD_{0.05}$	NS	NS	NS	NS	NS	NS

*Soil treatment with 25 kg/ha at sowing and foliar spray (3%) at 30 DAS

Table 3: Effect of CSR BIO on yield attributes and yield of CT-direct seeded rice basmati CSR-30

Treatment	Panicle length	Grains/ panicle	1000-GW (g)	Maturity	Grain yield (t/ha)	Straw yield (t/ha)
CSR BIO	26.3	90.7	24.8	138	4.13	6.63
Control	24.8	82.5	24.4	138	4.09	6.13
$LSD_{0.05}$	NS	7.5	NS	-	NS	NS

Grain yield of CT-DSR (CSR 30) was marginally higher (0.96%) with application of CSR BIO (solid + liquid formulation) than control.

2015-16

Till now very limited work has been done on direct seeded rice (DSR) especially on zero tillage (ZT)-DSR. Due to aerobic conditions under DSR availability of N, Zn and Fe reduced. Higher loss of N due to denitrification (N_2O, NO), leaching (NO_3), volatilization; results into higher N requirements; therefore, needs more efficient N management in DSR. Deficiencies of Zn and Fe are of concern in DSR due to aerobic conditions and its effective and timely management is need of the hour to spread DSR technology.

Keeping above background in mind direct seeding of salt tolerant rice cultivar Basmati CSR 30 was done on 17 June 2015 under ZT with 16 treatment combinations of residue and nutrient management (Table 4). During first year of investigation, results indicated that physiological traits (RWC, SPAD), yield attributes and yield of DSR basmati rice did not influence due to application of rice residues as mulch @ 5t/ha (Table 4 and Fig. 1). Effective tillers/hill, grains/panicle and 1000-grain weight was statistically similar in all the nutrient management treatments. However, maximum value of panicle length (23.0 cm), relative water content (RWC, 76.0) and chlorophyll content (SPAD reading, 33.7) was recorded where recommended dose of fertilizer (RDF) was supplemented with CSR-BIO (seed treatment + soil application), which was significantly higher than treatment T_1 (RDF) and some other treatments (Table 4 and Fig. 1). Grain yield of ZT-DSR basmati was highest in treatment T_4 [RDF+20% higher N with top cutting (31.1 q/ha)] closely followed by T_2 [RDF+10% higher N (30.8 q/ha)] and T_8 [RDF+CSR-BIO (30.8 q/ha)]. The significantly lower grain yield was observed in treatments T_1 and T_5 (RDF+30% higher N with top cutting) than other treatments in the study. Data on lodging indicated that with addition of higher N increased the lodging while top cutting at 70 days after sowing reduced it numerically.

After the harvest of the rice salt tolerant wheat cultivar KRL 210 was sown in November 2015 under ZT with recommended package of practices. Results (Table 5) indicated that residual effect of nutrient and residue management treatments of rice was non-significant on yield and yield attributes of wheat (KRL 210). After two years of experimentation, available N, available K and Zn status improved in soil with addition of rice mulch @ 5t/ha than without mulch treatment.

Table 4: Effect of residue and nutrient management on yield attributes and yield of ZT-DSR basmati CSR 30

Treatment	Effective tillers/hill	Panicle length (cm)	Grains/ panicle	1000-GW (g)	Grain yield (q/ha)	Straw yield (q/ha)	Lodging (%)
Residue management							
Rice mulch (5 t/ha)	8.53	21.5	58.1	22.98	29.1	39.4	4.38
Control	8.77	22.2	60.5	23.28	29.3	38.3	4.33
$LSD_{0.05}$	NS	NS	NS	NS	NS	NS	NS
Nutrient management							
T_1	8.80	21.8	60.8	22.85	26.7	45.6	5.00
T_2	8.20	22.3	58.0	23.54	30.8	39.6	6.66
T_3	8.73	21.9	58.9	23.25	28.2	48.4	10.0

T_4	8.27	21.7	57.3	23.04	31.1	31.4*	4.16
T_5	8.50	19.9	57.3	22.71	27.6	31.7*	0.00
T_6	8.50	22.0	59.7	24.00	30.2	40.0	1.66
T_7	9.30	22.0	59.8	22.27	28.2	36.9	4.00
T_8	8.87	23.0	62.2	23.38	30.8	36.9	3.33
$LSD_{0.05}$	NS	1.85	NS	NS	3.1	-	-

T_1: RDF (60 kg N+30 kg P_2O_5+30 kg K_2O+25 kg $ZnSO_4$/ha) + 5q/ha FYM (30 d); T_2: RDF+10% higher N; T_3: RDF+20% higher N: T_4: RDF+20% higher N with top cutting; T_5: RDF+30% higher with top cutting; T_6: RDF+25 kg/ha $ZnSO_4$; T_7: RDF+ foliar spray of $FeSO_4$ @ 3% (40 and 60 DAS); T_8: RDF + CSR-BIOPLUS (Seed treatment with 3% liquid formulation + soil application @ 25 kg/ha with FYM @ 5 q/ha at 30 DAS)

* Top cutting biomass not included

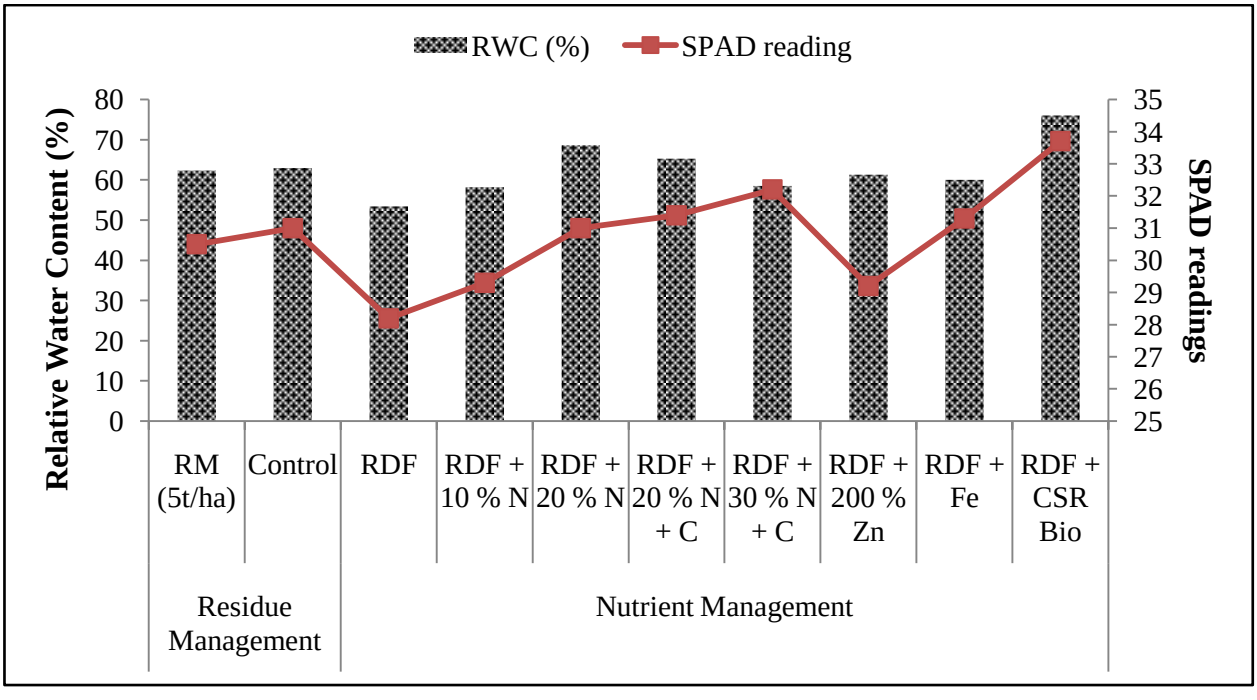

Fig 1: Effect of residue and nutrient management on physiological efficiency of ZT-DSR basmati CSR 30

Table 5: Residual effect of nutrient and residue management treatments of ZT-basmati rice on yield and yield attributes ZT-wheat

Treatment	**Ear length (cm)**	**Grains/ ear**	**1000-GW (g)**	**Grain yield (q/ha)**	**Straw yield (q/ha)**	**Harvest index (%)**
Nutrient management						
RDF*	15.0	48.0	36.9	43.5	63.4	41.0
RDF+10% N	15.2	48.4	37.8	37.9	59.2	39.1
RDF+20% N	15.2	46.6	39.0	39.6	55.5	42.5

RDF+20% N+ Cut	15.0	45.8	36.9	36.6	60.5	37.7
RDF+30% N+ Cut	15.9	50.8	38.1	43.5	65.5	39.9
RDF+25 kg $ZnSO_4$	15.6	49.2	38.4	38.0	64.4	37.4
RDF+ 3% $FeSO_4$ (40, 60 d)	15.4	49.8	36.7	38.9	62.1	38.5
RDF+CSR-BIO	15.0	50.9	37.8	41.0	53.6	45.8
$LSD_{0.05}$	NS	NS	1.85	NS	NS	7.16
Residue management						
Rice mulch (5 t/ha)	15.2	49.0	37.5	39.6	59.7	40.2
Control	15.3	48.4	37.9	40.1	61.4	40.3
$LSD_{0.05}$	NS	NS	NS	NS	NS	NS

2016-17

It is well documented that direct seeding of rice has many tangible and non-tangible benefits, especially saving of labour, water and ultimately low cost of cultivation than conventional transplanted rice. But there are certain agronomic issues especially weed, nutrient, residue and water management, needs to be resolved before its promotion so that this technology can be made farmers friendly. Keeping above background in mind a field experiment was conducted with eight nutrient management treatments under rice residue and without residue as control. Results indicated that residual effect of nutrient and residue management treatments of rice was non-significant on yield and yield attributes of wheat (KRL 210). After two years of experimentation, available N, available K and Zn status improved in soil with addition of rice mulch @ 5t/ha than without mulch treatment. Direct seeding of salt tolerant rice cultivar Basmati CSR 30 was done on 16 June 2016. It was observed that physiological traits like photosynthetic rate, chlorophyll fluorescence, stomatal conductance, transpiration rate, relative water content and chlorophyll content (SPAD readings) were recorded maximum with RDF+CSR-BIO with rice residues as mulch @ 5t/ha (Fig. 2 and Fig. 3). Higher physiological efficiency under rice residue also resulted in maximum grain yield of rice under RDF+CSR-BIO treatment, however under without residue treatment maximum rice grain yield was recorded with treatment RDF+20% higher N with top cutting (Table 6). Across residue management treatments, grain yield of ZT-DS basmati rice was highest in treatment RDF+20% higher N with top cutting (30.4 q/ha), at par with RDF+10% higher N (28.84 q/ha) and RDF+CSR-BIO (28.47 q/ha). Over nutrient management treatments rice mulch did not affect yield and yield attributes in ZT-DS basmati rice, but helped in biofortification of rice grains.

Table 6: Interaction effect of nutrient and residue management on grain yield of ZT-DSR basmati CSR 30

Nutrient management/ Residue management	**Grain yield (q/ha)**		**Mean**
	Rice mulch (5 t/ha)	**Control**	
RDF*	26.23	27.35	**26.79**
RDF+10% N	28.56	29.11	**28.84**
RDF+20% N	26.45	26.41	**26.43**
RDF+20% N+ Cut	27.97	32.82	**30.40**
RDF+25 kg $ZnSO_4$	24.58	28.72	**26.65**
RDF+ 3% $FeSO_4$ (40, 60 d)	23.27	28.77	**26.02**
RDF+CSR-BIO	29.54	27.41	**28.47**
RDF+CSR-BIO+ Cut	22.87	30.64	**26.76**
Mean	**26.19**	**28.91**	**-**
$LSD_{0.05}$	**NM=2.76; RM=NS; NM×RM=3.90**		

T_1: *RDF (60 kg N+30 kg P_2O_5+30 kg K_2O+25 kg $ZnSO_4$/ha) + 5q/ha FYM (30 d); T_2: RDF+10% higher N; T_3: RDF+20% higher N: T_4: RDF+20% higher N with top cutting; T_5: RDF+25 kg/ha $ZnSO_4$; T_6: RDF+foliar spray of $FeSO_4$ @ 3% (40 and 60 DAS); T_7: RDF + CSR-BIO (Seed treatment with 3% liquid formulation + soil application @ 25 kg/ha with FYM @ 5 q/ha at 30 DAS); T_8: RDF + CSR-BIO with top cutting

After the harvest of the rice salt tolerant wheat cultivar KRL 210 was sown in November 2016 under ZT with recommended package of practices. Results indicated that residual effect of nutrient and residue management treatments of rice was non-significant on yield and yield attributes of wheat (KRL 210). After three years of experimentation, available N, available K and Zn status improved in soil with addition of rice mulch @ 5t/ha than without mulch treatment.

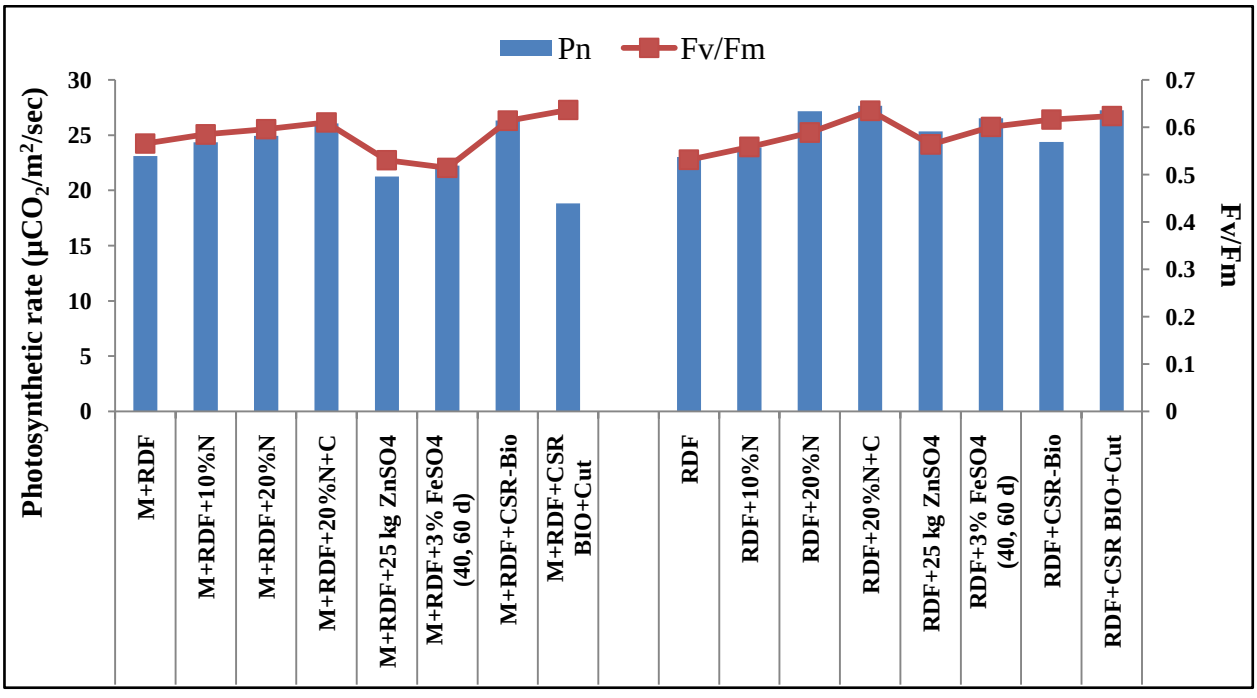

Fig 2: Effect of nutrient and residue management on physiological efficiency of ZT-DSR basmati CSR 30

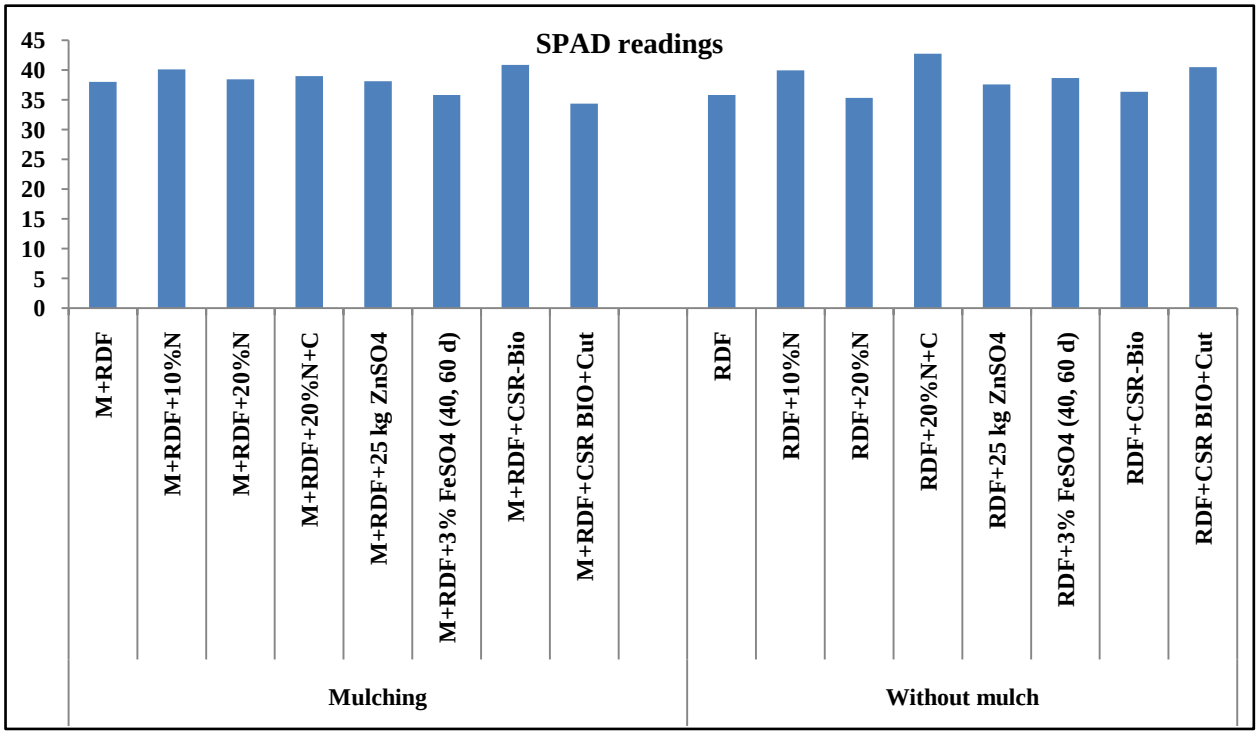

Fig 3: Effect of nutrient and residue management on chlorophyll content of ZT-DSR basmati CSR 30

2017-18

Direct seeding of rice is eco-friendly practice with higher resource use efficiency than conventional transplanted rice. However, certain agronomic issues especially weed, nutrient, residue and water management, needs to be standardized before its promotion on large scale. Keeping above background in mind a field experiment was conducted with eight nutrient management treatments under rice residue and without residue as control. Results indicated that residual effect of nutrient and residue management treatments of rice was non-significant on yield and yield attributes of wheat (KRL 210). After three years of experimentation, available N, available K and Zn status improved in soil with addition of rice mulch @ 5t/ha than without mulch treatment. Direct seeding of salt tolerant rice cultivar CSR 30 basmati was done on 14 June 2017. It was observed that plant height and tillers/rm of ZT-rice did not statistically influenced due to nutrient and residue management treatments. In DSR physiological traits *viz.,* photosynthetic rate, transpiration rate, stomatal conductance, chlorophyll content, chlorophyll fluorescence, relative water content and SPAD readings recorded higher under treatments, RDF + CSR BIO (with or without top cutting) and RDF + 20% N + cut with mulching and without mulching (Fig. 4). Yield traits (panicle length and 1000-grain weight) and grain yield of CSR 30 basmati was significantly higher under transplanting conditions (3.60 t/ha). ***Among ZT-DS basmati grain yield was highest in RDF+CSR-BIO with top cutting (2.95 t/ha) at par with RDF+CSR-BIO (2.80 t/ha) and RDF+20% higher N with top cutting (2.73 t/ha). Reduction in ZT-DSR was by 18% in best treatment than transplanted rice*** (Table 7). Additional Zn application and foliar Fe sprays did not increase grain yield than RDF. Top cutting reduced the lodging significantly in ZT-DSR which was also positively correlated with the grain yield.

After the harvest of the rice salt tolerant wheat cultivar KRL 210 was sown in November 2017 under ZT with recommended package of practices. Results indicated that residual effect of nutrient and residue management treatments of rice was non-significant on yield and yield attributes of wheat (KRL 210). After four years of experimentation, available N, available K and Zn status improved in soil with addition of rice mulch @ 5t/ha than without mulch treatment.

Table 7: Effect of nutrient and residue management on yield and yield attributes ZT-DSR basmati CSR 30

Treatment	Effective tillers/mrl	Panicle length (cm)	Grains/ panicle	1000-GW (g)	Grain yield (t/ha)	Lodging (%)
Nutrient management						
T_1: RDF*	88.47	21.83	85.07	21.46	2.46	53
T_2: RDF+10% N	88.10	21.90	87.97	21.69	2.51	41
T_3: RDF+20% N	90.53	22.17	90.87	21.51	2.47	43
T_4: RDF+20% N+ Cut	91.80	21.63	85.80	20.70	2.73	10
T_5: RDF+25 kg $ZnSO_4$	89.60	22.30	91.97	21.15	2.51	53
T_6: RDF+ 3% $FeSO_4$ (40, 60 d)	91.17	21.13	88.10	21.06	2.40	61
T_7: RDF+CSR-BIO	88.97	21.40	88.60	22.33	2.80	21
T_8: RDF+CSR-BIO+ Cut	89.17	22.03	84.87	22.65	2.95	6
$LSD_{0.05}$	NS	1.11	6.61	0.97	0.31	-
Residue management						
Rice mulch (5 t/ha)	89.08	21.84	87.23	21.47	2.59	39
Control	90.38	21.76	88.58	21.67	2.61	33
$LSD_{0.05}$	NS	NS	NS	NS	NS	-
NM × RM	NS	NS	NS	NS	NS	-
Transplanted rice	**81.0**	**25.2**	**85.0**	**26.0**	**3.60**	**60**

*RDF 60 kg N+30 kg P_2O_5+30 kg K_2O+25 kg $ZnSO_4$/ha + 5q/ha FYM (30 d)

T_1: *RDF (60 kg N+30 kg P_2O_5+30 kg K_2O+25 kg $ZnSO_4$/ha) + 5q/ha FYM (30 d); T_2: RDF+10% higher N; T_3: RDF+20% higher N: T_4: RDF+20% higher N with top cutting; T_5: RDF+25 kg/ha $ZnSO_4$; T_6: RDF+foliar spray of $FeSO_4$ @ 3% (40 and 60 DAS); T_7: RDF + CSR-BIO (Seed treatment with 3% liquid formulation + soil application @ 25 kg/ha with FYM @ 5 q/ha at 30 DAS); T_8: RDF + CSR-BIO with top cutting

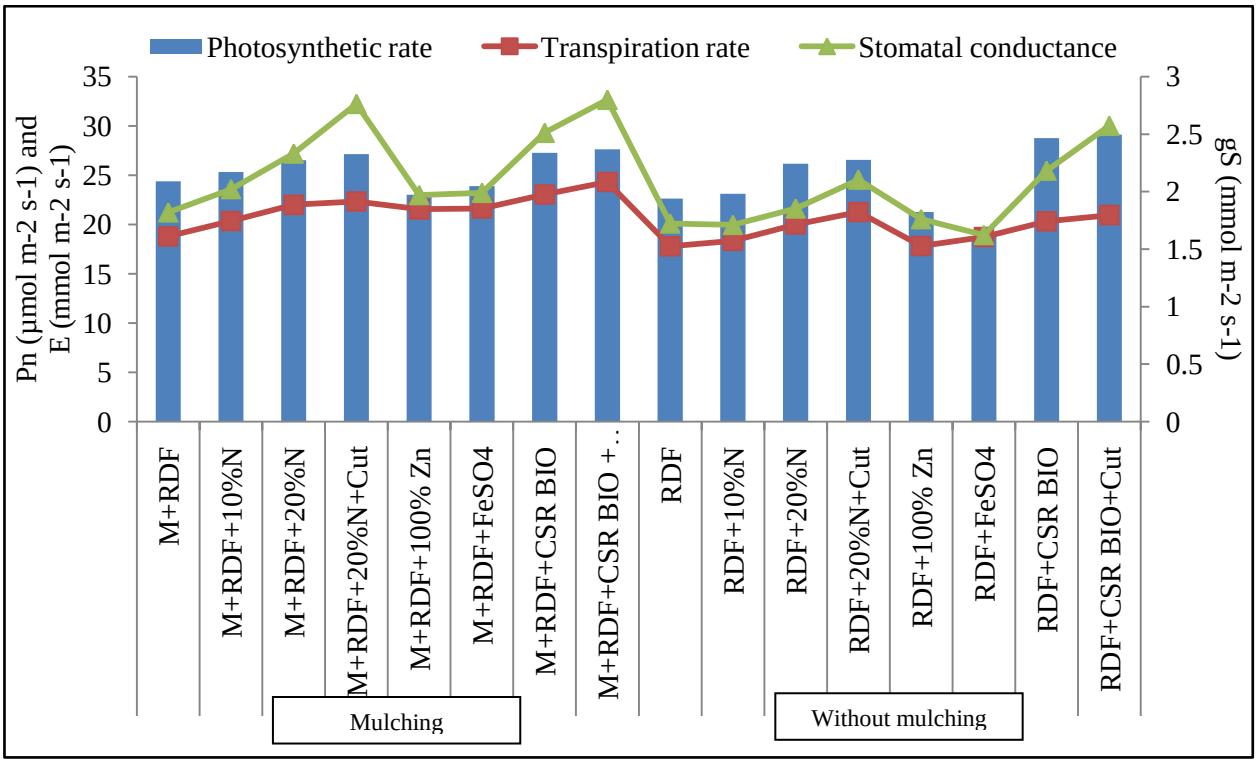

Fig 4: Effect of nutrient and residue management on physiological efficiency of ZT-DSR basmati CSR 30

ZT-DSR basmati CSR 30 under RDF+CSR-BIO with top cutting (best treatment)

Salient findings

- In DSR physiological traits *viz.,* photosynthetic rate, transpiration rate, stomatal conductance, chlorophyll content, chlorophyll fluorescence, relative water content and SPAD readings recorded higher under treatments, RDF + CSR BIO (with or without top cutting) and RDF + 20% N + cut with mulching and without mulching.
- Among ZT-DS basmati grain yield was highest in RDF+CSR-BIO with top cutting (2.95 t/ha) at par with RDF+CSR-BIO (2.80 t/ha) and RDF+20% higher N with top cutting (2.73 t/ha). Reduction in ZT-DSR was by 18% in best treatment than transplanted rice (3.60 t/ha).
- Additional Zn application and foliar Fe sprays did not increase grain yield than RDF, however, top cutting reduced the lodging significantly in ZT-DSR which was also positively correlated with the grain yield.
- Residual effect of nutrient and residue management treatments of rice was non-significant on yield and yield attributes of wheat (KRL 210).
- After four years of experimentation, available N, available K and Zn status improved in soil with addition of rice mulch @ 5t/ha than without mulch treatment.
- Over nutrient management treatments rice mulch did not affect yield and yield attributes in ZT-DS basmati rice, but helped in biofortification of rice grains.

Conclusions

- ✓ DSR under ZT in reclaimed soils have problems in germination, hence led to reduction in yield by 18% compared to transplanted rice.
- ✓ DSR needs ~20% higher N compared to transplanted rice, which can be substituted by adding CSR BIO.
- ✓ Mulching with rice residue helped in bio-fortification of rice grains besides improving the soil health.