

Enhanced nutrient uptake in rice-wheat cropping system

through the use of microbial inoculations and zinc fertilization

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Considering the contribution of rice-wheat cropping system to food and nutritional security, the nutrient requirement and uptake potential is needed to study in the face of changing cultivation practices and input addition. Our study involve the treatments of six different cultivation methods and nine nutrient management options showed that system nutrient uptake of nitrogen (N), phosphorus (P), potassium (K), zinc (Zn) and iron (Fe) was 148.4–275.5 kg ha⁻¹, 22.0–9.0 kg ha⁻¹, 152.8–248.2 kg ha⁻¹, 475.1–835.5 g ha⁻¹ and 4.46–6.03 kg ha⁻¹, respectively in RWCS. The highest nutrient uptake was in the aerobic rice system (ARS) followed by the zero tillage wheat (ZTW) system. Among the nutrient management options, the highest uptake of N, P, K, Zn and Fe was found in recommended dose of nutrient (RDN) (120 kg N ha⁻¹ and 25.8 kg P ha⁻¹) + Zn (5 kg Zn ha⁻¹ through zinc sulphate heptahydrate) which remained at par with application of 75% RDN + Anabaena-Pseudomonas biofilmed formulation + Zn indicating the significance of microbial inoculation in enhancing the nutrient uptake.

Keywords: Microbial inoculations, Nutrient uptake, Rice-wheat cropping system, Zinc fertilization

RICE and wheat are the staple food crops of India with production of 118.8 and 107.6 million tonnes (mt), respectively. These are the crops with the largest share of resource in consumption among all other crops (especially nutrients). The area under cultivation of both crops is 75.30 million ha. The energy required in production process of one ha rice and wheat is 15697.4 and 12905.7 MJ ha⁻¹ and if calculated over total cultivated area then it comes across 687.55 × 10⁹ MJ for rice and 406.53 × 10⁹ MJ for wheat. The share of rice and wheat to nutrient consumption together consume 7.9 mt (52.5% of total fertilizer consumption in India) nitrogen (N), 3.42 mt (48.4%) P₂O₅ and 1.2 mt (46.7%) K₂O of nutrient through fertilizer during 2017 in India.

Considering the resource endowment and the role of both crops in food and nutritional security, it is imperative to study the nutrient uptake potential at the cropping system level.

Being the high yielding and exhaustive cropping system, large amount of nutrients removed from the soil by rice-wheat cropping system (RWCS) creates the need for nutrient fertilization. Along with macronutrients, both crops respond to the application of micronutrient zinc (Zn) and iron (Fe) and secondary nutrient (sulphur). An estimate of nutrient deficient soil showed that 43% and 12.1% soil is deficient in Zn and Fe, respectively. Along with deficiency in soil, micronutrient malnutrition in humans is a serious health issue and for alleviating it, the biofortified

varieties and agronomic biofortification through fertilization is essential. Energy consumption in nutrient application out of total energy required in the production process is 54–62%, 66–75% and 59–68% in rice, wheat and RWCS, respectively. Considering the importance of RWCS in general and nutrient management in RWCS in particular, it is important to study nutrient uptake in RWCS as affected by suboptimal and optimal fertilizers applications along with cost effective options such as microbial inoculations in the front of changing cultivation methods. In this context, a study was conducted to access the impact of different rates and sources of N and P application and Zn fertilization on system nutrient uptake in three different methods of

cultivation each for rice and wheat.

Methodology

The field experiment was conducted continuously for 2 years (2013-14 and 2014-15) at the Research Farm of ICAR-Indian Agricultural Research Institute, New Delhi. The objective of the study was to evaluate the role of cultivation methods, sources and rate of nitrogen and phosphorus application, zinc fertilization and microbial inoculations on nutrient uptake in RWCS. The experiment was conducted in split-plot design with 3 cultivation methods as main plots and 9 nutrient management options as sub-plot treatments. Rice variety 'Pusa Sugandh 5' and wheat variety 'HD 2967' were grown in the experiment and all the treatment replicated thrice. The cultivation methods were puddled transplanted rice (PTR) followed by conventional drill-sown wheat (CDW), system of rice intensification (SRI) followed by system of wheat intensification (SWI) and aerobic rice system (ARS) followed by zero tillage wheat (ZTW). Microbial inoculations used were *Anabaena* sp. (CR1) + *Providencia* sp. (PR3) consortia (MI1) and *Anabaena-Pseudomonas* biofilmed formulation (MI2); while rate of N and P studied were 100% recommended dose of nutrient (RDN) (120 kg N ha⁻¹ crop⁻¹ and 25.8 kg P ha⁻¹ crop⁻¹ both for rice and wheat), 75% RDN and absolute control (no application). Microbial inoculation used in the study were taken from bacterial/ cyanobacterial strains culture collection maintained at Division of Microbiology, ICAR-Indian Agricultural Research Institute, New Delhi. Both these formulations were prepared by mixing with vermiculite (hydrous phyllosilicate mineral): compost (1:1) as the carrier. The paddy straw compost was C/N ratio of 16.22 and humus 13.8%. The cyanobacterial, fungal, and bacterial colony-forming units in the formulations were 10⁴, 10⁵, and 10⁸ g⁻¹ carrier, respectively.

Zn was soil applied at the time of sowing/transplanting @ 5 kg Zn/ha through zinc sulphate heptahydrate (ZnSO₄·7H₂O) as per the treatment

details mentioned in Table 1. In both rice and wheat crop, potassium was applied uniformly in all plots @ 49.8 kg K ha⁻¹ crop⁻¹ as a basal dose at the time of sowing. All dose of P as per the treatment was applied at the time of sowing and nitrogen was applied in 3 equal splits in both rice and wheat. All the standard cultivation practices were followed for each method of cultivation.

Research outcome

Among the studied nutrients, uptake of nitrogen was highest which varies between 148.8 to 275.5 kg ha⁻¹ followed by potassium (152.8 to 248.2 kg ha⁻¹). The total system Zn and Fe uptake were 475.1 to 835.5 g ha⁻¹ and 4.46 to 6.03 kg ha⁻¹, respectively. The cultivation methods differed significantly in both macro and micro nutrient uptake (Table 1), even though the system productivity as well as system straw production remained on par in all cultivation methods (Fig. 1). System productivity in the study varied between 5.36 t ha⁻¹ for control to 7.07 t ha⁻¹ for RDN + Zn; while the same for system straw yield was between 5.71 t ha⁻¹ for

control to 7.67 t ha⁻¹ for RDN + Zn.

The uptake of N in ARS-ZTW was 16.8 and 16.7 kg ha⁻¹ higher than PTR-CDW and SRI-SWI, respectively; while the same for potassium is 8.0 and 8.7 kg ha⁻¹, respectively. In case of phosphorus, though the cultivation methods differed significantly, the difference in uptake was very less (0.8 to 0.9 kg ha⁻¹). Better growth and yield in ZTW leading to significantly higher uptake of nutrient is the major reason for the superiority of ARS-ZTW; while in case of rice, the growth and yield was found superior in PTR and SRI then ARS, but it vanished at the system level.

Among nutrient management treatments, RDN + Zn had highest uptake of nitrogen and remained on par with 75% RDN + MI1 + Zn and 75% RDN + MI2 + Zn (Table 1). Improvement in nitrogen uptake due to the application of microbial inoculation was 29.6 to 32.5 kg ha⁻¹, indicating their significant role in the nitrogen nutrition of RWCS. The importance of optimal fertilization can be recognized based on the higher uptake of N in RDN by 39 and 92.1

Table 1. Effect of cultivation methods and nutrient management options on primary and micronutrients uptake in rice-wheat cropping system (2013-14 and 2014-15)

Treatment	System N uptake (kg ha ⁻¹)	System P uptake (kg ha ⁻¹)	System K uptake (kg ha ⁻¹)	System Zn uptake (g ha ⁻¹)	System Fe uptake (g ha ⁻¹)
<i>Cultivation methods</i>					
PTR-CDW	224.9	26.7	220.3	716.3	5,602.9
SRI-SWI	225.0	26.8	219.6	721.1	5,604.6
ARS-ZTW	241.7	27.6	228.3	737.0	5,559.8
SEm±	1.52	0.10	0.53	3.60	9.46
CD (P = 0.05)	5.96	0.40	2.08	14.12	37.15
<i>Nutrient management options</i>					
T1: Control (No fertilizer application)	148.4	22.0	152.8	475.1	4,459.1
T2: RDN	240.5	27.8	235.7	757.5	5,770.1
T3: RDN + Zn*	275.5	29.0	248.2	835.5	6,032.0
T4: 75% RDN	201.5	25.8	205.1	651.3	5,294.0
T5: 75% RDN + Zn	207.6	26.3	210.8	681.3	5,418.1
T6: 75% RDN + MI1	231.1	27.3	229.3	736.2	5,680.8
T7: 75% RDN + MI1 + Zn	266.7	28.7	244.0	817.4	5,958.9
T8: 75% RDN + MI2	234.0	27.5	232.4	743.2	5,710.8
T9: 75% RDN + MI2 + Zn	269.8	28.8	246.2	825.6	5,978.1
SEm±	3.72	0.15	2.57	5.55	22.78
CD (P = 0.05)	10.57	0.44	7.31	15.78	64.78

PTR-Puddled transplanted rice; SRI-System of rice intensification; ARS-Aerobic rice system; CDW-Conventional drill-sown wheat; SWI-System of wheat intensification; ZTW-Zero tillage wheat; RDN-Recommended dose of nutrients (120 kg N ha⁻¹ and 25.8 kg P ha⁻¹); Zn* = Soil applied 5 kg Zn ha⁻¹ through zinc sulphate heptahydrate; MI1-*Anabaena* sp. (CR1) + *Providencia* sp. (PR3); MI2-*Anabaena-Pseudomonas* biofilmed formulation

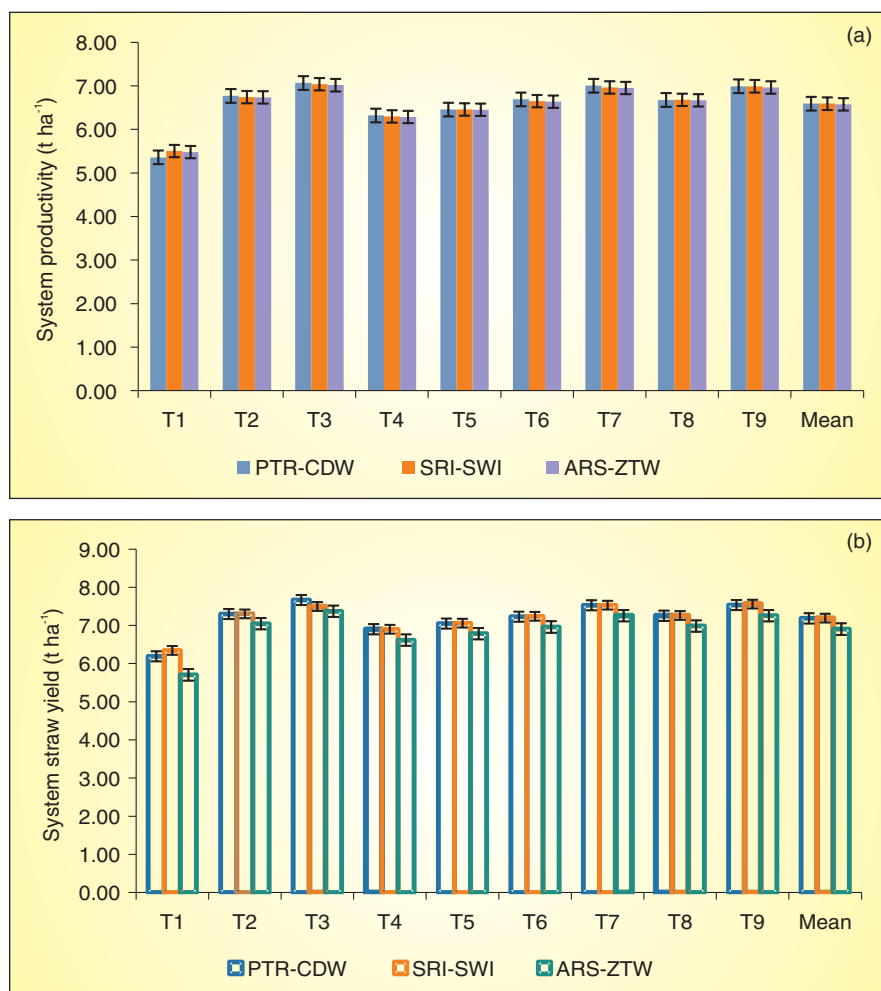


Fig. 1. Effect of cultivation methods and nutrient management options on system productivity (a) System straw yield (b) Rice-wheat cropping system (2013-14 and 2014-15).

kg ha⁻¹ over 75% RDN and control, respectively. The short and longterm problems in RWCS is soil fertility and nutrient deficiencies. The NAAS (2018) reported a negative balance of 8 to 10 million tonnes year⁻¹ in India and RWCS is followed on 10.2 million ha with the highest share in area and production in India, there is a need to study the role of different management factors and nutrient recommendations. Our study shows the significant variation in nutrient uptake across cultivation methods indicating the uniform recommendations will not work and variations in efficiency and losses across cultivation methods also need to be considered along with nutrient uptake. Zinc fertilization also showed the improvement in nitrogen uptake showing the positive effect of micronutrient fertilization is not only in crop yield but also in system nitrogen uptake. Application of Zn increases system nitrogen uptake by

35, 6.1, 35.6 and 35.8 kg ha⁻¹ when applied with RDN, 75% RDN + MI1, 75% RDN + MI2 and 75% RDN, respectively.

In case of uptake of phosphorus, the recommended dose of nutrient, microbial inoculation and Zn fertilization showed the significant impact; while the effect of cultivation methods was marginal. The improvement in P uptake due to optimal fertilization was 2.00 and 5.80 kg ha⁻¹ over 75% RDN and control; while the same for microbial inoculation was 1.50 to 170 kg ha⁻¹. The application of microbial inoculation having a capacity for P solubilization and mobilization is essential considering the low use efficiency of P (15-20%), phosphorus fixation and increase in prices of P fertilizers.

Potassium was applied uniformly in all the treatments, but significant variation across nutrient management was observed. The increase in uptake

due to application of an optimal dose of nutrients, microbial inoculation and zinc fertilization varied between 30.6-82.9, 24.2-27.3 and 5.7-14.7 kg ha⁻¹, respectively. This indicates that dry matter production (yield) of the crop also played a significant role along with the concentration of nutrients in deciding nutrient uptake.

The order of significance of applied factor in increasing Zn uptake was of optimal dose of nutrients > microbial inoculation > zinc fertilization > cultivation methods and their contribution to Zn uptakes were 106.2-282.4, 84.9-91.9, 30.0-82.4 and 15.9-20.7 g ha⁻¹ respectively. The Zn uptake was highest in RDN and lowest in control. The uptake in Zn applied treatment was 30.0 to 82.4 g ha⁻¹ higher than same treatment without Zn application indicating a positive effect of Zn application on crop nutrition and therefore Zn application was considered as important avenue for the Zn bio-fortification. On another side, Zn was applied @ 10,000 g ha⁻¹ cropping⁻¹ cycle, out of which only 4.75 to 8.35% of the applied Zn was absorbed; while the remaining was either got fixed in some other form or lost from the field.

In case of Fe, the order of significance of applied factor in increasing Fe uptake remained same as that of Zn uptake and their contribution to Zn uptake was 476.1-1311.0 g ha⁻¹ for the optimal dose of nutrients, 416.8-386.8 g ha⁻¹ for microbial inoculation, 278.1 to 124.1 g ha⁻¹ for zinc fertilization 43.1-44.8 g ha⁻¹ for cultivation methods. The highest Fe uptake was reported in RDN + Zn; while the lowest in case of control.

In nutshell, ARS-ZTW was found superior in increasing nitrogen, phosphorus, potassium and zinc uptake. Application of 75% RDN + MI2 + Zn was found superior in increasing nutrient uptake and can be better option to substitute 25% N and P applied through fertilizers.

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